VOL. 7, NO. 3, MARCH 2012 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

EVALUATION ENERGY BALANCE AND ENERGY INDICES OF BARLEY PRODUCTION UNDER WATERED FARMING IN NORTH OF IRAN

Ebrahim Azarpour
Department of Agriculture, Lahijan Branch, Islamic Azad University, Lahijan, Iran
E-Mail: e786_azarpour@yahoo.com

ABSTRACT

One way to evaluate sustainable development in agriculture is using of energy flow method. This method in an agricultural product system is the energy consuming in product operations and energy saving in produced crops. In this article, evaluation of energy balance and energy indices under watered farming barley in north of Iran (Guilan province) was investigated. Data were collected from 72 farms by using a face to face questionnaire method during 2011 year in Guilan province. By using of consumed data as inputs and total production as output, and their concern equivalent energy, energy balance and energy indices were calculated. In the present study, energy efficiency (energy output to input energy ratio) for seed and straw were found to be 2.70 and 2.89, respectively. Also, energy balance efficiency (production energy to consumption energy ratio) for seed and straw in this study were 1.79 and 1.38, respectively, showing the affective use of energy in the agro ecosystems barley production.

Keywords: barley, energy indices, energy balance, yield, Iran.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops of Iran and the world. The yield of barley has increased twofold because energy consumption in barley production has increased in recently years. The land area under barley production in Iran is about 1675654 ha which produces 3446228 ton of barley (Anonymous, 2010). Barley is a major staple food in several regions of the world and it is generally found in regions where other cereals do not grow well due to altitude, low rainfall, or soil salinity. It remains the most viable option in dry areas (<300mm of rainfall) (Ghasmi Mobtaker *et al*., 2010).

The vital role of precious energy in the development of key sectors of economic importance such as industry, transport and agriculture has motivated many researchers to focus their research on energy management. The importance of such study, especially for the agricultural sector, has increased due to the urgent need to meet the growing demand of food production for an ever-growing population. Energy has been a key input of agriculture since the age of subsistence agriculture. It has been an established fact worldwide that agricultural production is positively correlated with energy input (Baruah and Dutta, 2010).

Efficient use of energy is one of the principal requirements of sustainable agriculture. Energy use in agriculture has been increasing in response to increasing population, limited supply of arable lands, and a desire for higher standards of living. Continuous demand in increasing food production resulted in intensive use of energy inputs and natural resources. However, intensive use of energy causes problems threatening public health and environment. Efficient use of energy in agriculture will minimize environmental problems, prevent destruction of natural resources, and promote sustainable agriculture as an economical production system (Erdal *et al*., 2007). Economic production is a function of many factors such as human labor, capital, natural resources, availability of energy and technology. Therefore, both the natural resources are rapidly decreasing and the amount of contaminants is considerably increasing. The best way to lower the environmental hazard of energy use is to increase the energy use efficiency (Esengun *et al*., 2007). Energy input–output analysis is usually used to evaluate the efficiency and environmental impacts of production systems. It is also used to compare the different production systems. Khan *et al*., (2009) studied the energy inputs in wheat, rice and barley production for reducing the environmental footprint of food production in Australia. The results showed that barley crop seems more efficient in terms of energy and water use jointly.

The main aim of this study was to determine energy use in barley production, to investigate the efficiency of energy consumption and to make an energy balance and energy indices analysis of barley under watered farming in Guilan province of Iran.

MATERIALS AND METHODS

Data were collected from 72 farms by using a face to face questionnaire method during 2011 year in Guilan province (north of Iran). The random sampling of production agro ecosystems was done within whole population and the size of each sample was determined by using bottom equation (Kizilaslan, 2009):

$$n = \frac{N \times s^2 \times t^2}{(N-1)d^2 + s^2 \times t^2}$$

In the formula, n is the required sample size, s is the standard deviation, t is the t value at 95% confidence limit (1.96), N is the number of holding in target population and d is the acceptable error.

