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Pulses Production Systems in Term of Energy Use Efficiency and Economical Analysis in Iran

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ABSTRACT: Energy analysis of agroecosystems seems to be a promising approach to assess environmental problems and their relations to sustainability. The aim of the present study was to compare bean, lentil, irrigated and dryland chickpea farms in terms of energy efficiency, energy productivity, benefit to cost ratio and the amount of renewable energy use. Data were collected from 18 bean, 27 lentil, 24 irrigated chickpea and 46 dryland chickpea growers, using a face-to-face questionnaire during 2010. The results revealed that the total energy requirement were for bean 23666.8 MJ ha^{-1}, for lentil 14114.79 MJ ha^{-1}, for irrigated chickpea 15756.21 MJ ha^{-1}, and for dryland chickpea 2630.12 MJ ha^{-1}. The average energy input consumed in studied crops including direct, indirect, renewable and non-renewable energies in bean, lentil, irrigated chickpea and dryland chickpea farms were 67%, 33%, 30% and 70%, respectively. Energy use efficiency was 1.81 for bean, 1.79 for lentil, 1.21 for irrigated chickpea and 2.78 for dryland chickpea. The benefit to cost ratios in bean, lentil, irrigated chickpea and dryland chickpea farms were 6.18, 6.15, 3.71 and 8.10, respectively. Based on the results of the present study, dryland chickpea was the most efficient in terms of energy. Between studied irrigated crops, bean was the most efficient both in terms of energy and economical benefit.

Keyword: Energy Productivity, Net return, Bean, Chickpea, Lentil
JEL Classifications: O13, Q1, Q4

1. Introduction

Pulses are a staple food of poor rural and urban areas especially in developing countries while they are major cash crops in developed countries. Among pulses, Bean (*Phaseolus vulgaris* L.), lentil (*Lens culinaris* L.), and chickpea (*Cicer arietinum* L.) are the most important pulses worldwide. The cultivated area in Iran was about 697000 hectares, the share of chickpea, lentil and bean are 61.13%, 21.94% and 14.26%, respectively (MAJ, 2009). Khurasan Razavi province (Iran) is one of the pulse producing areas with cultivating area about 13500 ha where pulses are a main source of raw food material for many rural and urban families.

Today's agricultural production relies greatly on the consumption of non-renewable energies such as fossil fuel (Erdemir, 2006). Consumption of fossil energy results in direct negative environmental effects through release of CO_2 and other burning gases (Gallaher *et al.,* 2009). Nevertheless, great amounts of inexpensive fossil energy have indirect negative impacts on the environment such as less diversified nature etc. Energy, economics, and the environment are commonly dependent together (Refsgaard *et al.,* 1998; Pimentel *et al.,* 1994). Moreover, there is a close relationship between agriculture and energy. The productivity and profitability of agriculture depend upon energy consumption at the present. Thus, looking for agricultural production methods with higher energy productivity is today as typical as it was some 20 years ago (Refsgaard *et al.,* 1998). In agroecosystems, energy requirements are classified into four groups: direct and indirect, non-renewable and renewable. Direct energy is required to perform many tasks such as land preparation; irrigation, threshing, harvesting and transportation of agricultural inputs and farm products (Singh, 2000). Indirect energy contains the energy consumed in constructing, packaging and carrying fertilizers, biocides and machinery (Ozkan *et al.,* 2004). Non-renewable energy includes diesel, chemicals, fertilizers and machinery, and renewable energy consists of human labor, water, seeds and farmyard (Mohammadi *et al.,* 2008). Extensive use of direct and renewable energy enhances in energy supply and use efficiency is able to make a valuable contribution to meet sustainable energy development targets (Streimikiene *et al.,* 2007).

