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Energy Balance of Rice Production In Turkey: A Case Study For Kirklareli Province

Mehmet Firat Baran[1]*, Osman Gokdogan[2], M Cuneyt Bagdatli[3] and Korkmaz Belliturk[4]

[1]Department of Energy Systems Engineering, Adıyaman University, Turkey

[2]Department of Biosystem Engineering, Bingöl University, Turkey

[3]Department of Biosystem Engineering, Haci Bektas Veli University, Turkey

[4]Department of Soil Sciences and Plant Nutrition, Namik Kemal University, Turkey

***Corresponding Author:** Mehmet Firat Baran, Department of Energy Systems Engineering, Adiyaman University Faculty of Technology, 02040, Adiyaman/Turkey.

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Abstract

In this research, it was aimed to make an energy input-output analysis of rice production in Kirklareli province of Thrace region of Turkey. Kirklareli province has good opportunities for rice production in term of soil and water. In order to determine the energy balance of rice, surveys were done in 123 rice farms of Kirklareli province. These farms were selected on Neyman method. The data obtained from research were collected from these farms by face to face questionnaires and observations. Input-output of energy was also determined by observation and survey methods in production season (2012-2013). In rice production, energy inputs were calculated as 50412.21 MJ.ha^{-1} and energy output was calculated as 148750 MJha^{-1}. Energy inputs consist of 19293.75 MJha^{-1} (38.27%) irrigation energy, 12050.34 MJha^{-1} (23.90%) diesel fuel energy, 11211 MJha^{-1} (22.24%) chemical fertilizers, 3894.56 MJha^{-1} (7.73%) machinery energy, 3420 MJha^{-1} (6.78%) seed energy, 340.16 (0.67%) human labour energy and 202.40 MJha^{-1} (0.40%) chemicals energy. The use efficiency of energy, energy productivity, specific energy and net energy in rice production were calculated as 2.95; 0.17 kgMJ-1; 5.76 MJkg^{-1} and 98337.79 MJha^{-1}, respectively. The shares of direct, indirect, renewable and non-renewable energy were 31684.25 MJha^{-1} (62.85%), 18727.96 MJha^{-1} (37.15%), 23053.91 MJha^{-1} (45.73%) and 27358.30 MJha^{-1} (54.27%), respectively.

Keywords: *Energy use efficiency; Rice; specific energy; Turkey*

Introduction

FAO's global rice production forecast now stands at 730.2 million tonnes (486.9 million tonnes, milled basis), which is 1.5 million tonnes [1].

Rice cultivation is carried out 111 thousand hectares in Turkey and 900 thousand tons (540 thousand tons of rice equivalent) rice production is realized. In addition to Rice consumption is 600 thousand tons and rice yield is 8.14 ton ha^{-1} in Turkey agriculture areas [2].

Pishgar-Komleh *et al*. [3] reported that, "Rice (*Oryza sativa*) is the hugely important food crop for the world's population, especially in East, South, Southeast Asia, the Middle East, Latin America, and the West Indies. It is the grain with the second highest worldwide production, after maize (*Zea mays*) [4]". Researches were done on energy input-output analysis in agricultural products.

For example, researches have been made on energy usage activities of rice and maize [5], rice [3,6,7], wheat [8], lentil [9], barley [10], chick pea [11], maize [12] and barley [13] etc. In this study, it was aimed to determine energy input-output balance of rice production in Kirklareli province of Turkey.

Materials and Methods

The province of Kirklareli is located in the Thrace region of the Turkey. Kirklareli province is between 41° 44' - 42° 00' north latitude and 26° 53' - 41° 44' east meridians (Figure 1).

Figure 1: *The location of study area (Kırklareli Province).*

The land area of Kirklareli province is 6555 km^2. Kirklareli is neighboured by Bulgaria with a length of 159 km border the north; Black Sea coastline 58 km from the east; Edirne province in the west; Istanbul province in the southeast; and Tekirdag province in the south [14].