In order to calculate input-output ratios and other energy indicators, the data were converted into output and input energy levels using equivalent energy values for each commodity and input. Energy equivalents shown in Table-1 was used for estimation (Adapa *et al*., 2009; Ghasmi Mobtaker *et al*., 2010; Khan *et al*., 2009; Khan *et al*., 2010; Moradi and azarpour, 2011; Yousefi and Gazvineh, 2011). Firstly, the amounts of inputs used in the production of barley were specified in order to calculate the energy equivalences in the study. Energy input include human labor, machinery, diesel fuel, chemical fertilizers, poison fertilizers and seed and output yield include grain yield of barley. The energy use efficiency, energy specific, energy productivity and net energy gain were calculated according to bottom equations (Adapa *et al*., 2009; Ghasmi Mobtaker *et al*., 2010; Khan *et al*., 2009; Khan *et al*., 2010; Moradi and azarpour, 2011; Yousefi and Gazvineh, 2011).

$$\text{Energy ratio} = \frac{\text{Output energy (Mj/ha)}}{\text{Input energy (Mj/ha)}}$$

$$\text{Energy production} = \frac{\text{Grain yield (Kg/ha}}{\text{Input energy (Mj/ha)}}$$

$$\text{Energy intensity} = \frac{\text{Input energy (Mj/ha)}}{\text{Grain yield (Kg/ha)}}$$

$$\text{Water and energy productivity} = \frac{\text{Yield output (Kg/ha)}}{\text{Water applied (M}^3\text{/ha)} \times \text{Input energy (Mj/ha)}}$$

$$\text{Net energy gain} = \text{Output energy (Mj/ha)} - \text{Input energy (Mj/ha)}$$

The input energy was divided into direct, indirect, renewable and non-renewable energies (Kizilaslan, 2009; Ozkan *et al*., 2004). Direct energy covered human labor, water and diesel fuel, used in the barley production while indirect energy consists of seed, chemical fertilizers, poison fertilizers, and machinery energy. Renewable energy consists of human labor, water and seed and nonrenewable energy includes chemical fertilizers, poison fertilizers and machinery energy.

In order to indicators of energy balance, basic information on energy inputs were entered into excel spreadsheets and then energy equivalent were calculated according to Table-2 (Adapa *et al*., 2009; Taghavi *et al*., 2007). By using of consumed data as inputs and total production as output, and their concern equivalent energy, indicators of energy balance were calculated. Energy input include human labor, machinery, diesel fuel, chemical fertilizers, poison fertilizers, water, machinery depreciation for per diesel fuel and seed and output yield include grain yield and straw yield of barley.

RESULTS AND DISCUSSIONS

Analysis of input-output energy use in barley production

The inputs used in barley production and their energy equivalents and output energy equivalent are illustrated in Table-1.

Table-1. Amounts of inputs, output and their equivalent energy from calculated indicators of energy.

Parameter	Unit	Quantity per hectare	Energy equivalents	Total energy equivalents	Percent
Inputs					
Human labor	h/ha	360	1.96	705.60	4.26
Machinery	h/ha	12	62.7	752.40	4.54
Diesel fuel	L/ha	110	56.31	6194.10	37.36
Nitrogen	Kg/ha	63	69.5	4395.24	26.51
Phosphorus	Kg/ha	14	12.44	169.18	1.02
Potassium	Kg/ha	10	11.15	111.50	0.67
Poison	L/ha	3	120	360	2.17
Water	M^3/ha	1600	1.02	1632	9.84
Seed	Kg/ha	144	14.7	2258.76	13.62
Output					
Grain yield	Kg/ha	3045	14.7	44762	100
Straw yield	kg/ha	3837	12.5	47963	100

About 144 kg seed, 360 h human labor, 12 h machinery power and 110 L diesel fuel for total operations were used in agro ecosystems barley production on a hectare basis. The use of nitrogen fertilizer, phosphorus and potassium were 63, 14 and 10 kg per one hectare, respectively. The total energy equivalent of inputs was calculated as 16579 MJ/ha. The highest shares of this amount were reported for diesel fuel (37.36%), nitrogen fertilizer (26.51%), seed (13.62%) and water (9.84%), respectively. The energy inputs of potassium chemicals (0.67%), phosphorus chemicals (1.02%), and poison (2.17%) were found to be quite low compared to the other inputs used in production (Table-1). The average seed yield of barley was found to be 3045 kg/ha and its energy equivalent was calculated to be 44762 MJ/ha (Table-1). The average straw yield of barley was found to be 3837 kg/ha and its energy equivalent was calculated to be 47963 MJ/ha (Table-1).