Energy consumption in agriculture has increased year by year while more intensive energy use has led to some important human health and environmental problems. It is necessary to reduce fossil energy inputs in agricultural systems. It would help to reduce agricultural carbon dioxide emissions. Thus, efficient use of energy inputs has become important in terms of sustainable farming (Karimi *et al.,* 2008, Rathke and Diepenbrock, 2006), and is one of the principal requirements of sustainable agriculture. Energy use in agriculture section has been growing in reaction to population rise, limited supply of arable land, and a demand for higher standards of living (Ghasemi Mobtaker *et al.,* 2010). Continuous demand in increasing food production resulted in intensive use of chemical fertilizers, pesticides, agricultural machinery and other natural resources. Therefore, efficient use of energy in agriculture will also reduce environmental problems, prevent destruction of natural resources, and support sustainable agriculture as an economical production system (Erdal *et al.,* 2007). An input to output of energy analysis is used in determining the effects of production systems on environment and efficient use of energy (Franzluebbers and Francis, 1995). The rate of energy used in agriculture depends on environmental factors such as soil and climatic conditions, amount of inputs and techniques employed in production (FAO, 2005).

In developing countries like Iran, agricultural growth is essential for nurturing, the economic improvement and meeting the ever-higher demands of the growing population (Beheshti-Tabar *et al.,* 2010). Commercial farming has replaced subsistence farming as the dominant mode of agricultural production in Iran, within the past 30 years. The agricultural section is Iran's second chief employment provider and is an important contributing part to the Gross Domestic Product (GDP). The share of agriculture in GDP was 10.87% in 2009 (MAJ, 2009). In recent years, with increasing world energy prices, the Iranian organizations have taken steps to decrease fuel and energy consumption. Rationing subsidized petrol and diesel for consumers and taking measures to enhance the efficiency of energy use to slow down the growing energy demands in all sectors of economy have been implemented. Nowadays, people are getting more aware of the implications of such policies in energy use in Iran (Beheshti-Tabar *et al.* 2010).

Many studies investigated input and output energy, and economic analysis to determine the energy efficiency of crop production, such as chickpea, irrigated and dryland wheat, barley in Iran (Ghasemi Mobtaker *et al.,* 2010 ;Salami and Ahmadi 2010; Ghorbani *et al.,* 2011), dry bean and canola in Turkey (Ozkan *et al.,* 2004; Unakitan *et al.,* 2010), rice in Malaysia (Bockari Gevao *et al.,* 2005), and maize and sorghum in the United States (Mohammadi *et al.,* 2008). However, no studies are published on the energy and economical analysis of pulses production in Iran. Because of worldwide use of pulses for food and feed, extensive knowledge is needed about energy consumption in their production systems and thereby it could enhance energy use efficiency. Thus the aims of this study were (i) to determine the total amount of input-output energy used in three major pulse production systems (bean, lentil and irrigated and dryland chickpea), (ii) to analysis energy and economical use efficiency per hectare for the production of pulse systems and, (iii) to compare bean, lentil and irrigated and dryland chickpea production systems in term of energy use efficiency and economical analysis in Khorasan Razavi province, Iran.

2. Material and methods

2.1. Description site study

The present study was conducted in Khorasan Razavi province which is located northeast of Iran, within 30024 and 38017 north latitude and 55017 and 61015 east longitude. Total area of the province is 12842000 ha and the total farming area of bean, lentil and chickpea is 13486 ha consisting of 916 ha bean, 2245 ha lentil, 2108 ha irrigated chickpea and 8217 ha dryland chickpea. In order to determine the relation between pulse yield and energy consumption, required data were collected from growers by using a face to face questionnaire during 2010. In addition to the data obtained by surveys, previous studies of related organizations such as Food and Agricultural Organization (FAO) and Ministry of Agriculture of Iran (MAJ) were also utilized during this study. The number of operations involved in the pulse production systems, and their energy requirements influence the final energy balance. A random sampling method was used, and the sample size was calculated using Equation (Unakitan *et al.,* 2010).

$$\mathrm{n} = \frac{N \times S^2}{(N-1)S_X^2 + S^2} \qquad (1)$$

where n is the required sample size, N is population volume, S is standard deviation, S_X is standard deviation of sample mean ($S_X = d/z$) , d, the permissible error in the sample size, was defined to be 10% of the mean for a 95% confidence interval and z is the reliability coefficient (1.96, which represents 95% reliability). Based on the calculation the sample size were 18 for bean, 27 for lentil, 24 for irrigated chickpea and 46 for dryland chickpea farms.