In order to determine the energy balances of rice plant, observations and surveys were performed in rice farms of Kirklareli Province. Observations and surveys were performed face to face with 123 rice producers, in production season during in 2012-2013. Surveys were made in totally 123 rice producers in Kirklareli and farms were determined by using Neyman method "1" [15]. According to Yamane (2001), number of rice growers to which the survey was applied.

$$n = \frac{\sum (N_h S_h)^2}{N^2 D^2 + \sum N_h S_h^2}$$

In the formula, n, is the required sample size; N, the number of rice growers in total population; Nh, the number of the population in h (small or large); S_h, the variance of h stratification; $D^2 = d^2/z^2$; is d, the precision and z is the reliability coefficient (1.96 which represents 95% confidence). The permissible error in sample population was defined to be 5% and the sample size was calculated to be 48 for 95% reliability. Total energy input in unit area (ha) constitutes of each total of input's energy. Human labour, machinery, chemical fertilizers, chemicals, water of irrigation, diesel fuel and rice seed were the inputs calculated. Rice yield was the output calculated.

As energy inputs, human labour energy, machinery energy, chemical fertilizers energy, chemicals energy, water of irrigation energy, diesel fuel energy and rice seed energy values were taken into consideration. In the agricultural production in Table 1, energy equivalents of input and outputs were taken as energy values.

Energy balance calculations were made to determine the rice production productivity. The units shown in Table 1 was used to find out the values of the inputs in rice production. Input amounts were calculated and then these input data were multiplied by the energy equivalent coefficient. When determining the energy equivalent coefficients, previous energy analysis studies (sources) were used. By adding energy equivalents of all inputs in MJ unit, the total energy equivalent was found. For example, in order to determine the energy usage efficiency in wheat production, Mohammadi., *et al*. [16] reported that, "The energy ratio (energy use efficiency), energy productivity, specific energy and net energy were calculated using the following formulates [17,18]".

$$\text{Energy use efficiency} = \frac{\text{Energy output }\left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Energy input }\left(\frac{\text{MJ}}{\text{ha}}\right)}$$

$$\text{Energy productivity} = \frac{\text{Rice output }\left(\frac{\text{kg}}{\text{ha}}\right)}{\text{Energy input }\left(\frac{\text{MJ}}{\text{ha}}\right)}$$

$$\text{Specific energy} = \frac{\text{Energy input }\left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Rice output }\left(\frac{\text{kg}}{\text{ha}}\right)}$$

$$\text{Net energy} = \text{Energy output (MJ ha}^{-1}) - \text{Energy input (MJ ha}^{-1})$$

In the calculation of quantities of inputs used in rice production, energy equivalences in Table 1 were used. Quantities of inputs were calculated according to hectare and they were multiplied with the equivalence of these inputs. Resources of previous researches were used in determining the coefficients of energy equivalence. Other data was used from information by organizations related to rice producers.

The results were tabulated after the analysis of data was done using Microsoft Excel program considering the inputs. Examining the values of rice input - output and calculations were given in Table 2. Kocturk and Engindeniz [19] reported that, "The input energy is also classified into direct and indirect and renewable and non-renewable forms. The indirect energy consists of pesticide and fertilizer while the direct energy includes human and animal power, diesel and electricity energy used in the production process. On the other hand, non-renewable energy includes petrol, diesel, electricity, chemicals, fertilizers, machinery and renewable energy consists of human and animal [17,20]". Energy input - output and efficiency calculations in rice production in Table 3 was given. Energy equivalents of input and outputs in rice agriculture are given in Table 1.

Inputs and outputs	Unit	Energy Equivalent Coefficient	Sources
Inputs	**Unit**	**Values (MJ/unit)**	**Sources**
Human labour	h	1.96	Karaagac., *et al*., Mani., *et al*. [21,22]
Machinery	h	64.80	Kizilaslan, Singh [23,24]
Harvest	h	87.63	Tipi., *et al*., Hetz, Canakci [23,25,26]
Chemical Fertilizers			
Nitrogen	kg	60.60	Singh. [24]
Phosphorous	kg	11.10	Singh. [24]
Potassium	kg	6.70	Singh. [24]
Sulphur	kg	1.20	Mohammadi., *et al*. Esengun., *et al*. [18,27]
Chemicals	kg	101.20	Yaldiz., *et al*. [28]
Diesel fuel	l	56.31	Demircan., *et al*.[29]
Irrigation	m^3	0.63	Yaldiz., *et al*. [28]
Seed	kg	15.20	Yadav., *et al*. [28]
Outputs	**Unit**	**Values (MJ/unit)**	**Sources**
Rice	kg	17	Kitani. [30]

