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RESEARCH ARTICLE

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Energy budget and economic analysis in conventional and organic rice production systems and organic scenarios in the transition period in Iran

Abstract Compared to conventional agriculture, organic agriculture is reported to be more efficient and effective in reducing water and soil pollution, greenhouse gases (GHGs) emission and risk of human health. In additional, field management under organic condition can be useful for increasing energy efficiency. Rice is one of the important crops which are cultivated in two forms, organic and conventional, in Iran. In order to compare the energy efficiency and economic analysis of rice production in organic and conventional systems in Iran, needed information was collected by face-to-face questionnaire in 2011 and three scenarios were designed to predict the changes of energy budget and economic analysis in the transition period that included: 25%, 50% and 75% organic management in rice production. The results showed that all energy indexes were improved in organic rice production compared to conventional condition. Higher values of benefit to cost ratio, gross and net return and lower value of total cost of production were obtained from organic rice production which indicated that the organic management of farm improved economically in comparison with the conventional rice production system. The shares of direct and renewable energies were increased by approach to organic management. Increase in energy efficiency and productivity was predicted for the transition period but decrease trend in economic indexes was projected for this period in all scenarios. The main reason for decreasing economic indexes in organic scenarios was that the market price of organic rice was the same as that of conventional rice in the transition period.

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1 Introduction

In Iran, agricultural growth is essential for nurturing, the economic improvement and meeting the ever-higher demands of the growing population [1]. More than 25% of the total population of the country was engaged in agriculture. The total field crop production was estimated to be approximately 74 million tonnes which produced on 13500000 ha in Iran. Approximately 73% of the total field crop production consists of cereal (wheat, barley, maize and rice) production [2]. Rice (*Oryza sativa* L.) is one of the important grain crops grown in Iran, accounting for 6.29% of the total cereal production. The total organic production area of Iran was approximately 114000 ha, including 1% of field and 2.7% of horticultural crops [3].

Today, the conventional agricultural systems depend on the consumption of non-renewable energies which includes diesel, chemicals, fertilizers and machinery [4,5]. The consumption of fossil energy causes indirect negative environmental effects through release of GHGs [6], and intensive use of fossil energies leads to environmental problems and endangers human health. Therefore, it is necessary to reduce fossil energy inputs in agriculture. This issue would help to reduce agricultural GHGs emission [7]. In addition, other environmental problems, such as soil and water pollution, soil erosion, and global warming, are also related to intensive use of non-renewable energies. Thus, efficient use of energy inputs that is one of the principal requirements of sustainable agriculture can be one of the key ways to this objective [8,9]. Consequently, one main goal for improving the environmental performance of agricultural production has been minimizing energy consumption [1]. Energy input-output analysis is usually used to qualify the energetic and ecological efficiency and environmental impacts of crop productions. The energy analysis is one suitable indicator to determine more efficient and environment friendly production systems [10].

On the other hand, moving towards agricultural systems with low energy input, such as organic farming, can be useful to reduce agricultural GHGs emissions and energy use [11–13]. Organic farming technologies may offer opportunities to improve resource use and energy use efficiency in crop production based on the reduction of the use of non-renewable resources (e.g. fossil fuels), banning of synthetic biocides and of synthetic mineral fertilizers and conservation tillage practices [14–16]. Management of crop production systems under organic condition can help farmers to maintaining economic profitability [17,18]. This conservation management practice can result in a balance between environmental and food production systems [16].

Organic farming can contribute significantly to saving non-renewable energy through reducing the inputs that depend on this type of energy [19]. The amount of energy used in agricultural production depends on the mechanization level, quantity of active agricultural work and cultivable land [20,21]. However, low energy inputs production systems such as organic farming, are not yet well accepted by farmers who are interested in economic benefits rather than in energy productivity. It is realized that crop yields and food supplies are directly linked to energy [22].

Energy use and energy use efficiency for organic and conventional farming systems were compared in numerous studies. In most literature, higher energy efficiency and lower cost of production were reported in organic farming compared to conventional systems [23].