2.2. Energy analysis

Energy efficiency of agricultural system was evaluated by the energy ratio between output and input (Alam *et al.,* 2005). Human labor, machinery, diesel oil, fertilizer, pesticides and seed amounts and output yield values of bean, lentil, irrigated chickpea and dryland chickpea have been used to estimate the energy ratio. Energy equivalents shown in Table 1 were used for estimation. The sources of mechanical energy used on the selected farms included tractors and diesel oil. The mechanical energy was computed on the basis of total fuel consumption (l ha^{-1}) in different farm operations. Therefore, the energy consumed was calculated, using conversion factors and expressed in MJ ha^{-1} (Tsatsarelis, 1991). Basic information on energy inputs and also yield of bean, lentil, irrigated chickpea and dryland chickpea were transferred into Excel spreadsheets, and analyzed by SPSS program. Energy use efficiency, energy productivity, specific energy and net energy were calculated based on inputs and output energy equivalents (Bockari Gevao *et al.,* 2005; Ghorbani *et al.,* 2011).

$$\text{Energy use Efficiency} = \frac{Energy \;\; output(MJ\, ha^{-1})}{Energy \;\; input(MJ\, ha^{-1})} \qquad (2)$$

$$\text{Energy Productivity} = \frac{\text{crops} \;\; output(Kg\, ha^{-1})}{Energy \;\; input(MJ\, ha^{-1})} \qquad (3)$$

$$\text{Specific Energy} = \frac{\text{Energy input } (MJ\ ha^{-1})}{\text{crops output } (t\ ha^{-1})} \quad (4)$$

$$\text{Net Energy} = \text{Energy output } (MJ\ ha^{-1}) - \text{Energy Input } (MJ\ ha^{-1}) \quad (5)$$

Indirect energy included energy embodied in seeds, chemical fertilizers (NPK), herbicide (Treflan and Basagran), pesticide (Diazinon), fungicide (Carboxin) and machinery while direct energy covered human labor, diesel, electricity and water used in pulse production. Non-renewable energy includes diesel, electricity, chemical pesticides, chemical fertilizers and machinery, and renewable energy consists of human labor, seeds and water.

2.3. Economical analysis

The economic inputs of pulses production systems contained variable costs. The variable costs of production included current costs (for example: chemicals, fuel, human labor and electricity). The economic output of pulse production systems includes grain and straw yield. All prices of input and output were market prices (average prices of the year 2010). Gross and net return, total cost of production, benefit to cost ratio and productivity was calculated according to the following equations (Bockari Gevao *et al.,* 2005; Banaeian *et al.,* 2011):

Gross return = grain and straw yield (kg ha^{-1}) × grain and straw price ($) (6)
Net return = Gross return ($ ha^{-1}) - total cost of production ($ ha^{-1}) (7)
Benefit to cost ratio = Gross return ($ ha^{-1}) / total cost of production ($ ha^{-1}) (8)
Productivity = pulse yield (kg ha^{-1}) / total cost of production ($ ha^{-1}) (9)