Table-2. Amounts of inputs and their equivalent energy from calculated indicators of energy balance.

Parameter	Unit	Quantity per hectare	Energy equivalents	Total energy equivalents	Percent
Inputs					
Human labor	h/ha	360	500	180000.00	3.30
Machinery	h/ha	12	90000	1080000.00	19.80
Diesel fuel	L/ha	110	9237	1016070.00	18.63
Nitrogen	kg/ha	63	17600	1113038.08	20.40
Phosphorus	kg/ha	14	3190	43382.72	0.80
Potassium	kg/ha	10	1600	16000.00	0.29
Poison	L/ha	3	27170	81510.00	1.49
Water	M^3/ha	1600	272.2	435520.00	7.98
Seed	kg/ha	144	4200	604254.00	11.08
Depreciation for per diesel fuel	L	92.4	9583	885469.20	16.23

Evaluation indicators of energy in barley production

The energy use efficiency, energy production, energy specific, energy productivity, water and energy productivity, net energy gain, and intensiveness of barley seed production were shown in Table-3.

Table-3. Analysis of energy indices in barley production.

Item	Unit	Barley
Seed		
Yield	Kg/ha	3045
Input energy	Mj/ha	16579
Output energy	Mj/ha	44762
Energy use efficiency	-	2.70
Energy specific	Mj/Kg	5.44
Energy productivity	Kg/Mj	0.18
Net energy gain	Mj/ha	28183
Water and energy productivity	$g/m^3.Mj$	0.011
Direct energy	Mj/ha	8532 (51.46%)
Indirect energy	Mj/ha	8047 (48.54%)
Renewable energy	Kg/Mj	4596 (27.72%)
Nonrenewable energy	Mj/ha	11982 (72.28%)
Straw		
Yield	Kg/ha	3837
Input energy	Mj/ha	16579
Output energy	Mj/ha	47963
Energy use efficiency	-	2.89
Energy specific	Mj/Kg	4.32

Energy productivity	Kg/Mj	0.23
Net energy gain	Mj/ha	31384
Water and energy productivity	g/m^3.Mj	0.014
Direct energy	Mj/ha	8532 (51.46 %)
Indirect energy	Mj/ha	8047 (48.54 %)
Renewable energy	Kg/Mj	4596 (27.72 %)
Nonrenewable energy	Mj/ha	11982 (72.28 %)

Energy efficiency (energy output to input ratio) in this study was calculated 2.70, showing the affective use of energy in the agro ecosystems barley production. Energy specific was 5.44 MJ/kg this means that 5.44 MJ is needed to obtain 1 kg of barley seed. Energy productivity calculated as 0.18 Kg/MJ in the study area. This means that 0.18 kg of output obtained per unit energy. Net energy gain was 28138 MJ/ha. Water and energy productivity was 0.011 g/m3Mj.

The energy use efficiency, energy production, energy specific, energy productivity, water and energy productivity, net energy gain, and intensiveness of barley straw production were shown in Table-3. Energy efficiency (energy output to input ratio) in this study was calculated 2.89 showing the affective use of energy in the agro ecosystems barley production. Energy specific was 4.32 MJ/kg, this means that 4.32 MJ is needed to obtain 1 kg of barley straw. Energy productivity calculated as 0.23 Kg/MJ in the study area. This means that 0.23 kg of output obtained per unit energy. Net energy gain was 31384 MJ/ha. Water and energy productivity was 0.014 g/m^3Mj.