In the last decades, agricultural soils have been an important source of CO_2 and N_2O emissions, following intensive use of chemical fertilizers, pesticides and agricultural machinery in Iran. Energy consumption in Iranian agricultural systems is constantly increasing [1]. Therefore, the shifting towards organic production systems associated with low energy input can be effective for decreasing environmental hazards and conserving energy in agricultural systems of Iran.

The objectives of this study were to evaluate the differences in energy budget and economical use efficiency between organic and conventional rice production systems in two regions of Iran, to study the sensitivity and relationship between energy inputs and rice yield in organic and conventional systems based on Cobb-Douglas production function, to predict energy and economical indicators in the transition period based on different scenarios for rice production system, and to compare the scenarios with the conventional rice production.

2 Material and methods

2.1 Study area and crop production system

This study was conducted in two separated region in Iran: Esfahan province for conventional and Mazandaran province for organic rice production. Esfahan is located in the center of Iran, within 30°43' and 34°27' north latitude and 49°36' and 55°31' east longitude and Mazandaran is located between 35°47' and 36°35' north latitude and 47°38' and 50°34' east longitude in the north of Iran. The total area of Esfahan and Mazandaran is 105937 and 23756 km^2, the total farming area is 360181 and 356918 ha, and the rice planting area is approximately 17452 and 209037 ha, respectively. In Iran, organic rice is cultivated only in Mazandaran with 1300 ha being certified based on European Union (EU) standard systems.

2.2 Data collection

The data were collected from rice producers by using a face-to-face questionnaire in 2011. In addition to the data obtained by surveys, previous studies of related organizations such as Food and Agricultural Organization (FAO) and Ministry of Jihad-e-Agriculture of Iran (MAJ) were also utilized during this study. The number of operations involved in the conventional and organic rice crop production systems and their energy requirements affect the final energy balance.

2.3 Calculation of energy budget and economic analysis

A random sampling method was used and the sample size was calculated using Eq. (1) [24].

$$n = \frac{NS^2}{(N-1)S_X^2 + S^2}, \tag{1}$$

where n is the required sample size, N is the population volume, S is the standard deviation, S_X is the standard deviation of sample mean ($S_X = d/z$), d is the permissible error in the sample size defined to be 10% of the mean for a 95% confidence interval, and z is the reliability coefficient (1.96, which represents the 95% reliability). Based on the calculation, the size of 65 and 14 were considered as the sampling size for the conventional and organic rice production systems, respectively. The energetic efficiency of the agricultural system was evaluated by the energy ratio between the output and the input [20]. The human labor, machinery, diesel oil, fertilizer, pesticides, electricity, seed and output yield values of rice production systems were used to estimate the energy ratio. The energy equivalents for inputs and outputs were shown in Table 1. The mechanical energy used in the conventional and organic rice production systems included machinery and diesel

Table 1 Energy equivalent of inputs and outputs in rice production

Energy source	Energy equivalent/($MJ \cdot unit^{-1}$)	Source
Human labour (h)	1.96	[26]
Fertilize (kg)		
N	60.60	[18]
P_2O_5	11.10	[18]
K_2O	6.70	[18]
Manure (kg)	0.30	[18]
Chemicals (kg)		
Insecticide	199	[18]
Fungicides	92	[27]
Herbicide	238	[28]
Diesel (L)	56.31	[24]
Paddy (kg)		
Seed	14.57	[29]
Straw	12.50	[29]
Machinery (h)	62.70	[18]
Water (m^3)	0.63	[18]
Electricity ($kW \cdot h$)	11.93	[18]

fuel. The mechanical energy was computed based on total fuel consumption ($l\ ha^{-1}$) in different operations. Therefore, the energy consumed was calculated, using conversion factors (1 L diesel = 56.31 MJ) and expressed in MJ/ha [24]. Based on the energy equivalents of the inputs and outputs (Table 1), the energy use efficiency, the energy productivity, the specific energy and the net energy were calculated [25].