Table 1. Energy equivalent of inputs and outputs in agricultural production

Particulars	Unit	Energy equivalent (MJ unit^{-1})	Ref.
A. Inputs			
1. Human labor	h	1.95	(Taylor *et al.*, 1993)
2. Machinery	h	62.7	(Alam *et al.*, 2005; Ozkan *et al.*, 2004)
3. Diesel fuel	l	56.30	(Taylor *et al.,* 1993)
4. Chemical fertilizers			
(a) Nitrogen	kg	75.46	(Taylor *et al.,* 1993)
(b) Phosphate	kg	13.07	(Taylor *et al.,* 1993)
(c) Potassium	kg	11.15	(Demircan *et al.,* 2006; Kousar *et al.,* 2006; Sartori *et al.,* 2005)
5. Chemicals			
(a) Herbicides	l	238.3	(Taylor *et al.,* 1993; Kitani, 1999)
(b) Basagran	l	187.8	(Taylor *et al.,* 1993; Kitani, 1999)
(c) Pesticide	l	101.2	(Taylor *et al.,* 1993; Kitani, 1999)
(d) Fungicide	kg	181.9	(Taylor *et al.,* 1993)
6. Electricity	kWh	3.6	(Taylor *et al.,* 1993)
7. Water for irrigation	m^3	1.02	(Ozkan *et al.,* 2004; Yamane, 1967)
8. Seeds (bean)	kg	14.9	(Taylor *et al.,* 1993)
9. Seeds (chickpea)	kg	14.7	(Kitani 1999)
10. Seeds (lentil)	kg	14.7	(Taylor *et al.,* 1993)
B. Outputs			
1. Bean grain yield	kg	14.9	(Topak *et al.,* 2005)
2. Bean straw yield	kg	12.5	(Topak *et al.,* 2005)
3. chickpea grain yield	kg	14.7	(Kitani, 1999)
4. chickpea straw yield	kg	12.5	(Kitani, 1999)
5. lentil grain yield	kg	14.7	(Taylor *et al.,* 1993)
2. lentil straw yield	kg	12.5	(Taylor *et al.,* 1993)

3. Results and discussion

3.1. Structures of farms

Structures of farms where pulse was produced and all essential cultural practices were determined and presented in Table 2. Chemicals were sprayed 3.3, 2.4, 2.8 and 1 times on bean, lentil, irrigated chickpea and dryland chickpea farms, respectively. Irrigation operations were performed on average 13.7, 4.3 and 6.1 times in bean, lentil and irrigated chickpea farms. Land preparation and soil tillage were frequently accomplished by a Massey Ferguson 28,575 hp tractor along with moldboard plow, disc harrows, land leveler (for irrigated), and chisel (for dryland). The average farm sizes were in bean 1.2 ha, in lentil 0.7 ha, in irrigated chickpea 1.1 ha and in dryland chickpea 2.9 ha. About 79.6% of total land in chickpea production was dryland and only 20.4% was used as irrigated. Winter wheat, barley, cotton, corn, sorghum, tomato and alfalfa were grown along with pulse in the studied farms. The number of tractors per farm was 0.3 ha^{-1}. Other agronomic practices are shown in Table 2.

Table 2. Management practices for bean, lentil and irrigated and dryland chickpea

Practices/operations	Bean	Lentil	Irrigated chickpea	Dryland chickpea
Names of varieties	Derakhshan, Naze	Robat, Gachsaran	Jam, Kermanshahi, Karaj 12-60-31	Jam, Kermanshahi, Karaj 12-60-31
Land preparation tractor used: 285 MF 75 hp	Moldboard plow, Disc harrows, Land leveller	Moldboard plow, Disc harrows, Land leveller	Moldboard plow, Disc harrows, Land leveller	Chisel
Land preparation period	April	February	February	October
Average tilling number	2.2	2.2	2.2	1.2
Planting period	May	March	March	November
Fertilization period (Before planting)	April	February	February	___
Fertilization period (Top dressing)	May	April	April	___
Average number of fertilization	2.2	1.2	1.5	___
Irrigation period	May-September	March-June	March-July	___
Average number of irrigation	13.7	4.3	6.1	___
Spraying period	April-July	March-May	March-May	May
Average number of spraying	3.3	2.4	2.8	1
Harvesting period	August-September	May –June	June-July	May –June

3.2. Input energy

Total energy used in different production processes for producing bean, lentil, irrigated chickpea and dryland chickpea are shown in tables 3, 4, 5 and 6. The main factors resulting in excessive energy use in irrigated chickpea were application of diesel fuel and irrigation water. However, the share of energy use of total energy for diesel and machinery were higher in dryland farms. But, the amount of energy used in different farming practices such as machinery, electricity and fertilizer in irrigated farms was higher than that of dryland farms. Salami and Ahmadi (2010) reported that diesel energy engrossed 37.9% of total energy, followed by chemical fertilizer 29.6% during production period in chickpea in Kurdistan province of Iran. Asakereh *et al.* (2010) showed that the total energy input in organic lentil was 5062 and in non-organic lentil was 6196.5 MJ ha^{-1} in Kurdistan County of Iran.