Yousefi and Gazvineh (2011) analyzed the energy indices of barley production in Kangavar, Iran, and found that the results showed that total energy input and output in these production systems were 12400 and 43600 MJ/ha, respectively. The highest share of input energy was recorded for diesel fuel (53%) which is a nonrenewable resource. Energy use efficiency and energy productivity of rain fed barley production agro ecosystems were 3.52 and 0.11 kg/MJ, respectively. Total mean energy input as biologic and industrial forms were 24 and 76%, respectively. Thus, application high consumption of diesel fuel in agro ecosystems can reduce the energy use efficiency by increasing input energy.

This means that the amount of output energy is more than input energy and production in this situation is logical. Direct, indirect, renewable and non-renewable energy forms used in barley production are also investigated in Table-3. The results show that the share of direct input energy was 51.46% (8532MJ/ha) in the total energy input compared to 48.54% (8047MJ/ha) for the indirect energy. On the other hand, nonrenewable and renewable energy contributed to 72.28% (11982 MJ/ha) and 27.72% (4596 MJ/ha) of the total energy input, respectively.

Analysis of energy balance in barley production

The inputs used in barley production and their energy equivalents and output energy equivalent are illustrated in Table-2. About 144 kg seed, 360 h human labor, 12 h machinery power and 110 L diesel fuel for total operations were used in agro ecosystems barley production on a hectare basis. The use of nitrogen fertilizer, phosphorus and potassium were 63, 14 and 10 kg per one hectare, respectively. Also 92.4 L depreciation power in this system was used. The total energy equivalent of inputs was calculated as 5455244 MJ/ha. The highest shares of this amount were reported for nitrogen (20.4%), machinery (19.80%), diesel fuel (18.63%), depreciation for per diesel fuel (16.23%) and seed (11.08%), respectively. The energy inputs of potassium chemicals (0.29%), Phosphorus chemicals (0.80%), and poison (1.49%) were found to be quite low compared to the other inputs used in production (Table-1).

The highest percent of compositions (65%), amounts (1979.25 kg/ha), production energy (7917000 kcal/ha) and production energy to consumption energy ratio (1.45) in barley seed were obtained from starch as compared with protein and fat, The lowest consumption energy to production energy ratio (0.69) in barley seed was obtained from starch as compared with Protein and fat (Table-4).

The highest percent of compositions (43.3 %), amounts (1661.42 kg/ha), production energy (6645684 kcal/ha) and production energy to consumption energy ratio (1.22) in barley straw were obtained from starch as compared with protein and fat. The lowest consumption energy to production energy ratio (0.82) in barley straw was obtained from starch as compared with Protein and fat (Table-4).

Evaluation indicators of energy balance in barley production

The consumption energy (5455244 kcal/ha), production energy (9765315 kcal/ha), energy per unit (3207 kcal), production energy to consumption energy ratio (1.79) and consumption energy to production energy ratio (13.82) of barley seed production were shown in Table-4. Energy balance efficiency (production energy to consumption energy ratio) in this study was calculated 1.79, showing the affective use of energy in the agro ecosystems barley seed production.

The consumption energy (5455244 kcal/ha), production energy (7524357 kcal/ha), energy per unit

(1961 kcal), production energy to consumption energy ratio (1.38) and consumption energy to production energy ratio (28.82) of barley straw production were shown in Table-4. Energy balance efficiency (production energy to consumption energy ratio) in this study was calculated 1.38, showing the affective use of energy in the agro ecosystems barley seed production.

Taghavi *et al*., (2007) analyzed the energy balance indices of barley production in Iran (Azarbijan province), and found that energy value of used inputs of this type cultivation was 5923739.4 kcal/ha and output (production) energy of value of barley grain yield and straw were 4096000 kcal/ha and 3548160 kcal/ha, respectively. Also, energy efficiency value was 1.222 and that of grain and straw separately was 0.69 and 0.53, respectively. Results showed that the highest input energy was due to machinery using, nitrogen fertilizer and fuel; and lowest ones were related to human muscle power and herbicide.