$$\text{Energy use efficiency} = \frac{\text{Energy output}}{\text{Energy input}}, \tag{2}$$

$$\text{Energy productivity} = \frac{\text{Rice output}}{\text{Energy input}}, \tag{3}$$

$$\text{Specific energy} = \frac{\text{Energy input}}{\text{Rice output}}, \tag{4}$$

$$\text{Net energy} = \text{Energy output} - \text{Energy input}(\text{MJ/ha}). \tag{5}$$

Indirect energy included the energy embodied in seeds, chemical fertilizers, herbicide (Treflan and Metribuzin), pesticide (Metasystox), fungicide (Mancozeb and Metalaxyl), manure and machinery, while direct energy enclosed human labor, diesel, electricity and water for irrigation used in the crops. Non-renewable energy included diesel fuel, electricity, chemical fertilizers, herbicides, pesticides, fungicides and machinery, and renewable energy consisted of human labor, manure, seeds and water for irrigation.

The economic output of the conventional and organic rice production systems was calculated based on the prices of conventional and organic rice in Esfahan and Mazandaran, respectively. All prices of inputs and outputs were market prices (average prices of the year 2011). One hectare of experimental field was the basic unit for costs analysis. The net and the gross return, the gross value of production, the total cost of production, the benefit to cost ratio and the productivity were calculated according to the following equations for the two systems [25,30]:

$$\text{Gross return} = \text{Gross value of production} - \text{Variable cost of production}(\$/\text{ha}), \tag{6}$$

$$\text{Gross value of production} = \text{Rice yield}(\text{kg} \cdot \text{ha}^{-1}) \times \text{Rice price}(\$ \cdot \text{ha}^{-1}), \tag{7}$$

$$\text{Net return} = \text{Gross value of production} - \text{Total cost of production}(\$/\text{ha}), \tag{8}$$

$$\text{Total cost of production} = \text{Variable cost of production} + \text{Fixed cost of production}(\$/\text{ha}), \tag{9}$$

$$\text{Benefit to cost ratio} = \frac{\text{Gross value of production}}{\text{Total cost of production}}, \tag{10}$$

$$\text{Productivity} = \frac{\text{Rice yield}}{\text{Total cost of production}}. \tag{11}$$

2.4 Function selection

In order to analyze the relationship between energy inputs and energy output, the Cobb-Douglas function [31–33] was selected as the function suitable pattern. The Cobb-Douglas function relation is a power function, which is linear in logs [34].

Cobb-Douglas function is expressed as

$$Y = f(x)\exp(u), \tag{12}$$

which can be further written as

$$\ln Y_i = a + \sum_{j=1}^{n} a_j \ln X_{ij} + e_i, \tag{13}$$

where Y_i denotes the yield of the ith farmer, X_{ij} is the vector of inputs used in the production process, a is a constant, a_j represents coefficients of inputs which are estimated from the model, and e_i is the error term. Eq. (14) can be expressed in the following form for conventional rice production system:

$$\ln Y_i = a_0 + a_1 \ln X_1 + \cdots + a_8 \ln X_8 + e_i, \quad (14)$$

where X_1 denotes human labor energy; X_2, diesel fuel energy; X_3, water for irrigation energy; X_4, machinery energy; X_5, total fertilizer energy; X_6, chemicals energy; X_7, electricity; and X_8, seed for planting. In the organic rice production system, Eq. (14) is in the following form:

$$\ln Y_i = a_0 + a_1 \ln X_1 + \cdots + a_6 \ln X_6 + e_i, \quad (15)$$

where X_1 indicates the human labor energy; X_2, diesel fuel energy; X_3, water for irrigation energy; X_4, machinery energy; X_5, manure; and X_6, seed for planting. With respect to this pattern, in this study, the impact of the energy of each input on the rice yield was studied. Basic information on energy inputs and rice yield in different production systems were entered into Excel's spreadsheet and Shazam 9.0 software program.

2.5 Scenarios of transitional period to organic

Three scenarios were designed to predict the changes of energy budget and economic analysis during the transitional period which consider the time period from the conventional to organic rice production. These scenarios were considered based on the decrease in non-allowable inputs such as chemical fertilizer and pesticides and the increase in allowable inputs including human labor and organic manure. The three scenarios included 25%, 50% and 75% change in the conventional system were considered as transitional period to organic rice production.