Table 3. Energies consumed in bean farms

Energy	Quantity per unit area (ha)	Total energy equivalent (MJ)	Percentage of total energy input (%)
Input			
Human labor	525.90	1031.45	4.30
Machinery	24.45	1533.10	6.51
Diesel fuel	81.35	4086.20	17.26
Nitrogen	23.00	1735.60	7.33
Phosphate (P_2O5)	92.00	1202.40	5.10
Potassium (K_2O)	25.00	275.80	1.21
Herbicides	1.50	357.51	1.50
Pesticide	2.00	202.40	0.87
Fungicide	0.50	90.95	0.38
Electricity	1400	5040.0	21.29
Water for irrigation	7000	7140.0	30.16
Seed	65.0	964.50	4.09
Total energy input		23666.8	100.00
Outputs			
Bean grain yield	1217.50	18140.80	42.26
Bean straw yield	1982.50	24781.30	57.73
Total energy output		42922.00	

Table 4. Energies consumed in lentil farms

Energy	Quantity per unit area (ha)	Total energy equivalent (MJ)	Percentage of total energy input (%)
Input			
Human labor	441.15	860.24	6.09
Machinery	20.15	1263.40	8.96
Diesel fuel	68.45	3438.24	24.36
Nitrogen	23.00	1735.60	12.29
Phosphate (P_2O5)	46.00	601.22	4.25
Potassium (K_2O)	25.00	278.75	1.98
Herbicides	1.00	238.00	1.68
Pesticide	2.00	202.40	1.44
Fungicide	0.50	90.95	0.64
Electricity	520	1872.00	13.27
Water for irrigation	2600	2652.00	18.79
Seed	60.00	882.00	6.25
Total energy input		14114.79	100.00
Outputs			
Bean grain yield	696.60	10240.02	40.50
Lentil straw yield	1203.40	15042.50	59.50
Total energy output		25282.52	

Table 5. Energies consumed in irrigated chickpea farms

Energy	Quantity per unit area (ha)	Total energy equivalent (MJ)	Percentage of total energy input (%)
Input			
Human labor	434.55	847.37	5.37
Machinery	21.55	1351.18	8.57
Diesel fuel	72.85	3659.25	23.23
Nitrogen	23.00	1735.60	11.01
Phosphate (P_2O5)	46.00	601.22	3.81
Potassium (K_2O)	25.00	278.75	1.77
Herbicides	1.00	238.00	1.52
Pesticide	2.00	202.40	1.28
Fungicide	0.50	90.95	0.58
Electricity	700	2520.00	16.00

Water for irrigation	3500	3570.00	22.66
Seed	45.00	661.50	4.20
Total energy input		15756.21	100.00
Outputs			
Chickpea grain yield	453.50	6666.45	34.86
Chickpea straw yield	996.50	12456.25	65.14
Total energy output		19122.70	

Table 6. Energies consumed in dryland chickpea farms

Energy	Quantity per unit area (ha)	Total energy equivalent (MJ)	Percentage of total energy input (%)
Input			
Human labor	103.00	200.85	7.64
Machinery	9.00	564.30	21.45
Diesel fuel	29.00	1456.67	55.38
Nitrogen	-	-	-
Phosphate (P_2O5)	-	-	-
Potassium (K_2O)	-	-	-
Herbicides	1.00	187.80	7.14
Pesticide	-	-	-
Fungicide	-	-	-
Electricity	-	-	-
Water for irrigation	-	-	-
Seed	15.00	220.50	8.39
Total energy input		2630.12	100.00
Outputs			
Chickpea grain yield	144.70	2127.09	29.06
Chickpea straw yield	415.30	5191.25	70.94
Total energy output		7318.34	