Table-4. Analysis of energy balance indices in barley production.

Seed						
Item	Percent of compositions	Energy per gram (kcal)	Amounts (kg/ha)	Production energy (kcal/ha)	production energy/ consumption energy	Consumption energy/ production energy
Protein	10	4	304.50	1218000	0.22	4.48
Fat	2.3	9	70.04	630315	0.12	8.65
Starch	65	4	1979.25	7917000	1.45	0.69
Item	Grain yield (kg/ha)	consumption energy (kcal/ha)	Production energy (kcal/ha)	Energy per unit (kcal)	Production energy/ consumption energy	Consumption energy/ production energy
	3045	5455244	9765315	3207	1.79	13.82
Straw						
Item	Percent of compositions	Energy per gram (kcal)	Amounts (kg/ha)	production energy (kcal/ha)	production energy/ consumption energy	consumption energy/ production energy
Protein	1.9	4	72.90	291612	0.05	18.71
Fat	1.7	9	65.23	587061	0.11	9.29
Starch	43.3	4	1661.42	6645684	1.22	0.82
Item	Grain yield (kg/ha)	consumption energy (kcal/ha)	production energy (kcal/ha)	Energy per unit (kcal)	production energy/ consumption energy	consumption energy/ production energy
	3837	5455244	7524357	1961	1.38	28.82

CONCLUSIONS

Finally, energy use is one of the key indicators for developing more sustainable agricultural practices one of the principal requirements of sustainable agriculture. Therefore energy management in systems barley production should be considered an important field in terms of efficient, sustainable and economical use of energy. Using of combination machines, doing timely required repairs and services for tractors and representing a fit crop rotation are suggested to decrease energy consuming for dry farming barley in Guilan province.

REFERENCES

Adapa P, Tabil L and Schoenau G. 2009. Compaction characteristics of barley, canola, oat and wheat straw. biosystems engineering. pp. 1-10.

Anonymous. 2010. Department of statistics and information, Ministry of Jihad-e-Agriculture, Tehran, Iran. http://www.maj.ir.

Baruah DC and Dutta PK. 2007. An investigation into the energy use in relation to yield of rice (*Oryza sativa*) in Assam, India. Agriculture, Ecosystems and Environment. 120: 185-191.

Erdal G, Esengun K, Erdal H and Gunduz O. 2007. Energy use and economical analysis of sugar beet production in Tokat Province of Turkey. Energy. 32: 35-41.

Esengun K, Gunduz O and Erdal G. 2007. Input-output energy analysis in dry apricot production of Turkey. Energy Convers. Manage. 48: 592-598.

Ghasemi Mobtaker H, Keyhani A, Mohammadi A, Rafiee S and Akram A. 2010. Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran. Agriculture, Ecosystems and Environment. 137: 367-372.

Khan S, Khan MA and Latif N. 2010. Energy requirements and economic analysis of wheat, rice and barley production in Australia. Soil and Environ. 29(1): 61-68.

Khan S, Khan MA, Hanjra MA and Mu J. 2009. Pathways to reduce the environmental footprints of water and energy inputs in food production. Food Policy. 34: 141-149.

Kizilaslan H. 2009. Input-output energy analysis of cherries production in Tokat Province of Turkey. Applied Energy. 86: 1354-1358.

Moradi M and Azarpour E. 2011. Study of energy Indices for native and breed rice varieties production in Iran. World Applied Sciences Journal. 13(1): 137-141.

Ozkan B, Akcaoz H and Fert C. 2004. Energy input-output analysis in Turkish agriculture. Renew. Energy. 29: 39-51.

Taghavi D, Ajli J, Valdiani A and Fatahi E. 2007. Evaluation energy balance of *Hordeum vulgar* L. production under rain fed farming in Azarbijan north of Iran. Modern science of sustainable agriculture. pp. 41-48.

Yousefi M and Gazvineh S. 2011. Diesel Fuel Consumption and Energy Use Efficiency of Rainfed Barley Production Systems in Iran. World Applied Sciences Journal. 13(6): 1375-1379.