3 Results and discussion

3.1 Analysis of input-output energy use in rice production

The total input energy consumed for rice in organic and conventional systems based on different input and agronomical practices in hectare are presented in Table 2. The highest percentage of energy input for rice production in the conventional system was related to diesel fuel and electricity, which were 48.84% and 28.13%, respectively, the rate of used energy for these inputs were 68360.3 MJ/ha and 39369 MJ/ha, respectively, and the lowest percentage was related to the use of fungicides

Table 2 Energy consumption and energy input-output relationship in organic and conventional rice production

		Quantity per unit area/ha		Total energy equivalent/MJ		Percentage of total energy/%	
		Organic	Conventional	Organic	Conventional	Organic	Conventional
Inputs	Human labour (h)	718.28	483.34	1407.3	947.35	2.54	0.68
	Machinery (h)	23	58.1	1442.1	3642.9	2.59	2.60
	Fertilizer (kg)	–	–	–	–	–	–
	Nitrogen fertilizer (kg)	–	190	–	11514	–	8.23
	Phosphorus (kg)	–	91.4	–	1014.5	–	0.72
	Potassium (kg)	–	56.2	–	376.5	–	0.27
	Manure (kg)	3000	0	900	0	1.62	–
	Chemicals (kg)	–	–	–	–	–	–
	Insecticides (kg)	–	1.3	–	258.7	–	0.185
	Fungicides (kg)	–	1.1	–	101.2	–	0.072
	Herbicide (kg)	–	4.9	–	1166.2	–	0.833
	Diesel fuel (L)	560	1214	31533.6	68360.3	56.82	48.84
	Electricity (kW·h)	–	3300.0	–	39369	–	28.13
	Water for irrigation (m^3)	30240	17500	19051.2	11025	34.33	7.88
	Seed (kg)	80	150	1165.6	2185.5	2.1	1.56
	Total energy input (MJ/ha)	–	–	55304.33	139961.15	100	100
Outputs	Grain (kg)	4880	5920.4	71101.6	86260.2	52.73	55.38
	Straw(kg)	5100	5560.2	63750	69502.5	47.27	44.62
	Total energy output (MJ/ha)			134851.60	155762.70	100	100
Net energy				79351.27	15801.46		
Specific energy (MJ/kg)				5.56	12.19		
Energy efficiency				2.43	1.11		
Energy productivity (kg/MJ)				0.18	0.08		

(101.2 MJ/ha), which was 0.072% (Table 2). However, the highest energy input for organic rice production was related to diesel fuel and water for irrigation, which was 56.82% and 34.33%, respectively, and the lowest percentage of energy input was related to manure (900 MJ), which was 1.62% (Table 2). Therefore, diesel fuel was the highest energy input for rice in both production systems. Demircan et al. [25] stated that chemical fertilizer and diesel fuel had the highest energy input for sweet cherry production under conventional management. The total energy input for the conventional and organic rice production were 139961.2 MJ/ha and 55304.3 MJ/ha, respectively (Table 2). The total energy input for rice production in the conventional system was 84656.8 MJ/ha more than that in the organic system. In other words, the total energy input in the conventional system was 153% more than that in the organic system. No application of chemical inputs caused lower energy input under organic rice production than conventional.

The results indicated that the grain and straw yield of conventional rice were higher than that of organic rice (by 21.32% and 9%, respectively). The total energy output per hectare in the conventional and the organic rice production system were 155762.7 and 134851.6 MJ/ha, respectively (Table 2), indicating that the amount of energy output in the conventional condition was 15.51% higher than that in the organic condition. The share of grain from total energy output was higher than straw in both systems, especially in the conventional production system. The high energy output in conventional olive production compared to organic condition was reported by Kaltsas et al. [35].