Table 1: *Energy equivalents of inputs and outputs in agricultural production of rice.*

Results and Discussion

During the studies in the farms, the amount of rice produced per hectare during the 2012-2013 production season was calculated as an average of 8750 kg. In rice production, it is noteworthy that water of irrigation, diesel fuel, chemical fertilizers energy were used as the highest input.In this study, cultivations for rice production and the energy output-input analysis of rice production in 2012-2013 were given in Table 2. It can be seen that the first, second and third of the highest energy of inputs in rice production are 38.27% irrigation energy, 23.90% diesel fuel energy and 22.24% chemical fertilizers energy were the inputs calculated.

If the average values are examined by considering Table 2, it can be seen that the highest energy inputs in rice production has Energy inputs consist of 19293.75 MJ ha^{-1} (38.27%) water of irrigation energy, 12050.34 MJ ha^{-1} (23.90%) diesel fuel energy, 11211 MJ ha^{-1} (22.24%) chemical fertilizers, 3894.56 MJ ha^{-1} (7.73%) machinery energy, 3420 MJ ha^{-1} (6.78%) seed energy, 340.16 (0.67%) human labour energy and 202.40 MJ ha^{-1} (0.40%) chemicals energy were the inputs calculated. In this study, irrigation energy had the biggest share 38.27%. Similarly, in previous studies, Alipour., *et al*. [6] found that in rice study the irrigation energy had the biggest share with 18487.40 MJ ha^{-1}.

Inputs	Unit	Energy equivalent (MJ / unit)	Input used per hectare (unit ha^{-1})	Energy value (MJ ha^{-1})	Rate (%)
Human labour				**340.16**	**0.67**
Land prepartion	h	1.96	23.20	45.47	
Planting	h	1.96	8.60	16.86	
Cultivation	h	1.96	122	239.12	
Harvesting-Threshing	h	1.96	18.50	36.26	
Transportation	h	1.96	1.25	2.45	
Machinery				**3894.56**	**7.73**
Land prepartion	h	64.80	10.70	693.36	
Cultivation	h	64.80	44.50	2883.60	
Harvesting-Threshing	h	87.63	2.70	236.60	
Transportation	h	64.80	1.25	81	
Chemical fertilizers				**11211**	**22.24**
Nitrogen	kg	60.60	165	9999	
Phosphorous	kg	11.10	60	666	
Potassium	kg	6.70	60	402	
Sulfur	kg	1.20	120	144	
Chemicals	kg	101.20	2	202.40	0.40
Irrigation	m3	0.63	30625	19293.75	38.27
Diesel fuel	l	56.31	214	12050.34	23.90
Seed	kg	15.20	225	3420	6.78
Total inputs				**50412.21**	**100**
Outputs	**Unit**	**Energy equivalent (MJ / unit)**	**Output per hectare (unit ha^{-1})**	**Energy value (MJ ha^{-1})**	**Rate (%)**
Rice	kg	17	8750	148750	100.00
Energy Ratio				2.95	

Table 2: *Energy input-output analysis in rice production.*

The results indicated that human labour energy input was calculated 340.16 MJ ha^{-1}. Human labour energy was used for tractor and farm operations such as land prepartion, planting, cultivation, harvesting-threshing and transportation. Diesel energy input was calculated 12050.34 MJ ha^{-1}. Machinery energy input was calculated 3894.56 MJ ha^{-1}.

Machinery energy and diesel energy were used for operating tractor to perform the farm operations such as land prepartion, cultivation, harvesting-threshing and transportation. The amount of chemical fertilizers used for rice production were 405 kg ha^{-1}. Nitrogen was the most common chemical fertilizer used 165 kg ha^{-1}, followed by sulfur 120 kg ha^{-1}, 60 kg ha^{-1} phosphorous and 60 kg ha^{-1} potassium in rice production.