3.3. Output Energy

Grain and straw yield in bean, lentil, irrigated chickpea and dryland chickpea farms were calculated and presented in tables 3, 4, 5 and 6. Energy use efficiency in dryland chickpea was nearly 2.4 times more than irrigated chickpea, which could be due to using low input energy in dryland systems. Therefore, our results indicate that the energy was used most efficiently in dryland chickpea, followed by bean, lentil and irrigated chickpea. Among irrigated production systems, bean farms showed the highest energy use efficiency. It seems that high energy efficiency for bean was due to its high output compared to lentil and irrigated chickpea. In another study conducted by Topak *et al.* (2009), the total energy output and energy efficiency for bean was 37250 MJ ha^{-1} and 1.11, respectively. Salami and Ahmadi (2010) showed that the energy use efficiency was 1.04 in chickpea in Kurdistan province of Iran.

Mean grain yield in dryland farms was 68.18% lower than that in irrigated farms. While chickpea yield was lower in dryland farms, the energy output-input ratio was higher. In another study in Iran, reported by Ghorbani *et al.* (2011), the total energy requirement in wheat low-input systems was 9354.2 MJ ha^{-1}, whereas in wheat high-input systems it was 45367.6 MJ ha^{-1} and energy ratio in low-input systems was 3.38, however, it was 1.44 in high-input systems.

3.4. Energy production

The total energy input consumed could be classified as direct (73.1%, 62.5%, 67.2% and 63.0%), indirect (26.9%, 37.5%, 32.8% and 37.0%), renewable (38.6%, 31.1%, 32.2% and 16.0%) and non-renewable (61.4%, 68.9%, 67.8% and 84.0%) energy in bean, lentil, irrigated chickpea and dryland chickpea, respectively (Table 7). The share of direct energy from total energy used in the studied crops was higher than indirect energy. Although, the share of direct energy in dryland chickpea farms (63.0%) was low, energy use efficiency was higher than other crops due to lack of irrigation and not using fertilizer. Total energy input in dryland chickpea systems were 83.3% lower than irrigated systems. In other words, total energy input needed in dryland chickpea system was 16.7% compared to the irrigated systems.

Our results indicated that the share of renewable energy from the total energy used in investigated crops was lower than non-renewable energy. Renewable energy in bean was higher than in other crops. It is necessary to reduce the share of non-renewable energy for achieving high energy efficiency in agricultural production systems. Due to the highly mechanized agricultural systems in most area of Iran, fuel consumption has risen by 10% in recent years (Beheshti-Tabar *et al.,* 2010). Reducing consumption of diesel fuel and fertilizer (especially Nitrogen) has major effect in decreasing total energy consumption. Saving in diesel by changing tillage, harvest system, and other agronomic operations could enhance field energy efficiency. Moreover, using direct and local marketing crops improves profitability for growers and reduces energy needed for their transport. Ghorbani *et al.* (2011) reported that the share of non-renewable energy (76%) in comparison with renewable energy (24%) was higher in irrigated and dryland wheat production systems in Iran. Beheshti-Tabar *et al.* (2010) stated that with higher yields and improved agricultural practices in the wheat irrigated systems, the unit of land used per unit of output, reduced by 32% in 2006 compared to 1990. It can be inferred that improvement in irrigation efficiency together with the promotion of targeted application of fertilizers can have a significant effect on energy efficiency in Iran agriculture. Advances in irrigation will also alleviate the effect of droughts on energetic parameters. Employment of more productive cultivars along with more intense crop management will cause higher outputs, and consequently lead to a higher energy ratio (Ghorbani *et al.,* 2011).

Table 7. Total energy input in the form of direct, indirect, renewable and non-renewable energies in bean, lentil, irrigated chickpea and dryland chickpea farms.