The rate of net energy in organic rice production (79351.3 MJ/ha) was higher than that of conventional rice production (15801.5 MJ/ha), due to lower energy input for the organic system compared to the conventional system. However, the energy output in the conventional system was higher than that in the organic system (Table 2). This means that to obtain per energy output of conventional rice need higher unit of energy input in comparison with organic rice. The fact that the net energy of organic production system was higher than that of the conventional system was demonstrated in Refs. [31–38]. The average energy productivity of rice in conventional and organic systems was 0.08 and 0.18 kg/MJ, respectively, so the energy productivity in organic rice was higher than conventional rice by 125%. On the other hand, the specific energy in the organic rice production system was lower than that in the conventional one. The rate of specific energy for organic rice was 5.56 MJ/kg and that for the conventional system was 12.19 MJ/kg. This means that the energy needed to produce 1 kg of organic rice was lower than that of conventional rice by 54.39%. The energy efficiency in the organic and conventional rice production system was 2.43 and 1.11, respectively (Table 2). The energy efficiency was approximately 119% higher in organic rice production than that in conventional rice production. Dalgaard et al. [39] compared organic and conventional farming systems in Danish agriculture and concluded that the conventional crop production had the highest energy production, whereas the organic crop production had the higher energy efficiency. It should be considered that the values of energy efficiency can be decreased if solar energy, either as radiation or heat, was taken into account as energy input [40].

3.2 Energetics of producing rice

The total energy input consumed in rice production could be classified as direct, indirect, renewable and non-renewable energy whose amount and share are illustrated in Table 3. The share of direct energy from total energy input was higher than that of indirect energy in both production systems. The conventional system involves more than 130% of the direct energy (119701.7 MJ/ha) compared to the organic system (51992.7 MJ/ha). In addition, the share of direct energy was higher in the organic (93.68% of total energy input) compared to the conventional system (85.52% of total energy input). The indirect energy in the conventional rice production system (20259.5 MJ/ha) was higher than that in the organic system (3507.7 MJ/ha) and the share of it from the total energy input in the conventional system (14.5%) was higher than that in the organic production system (6.32). Gundogmus [18] reported that the share of direct energy input was higher in organic apricot production compared to conventional, and the conventional system obtained the higher

Table 3 Total energy input in the form of direct, indirect, non-renewable and renewable energy for organic and conventional rice production systems

Type of energy	Organic		Conventional	
	MJ/ha	% (a)	MJ/ha	% (a)
Direct energy (b)	51992.6	93.68	119701.7	85.52
Indirect energy (c)	3507.7	6.32	20259.5	14.48
Renewable energy (d)	3473.4	6.26	3132.8	2.24
Non-renewable energy (e)	52026.9	93.74	136828.4	97.76
Total energy input	55500.3		139961.2	

Notes: a—percentage of total energy input; b—human labor, diesel, electricity and water; c—seeds, chemical fertilizers (NPK), pesticide (Metasystox), fungicide (Mancozeb and Metalaxyl) and machinery; d—human labor, seeds and water; e—diesel, electricity, chemical fertilizers (NPK), pesticide (Metasystox), fungicide (Mancozeb and Metalaxyl) and machinery share of indirect energy. The share of non-renewable energy was higher than that of renewable energy in both production systems. The amount of renewable energy was higher for the organic system (3473.4 MJ/ha) compared to the conventional one (3132.8 MJ/ha) and that of non-renewable energy was higher for the conventional system (136828.4 MJ/ha) in comparison with the organic one (52026.9 MJ/ha). The same result was stated by Gundogmus [18], so that the share of renewable energy input in the total energy input was 14.42% in the organic apricot production system and 6.08% in the conventional one. For shifting to sustainability in agricultural systems, it is necessary to reduce the non-renewable and indirect energies [1,41]. There are also environmental advantages such as declining water and soil pollution and GHGs emission by applying renewable and direct energies.

3.3 Economic analysis of rice production

The total cost of rice production was found to be 2112.56 \$/ha and 2275.26 \$/ha for organic and conventional production systems, respectively (Table 4). Thus, the conventional system has a higher cost for producing of rice compared to the organic one. So the cost of production of rice per hectare in the conventional system is 162.7 \$ higher compared to the organic system. However, the total cost of production as a term of \$/kg and \$/MJ in the organic system was higher than that in the conventional one (Table 4). On the other hand, the energy output for the production of 1 kg of rice in the organic system is 1 MJ more than that in the conventional system.