In rice production, energy input, energy output, energy use efficiency, energy productivity, specific energy and net energy in rice production were calculated as 50412.21 MJ ha^{-1}, 148750 MJ ha^{-1}, 2.95; 0.17 kg MJ^{-1}; 5.76 MJ kg^{-1} and 98337.79 MJ ha^{-1}, respectively. In previous studies, Yadav., *et al*. [5], Alipour., *et al*. [6], Pishgar-Komleh [3], Ibrahim and Ibrahim [7] calculated energy use efficiency in rice studies as 7.66, 2.19, 1.53, 4.10 respectively.

Calculations	Unit	Values
Rice	kg ha^{-1}	8750
Energy input	MJ ha^{-1}	50412.21
Energy output	MJ ha^{-1}	148750
Energy use efficiency		2.95
Energy productivity	kg MJ^{-1}	0.17
Specific energy	MJ kg^{-1}	5.76
Net energy	MJ ha^{-1}	98337.79

Table 3: *Energy input-output and efficiency calculations in rice production.*

The distribution of inputs used in the production of rice according to the direct, indirect, renewable and non-renewable energy groups were given in Table 4. It can be seen from the Table 4, the total energy input consumed could be classified as direct 62.85%, indirect 37.15% in rice production. Similarly, in previous studies, wheat [6], lentil [9], irrigated wheat [10] were found that ratio of direct energy is higher than ratio of indirect energy. It can be seen from the Table 4, the total energy input consumed could be classified as renewable 45.73% and non-renewable 54.27% in rice production.

Similary, maize [31], garlic [32], wheat [33], wheat [34], wheat [6], lentil [9], wheat [35], barley [10,13] were found that ratio of non-renewable energy is higher than ratio of renewable energy [36].

Type of energy	Energy input (MJ ha^{-1})	Ratio (%)
Direct energy[a]	31684.25	62.85
Indirect energy[b]	18727.96	37.15
Total	**50412.21**	**100.00**
Renewable energy[c]	23053.91	45.73
Non-renewable energy[d]	27358.30	54.27
Total	**50412.21**	**100.00**

Table 4: *Energy input in the form of direct, and direct renewable and non-renewable energy for rice production.*

Conclusion

In research, energy inputs were calculated as 50412.21 $MJha^{-1}$ and energy output was calculated as 148750 $MJha^{-1}$. Energy inputs consist of 19293.75 $MJha^{-1}$ (38.27%) irrigation energy, 12050.34 $MJha^{-1}$ (23.90%) diesel fuel energy, 11211 $MJha^{-1}$ (22.24%) chemical fertilizers, 3894.56 $MJha^{-1}$ (7.73%) machinery energy, 3420 $MJha^{-1}$ (6.78%) seed energy, 340.16 (0.67%) human labour energy and 202.40 MJha-1 (0.40%) chemicals energy. The use efficiency of energy, energy productivity, specific energy and net energy in rice production were calculated as 2.95; 0.17 kg MJ-1; 5.76 $MJkg^{-1}$ and 98337.79 $MJha^{-1}$, respectively. The shares of direct, indirect, renewable and non-renewable energy were 31684.25 $MJha^{-1}$ (62.85%), 18727.96 $MJha^{-1}$ (37.15%), 23053.91 $MJha^{-1}$ (45.73%) and 27358.30 $MJha^{-1}$ (54.27%), respectively.

According to the evaluated results, rice production is a profitable production in terms of energy usage. The research results indicate that ratio of non-renewable energy is higher than ratio of renewable energy and ratio of indirect energy is higher than ratio of direct energy. On the other hand the application of manure and other organic all fertilizers are very important for soil quality and also farmers budget. Farm fertilizer (cow manure, green manure, compost, vermicompost etc.) can also be used in rice production, instead of chemical fertilizers, which make up an important part of the inputs. Similarly, these all situations should be considered in rice production.

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