Type of energy	Bean		Lentil		Irrigated chickpea		Dryland chickpea	
	(MJ ha^{-1})	% [a]	(MJ ha^{-1})	% [a]	(MJ ha^{-1})	% [a]	(MJ ha^{-1})	% [a]
Direct energy[b]	17297.66	73.09	8822.49	62.50	10596.63	67.25	1657.52	63.02
Indirect energy[c]	6369.08	26.91	5292.30	37.50	5159.58	32.74	972.6	36.98
Renewable energy[d]	9139.95	38.62	4394.24	31.13	5078.87	32.24	421.35	16.02
Non-renewable energy[e]	14526.80	61.38	9720.55	68.87	10677.34	67.76	2208.77	83.98
Total energy input	23666.75		14114.79		15756.21		2630.12	

3.5. Energy Productivity and specific energy

Energy input and output, energy use efficiency, specific energy, energy productivity and net energy are summarized in Table 8. The highest energy use efficiency was 2.78 for dryland chickpea and the lowest was 1.21 for irrigated chickpea. Average energy productivity of bean, lentil, irrigated chickpea and dryland chickpea were 0.051, 0.049, 0.029 and 0.055 kg MJ^{-1}, respectively. This means that 0.051, 0.049, 0.029 and 0.055 outputs were obtained per unit energy in bean, lentil, irrigated chickpea and dryland chickpea, respectively. Calculation of energy productivity rate is documented in the literature for tomato (1.0) (Esengun *et al.,* 2007), cotton (0.06) (Yilmaz *et al.,* 2005) and sugar beet (1.53) (Erdal *et al.,* 2007). Our results indicated that specific energy was higher in irrigated chickpea than other studied crops. Also, net energy was 19255.2 MJ ha^{-1} in bean which is higher than other crops. Canakci and Akinci (2006) reported that specific energy was 16.2 for Sesame, 11.2 for cotton, 5.2 for wheat, 3.9 for maize, 1.1 for tomato, 0.98 for melon and 0.97 for water-melon in Turkey.

Development of low-input systems with using minimum rate of fossil energy while maintaining high output of food would help to reduce carbon dioxide emissions (Rathke and Diepenbrock, 2006). Better knowledge of fossil energy use in agricultural systems is needed in order to develop agronomic practices that allow utilizing limited energy resources more efficiently (Dalgaard *et al.,* 2001). It seems that production of nitrogen fertilizer represents the largest component of energy consumption for production among all chemical fertilizers (McLaughlin *et al.,* 2000). Traditionally, legumes have been viewed as excellent sources of nitrogen in agriculture (Kinzig and Socolow, 1994). Crop rotations with legumes, capable for fixing atmospheric nitrogen, can maintain production levels with reduced reliance on energy intensive mineral fertilizers (Rathke and Diepenbrock, 2006).

Table 8. Energy input-output ratio in bean, lentil, irrigated chickpea and dryland chickpea farms.

Items	Unit	Bean	Lentil	Irrigated chickpea	Dryland chickpea
Energy input	MJ ha^{-1}	23666.75	14114.79	15756.21	3630.12
Energy output	MJ ha^{-1}	42922.00	25282.52	19122.70	7318.34
Energy use efficiency	-	1.81	1.79	1.21	2.78
Specific energy	MJ kg^{-1}	19.45	20.26	34.74	18.18
Energy productivity	kg MJ^{-1}	0.051	0.049	0. 029	0.055
Net energy	MJ ha^{-1}	19255.25	11167.73	3366.49	4688.22

Table 9. Economic analysis in bean, lentil, irrigated chickpea and dryland chickpea farms.

Cost and return components	Bean (value)	Lentil (value)	Irrigated chickpea (value)	Dryland chickpea (value)
Grain Yield (kg ha^{-1})	1217.50	696.60	453.50	144.70
Grain sale price ($)	0.557	0.620	0.620	0.620
Straw yield(kg ha^{-1})	1982.50	1203.34	996.50	415.30
Straw sale price ($)	0.077	0.077	0.077	0.077
Gross return ($ ha^{-1})	830.24	524.34	357.67	121.58
Gross return ($ kg^{-1})	0.26	0.28	0.25	0.22
Gross return ($ MJ^{-1})	0.019	0.021	0.019	0.017
Total cost of production ($ ha^{-1})	134.42	85.18	96.48	15.18
Total cost of production ($ kg^{-1})	0.042	0.045	0.066	0.027
Total cost of production ($ MJ^{-1})	0.003	0.003	0.005	0.002
Net return ($ ha^{-1})	695.82	439.15	261.19	106.40
Net return ($ kg^{-1})	0.22	0.23	0.18	0.19
Net return ($ MJ^{-1})	0.016	0.017	0.017	0.014
Benefit to cost ratio	6.18	6.15	3.71	8.10
Productivity (kg $\$^{-1}$)	9.06	8.18	4.70	9.53