Table 4 Economic analysis of organic and conventional rice production systems

Cost and return components	Organic	Conventional
Total cost of production/($\$\cdot ha^{-1}$)	2112.56	2275.26
Total cost of production/($\$\cdot kg^{-1}$)	0.21	0.19
Total cost of production/($\$\cdot MJ^{-1}$)	0.016	0.015
Gross return/($\$\cdot ha^{-1}$)	10168.0	8141.3
Gross return/($\$\cdot kg^{-1}$)	1.02	0.71
Gross return/($\$\cdot MJ^{-1}$)	0.075	0.052
Net return/($\$\cdot ha^{-1}$)	8055.4	5866.1
Net return/($\$\cdot kg^{-1}$)	0.81	0.51
Net return/($\$\cdot MJ^{-1}$)	0.059	0.038
Benefit to cost ratio	4.81	3.58

A higher gross return was achieved for the organic production system compared to the conventional one. The gross return per hectare for organic rice was 10168.0 \$ and for conventional was 8141.3 \$ (Table 4), approximately 24.9% higher.

The gross return was 1.02 \$ per 1 kg rice production and 1.02 \$ per 1 MJ of energy output in the organic production system, whereas these values were 0.71 \$ and 0.052 \$ for the conventional, respectively (Table 4). The organic rice production had a higher net return compared to the conventional. The net return of organic rice production per hectare, per 1 kg of rice and per 1 MJ of output energy were 8055.4 \$, 0.81 \$ and 0.059 \$, respectively and that of conventional rice production were 5866.1 \$, 0.51 \$ and 0.038 \$, respectively (Table 4). The benefit to cost ratio in organic rice production (4.81) was calculated as 34.36% higher than that in conventional rice production (3.58).

3.4 Econometric model estimation of energy inputs for rice production

The Cobb-Douglas production function on different categories of farms was used for estimation of relationship between the energy input and rice yield. Therefore, the biomass yield of rice (dependent variable) was supposed to be a function of human labor, diesel fuel, irrigation, machinery, total fertilizer, chemicals, electricity and seed (independent variables) as a multiple regression. For the data used in this study, autocorrelation was tested by using Durbin-Watson test [28].

The values of Durbin-Watson are listed in Table 5. This means that there is no autocorrelation at the 5% significance level in the estimated models for both rice production systems. The r^2 values were 0.974 and 0.952 for the organic and the conventional system, respectively (Table 5). The results of Cobb-Douglass function indicated that the impact of each one of the inputs in rice production differ in constitution production level (Table 5). All inputs had positive impacts on biomass yield of rice expect seed in both production systems. Human labor had the highest impact on rice biomass among the other inputs in the organic system. This indicates that by increasing in the energy of human labor input, the amount of output level improves in present condition. For example, based on the coefficient of function for human labor (0.15), a 1% increase in the energy of human labor input caused 0.15% of increase in biomass yield of rice. In contrast, water for irrigation and fertilizer inputs had the highest impact on biomass yield in the conventional system, whose coefficient of function was 0.11 (Table 5). The second effective input on rice biomass was found as irrigation water for the organic system and human labor for the conventional one by 0.12 and 0.10 as Cobb-Douglas function coefficient, respectively (Table 5). Diesel fuel had the lowest impact on biomass in both organic and conventional systems by 0.03 and 0.01 as function coefficient, respectively (Table 5).

3.5 Scenarios for transition period to organic rice

The total energy input and output was deceased by approach to organic production so that, higher energy input and output was gained under conventional production system of rice in comparison with organic scenarios.

Table 5 Coefficient of Cobb-Douglas function and *t*-value for rice production

Source	Coefficient		*t*-value	
	Organic	Conventional	Organic	Conventional
Human labor	0.15	0.10	2.10**	1.70**
Diesel fuel	0.03	0.01	0.97**	0.58*
Water	0.12	0.11	1.61*	2.07*
Machinery	0.04	0.05	1.84**	0.79**
Fertilizers	–	0.11	–	0.11
Chemicals	–	0.02	–	2.31**
Manure	0.09	–	3.01**	–
Electricity	–	0.09	–	1.52*
Seed	–0.05	0.06	–0.71	–0.56
r^2	0.974**	0.952**		
Durbin-Watson	2.21*	2.29*		

Note: * = Significant at 5% level; ** = Significant at 1% level

Besides, 75% of organic system had the lowest energy input and output among the scenarios (Fig. 1). The total energy input in 25%, 50% and 75% organic was 15.1%, 30.2% and 45.3% lower than conventional system, respectively and these values for the total energy output was approximately 3.36%, 6.71% and 10.07%, respectively (Fig. 1). The energy efficiency and productivity of rice were increased by the increase in the share of organic management in rice production. The energy efficiency in 75% organic was the highest (1.83) and under the conventional condition (1.11) was the lowest among others and the same trend was obtained for energy productivity by 0.135 kg/MJ and 0.082 kg/MJ for 75% organic system and conventional, respectively (Fig. 1).

The increase of energy efficiency by the increase in organic management was 13.81%, 33.59% and 64.29% compared to conventional management, respectively. The amount of direct and indirect energy was decreased by approaching to organic management (Fig. 1). The conventional production system had the highest amount of direct and indirect energy in comparison with the organic scenarios. The share of direct energy was increased by moving from the conventional production system toward the organic system and the highest share of direct energy was obtained in 75% organic by 90.75% of total energy input (Fig. 1).

The renewable energy in the conventional system was lower than that in the organic scenarios and high management of organic (75% organic) had the highest renewable energy (3388.3 MJ/ha) among other scenarios (Fig. 1). Moving towards organic management increased the share of renewable energy of the total input energy which led to the increase in renewable energy by 2.72%, 5.44% and 8.15% for 25%, 50% and 75% organic in comparison with conventional management, respectively. The share of renewable energy for 25%, 50% and 75% organic was 2.71%, 3.38% and 4.42% of total input energy, respectively.

The change percentage of economic indexes in the organic scenarios compared to the conventional system is illustrated in Fig. 2. The decease of total cost production, gross return, net return and benefit to cost were shown by approach to organic management for rice production. The highest change percentage of economic indexes was related to gross return and the lowest change was shown in benefit to cost index (Fig. 2). It seems that moving towards organic management according to organic scenarios resulted in improvement in energy indexes but decrease in economic indexes due to the same market price of rice in the transition period with conventional rice. It should be considered that the reduction of economic indexes in the transition period take place in initial years of organic management and high market price of crops after certification of organic farm led to improvement of these indexes.

4 Conclusions

The finding in this paper illustrated that the organic rice production system based on no-application of chemical inputs caused the increase in output to input ratio and economic indexes such as gross and net return and also benefit to cost ratio. The calculation of Durbin-Watson function indicated that human labor and fertilizer had the highest impact on rice biomass for organic and conventional systems, respectively. Direct and renewable energies for organic rice were higher than conventional system. Organic farming led to save of energy resource by decrease in non-renewable energy inputs associated to mitigation of environmental problems.