3.6. Economical indices

Production costs and gross product values are shown in Table 9. Total costs of production in bean were higher than other investigated crops. Results of our study indicated that the total cost of production in bean, lentil, and irrigated chickpea were higher than dryland chickpea. It seems that this was due to intensive use of fuel, fertilizer, water for irrigation and electricity in irrigated chickpea. Large quantities of locally available non-commercial energies, such as seed, manure and animal energy, and commercial energies directly and indirectly in form of diesel, electricity, fertilizer, chemicals, irrigation water and machinery are applied in agriculture. Efficient use of these inputs helps to achieve higher production and improvement of economy stability, profitability and competitiveness of agriculture sustainability (Singh *et al.,* 2002). Moreover, in recent decades, fossil resources consumption has enormously increased to achieve higher yield. Utilization of fossil energies threatens soil fertility and weakens the economic independence of farmers. Therefore, any positive change in energy consumption leading reducing them will bring a positive effect in agricultural ecosystems (Zahid *et al.,* 2010; Schneider and Smith, 2009).

4. Conclusions

The objective of this study was to perform an energy input-output analysis of Iranian farmers' pulse production systems. Results indicate that diesel fuel, water for irrigation, machinery and electricity energies constituted the major part of energy inputs used in irrigated farms. High amount of diesel fuel consumption is due to intensive use of machinery for operations such as soil preparation, cultural practices, harvest and transportation. This is somewhat because of the small average size of pulse farms. Nevertheless, our results revealed that water for irrigation was not used efficiently in the studied farms. It seems to be due to the fact that farmers applying unsuitable irrigation methods according to the scientific principles.

Bean, lentil and irrigated chickpea consumed a total energy of 23666.7, 14114.8 and 15756.2 MJ ha^{-1}, which was mainly due to the application of diesel fuels, water for irrigation and electricity. Total energy input consumed in dryland chickpea was 2630.1 MJ ha^{-1}, which was mainly due to diesel fuel and machinery energy. With the exception of bean, the energy input in form of diesel fuels, water for irrigation and electricity had the first, secondary and third share within the total energy inputs in lentil and irrigated chickpea.

Energy use efficiency was 1.81 in the bean, 1.79 in the lentil, 1.21 in the irrigated chickpea and 2.78 in the dryland chickpea. Although net return per ha in dryland chickpea was less than irrigated one, energy efficiency and benefit to cost ratio in dryland were much higher than irrigated systems, meanwhile, there was at least a minimum crop production in areas with water deficiency. In terms of energy use efficiency, dryland chickpea farms reflected more than 1.5, 1.6 and 2.3 times the rate compared to irrigation investigated farms, subsequently a growing trend towards higher sustainability.

Attaining minimum production with high energy efficiency in present market where crop prices rise rapidly and as Moria *et al.* (2010) predicted will grow even higher in future. This seems to be essential for governments and policy makers to prevent the growth of a vulnerable food market and low income individuals. Therefore, there is a need to follow a new policy persuading farmers to undertake energy efficient practices that increase crop yield without destructive natural resources. Based on results of the present study, dryland chickpea was most efficient in terms of energy. Other positive aspects of dryland farming in Iran are reducing erosion by covering soil and minimum or no consumption of biocides and chemical synthetic fertilizers which cause lower using energy input and also more environmental friendly production systems (Ghorbani *et al.,* 2011). Among the investigated irrigation crops, bean was the most efficient in terms of energy and economical benefit.

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