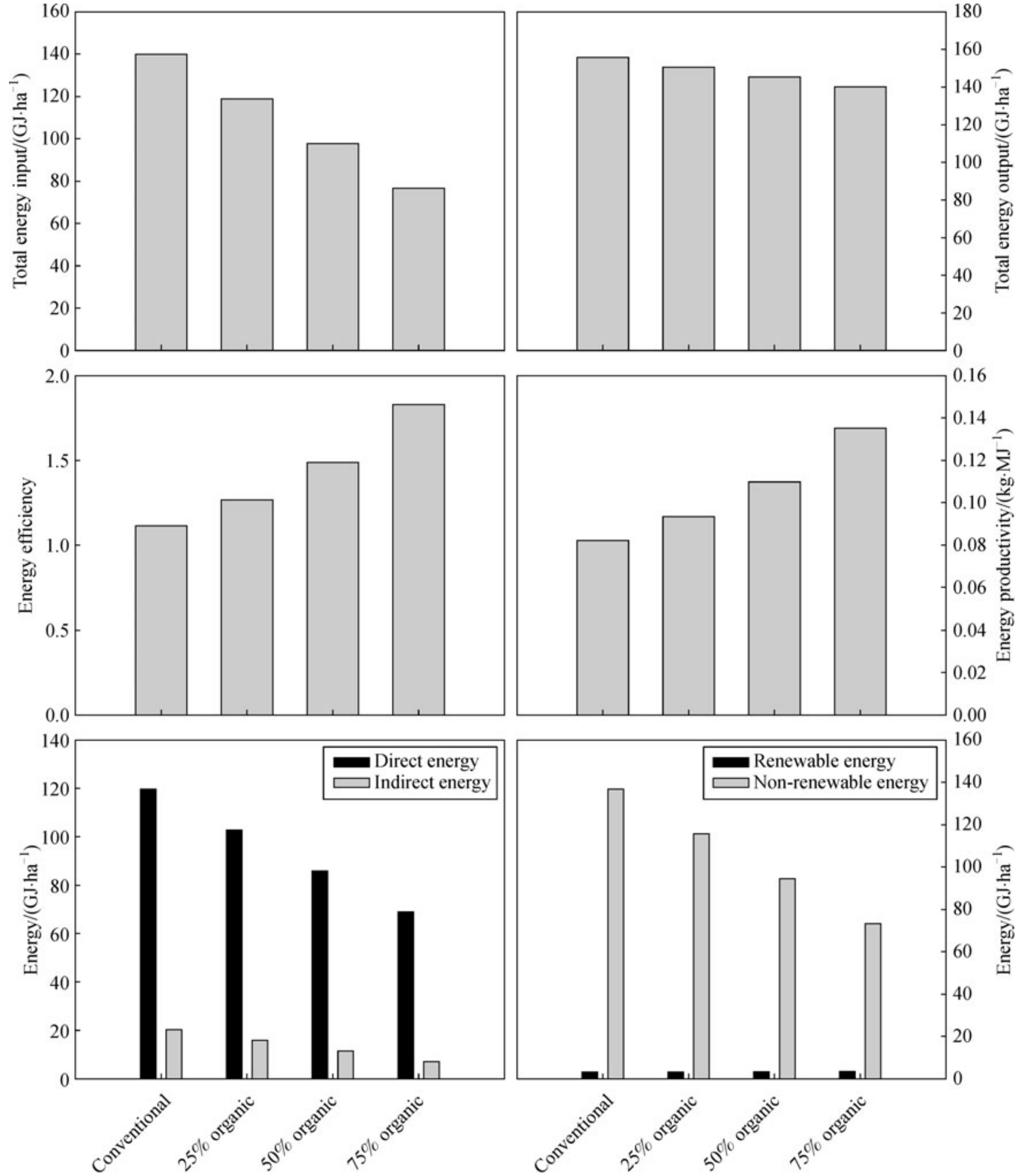

Fig. 1 Energy indexes in conventional and transition period to organic production rice

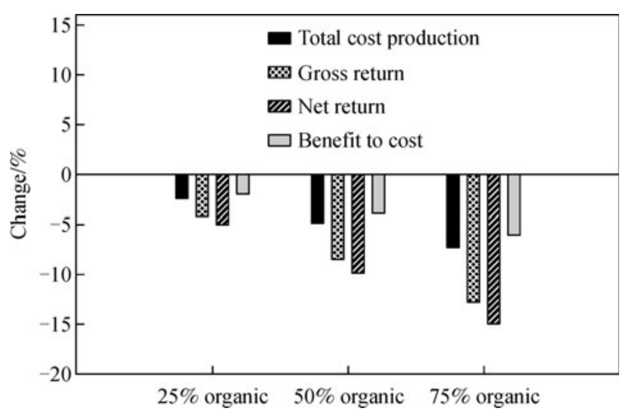

Fig. 2 Percentage change in economic indexes in transition period to organic production rice

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