VOL. 7, NO. 4, APRIL 2012 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

DETERMINATION OF ENERGY BALANCE AND ENERGY INDICES IN WHEAT 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 evaluation of 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 wheat 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. Energy efficiency (energy output to input energy ratio) for seed and straw in this study were calculated to be 2.47 and 2.48, respectively, showing the affective use of energy in the agro ecosystems wheat production. Energy balance efficiency (production energy to consumption energy ratio) for seed and straw in this study were calculated 1.50 and 1.29, respectively, showing the affective use of energy in the agro ecosystems wheat production.

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

INTRODUCTION

Wheat is one of the eight food sources (wheat, rice, corn, sugar, cattle, sorghum, millet and cassava) which provide 70-90% of all calories and 66-90% of the protein consumed in developing countries. Globally, wheat provides nearly 55% of the carbohydrate and 20% of the calories consumed. Also, more than 40% of world grain is being fed to livestock. Wheat is cultivated under a wide range of climatic conditions. Most people consume wheat more than any other cereal grain (safa *et al*., 2011).

The excessive use of energy in developed and developing countries have created several environmental, commercial, technical, and even social problems, which requires in depth investigation in order to mitigate ensuing negative impacts. Analyzing all the relevant information is necessary to reduce the energy consumption and its environmental impacts. Energy is one of the important elements in modern agriculture as it heavily depends on fossil and other energy resources. Energy consumption in agriculture has been increasing in response to the limited supply of arable land, increasing population, technological changes, and a desire for higher standards of living (Kizilaslan, 2009). In contrast to other sectors, the energy use in agriculture has generally received very little attention from scientists in different countries. The main reasons for this little scientific attention are data shortage and lower level of multi-disciplinary work, implying that researchers give little attention to marginal subjects of science. However, energy use in agricultural production has been increasing faster than in many other sectors (Karkacier and Gokalp Goktolga, 2005). It is clear that energy use in modern agriculture has increased; however, this has produced the intended result of increased rate of production. The modern agriculture has made it possible to reduce the energy use per unit of production (Sauerbeck, 2001). Some studies show that there is a positive relationship between energy usage and productivity (Hatirli *et al*., 2006; smil, 2008; Outlaw *et al*., 2005). Also, there is a significant relationship between energy output and weather, price, yield, and technology (ozkan and akcaoz, 2004). Some of the energy sources in agriculture sector are classified in other sectors; for example, fuel consumption in farm operations sometimes feature in the transport sector, or indirect energy sources (fertilizers, seeds, and agrichemicals) have become part of the industrial sector. Consequently, official national statistics do not usually show accurate energy use in agriculture and do pay very little attention to energy consumption in the agriculture sector.

The main aim of this study was to determine energy use in wheat production, to investigate the efficiency of energy consumption and to make an energy balance and energy indices analysis of wheat 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.

ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

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 were used for estimation (Houshyar *et al*., 2010; main *et al*., 2007; Moradi and azarpour, 2011; safa *et al*., 2011). Firstly, the amounts of inputs used in the production of wheat were specified in order to calculate the energy equivalences in the study. Energy input include human labor, machinery, diesel fuel, chemical fertilizers, poison fertilizers, water and seed and output yield include grain yield of wheat. The energy use efficiency, energy specific, energy productivity and net energy gain were calculated according to bottom equations (Hulsbergen *et al*., 2005; Ma *et al*., 2008; Mandel *et al*., 2002; Mohammadi and Omid, 2010; Mohammadi *et al*., 2008, Moradi and azarpour, 2011; Ozkan *et al*., 2003; Ozkan *et al*., 2004; Taheri *et al*., 2010; Yilrmnaz *et al*., 2005).

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

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

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

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

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

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 wheat 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.

The indicators of energy balance, basic information on energy inputs was entered into Excel spreadsheets and then energy equivalent were calculated according Table-2 (Abdollahpour and Zaree, 2009). 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, machinery depreciation for per diesel fuel and seed and output yield include grain yield and straw yield of wheat.

RESULTS AND DISCUSSIONS

Analysis of input-output energy use in wheat production

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

Table-1. Amounts of input and 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	450	1.96	882	4.91
Machinery	h/ha	12	62.7	752.40	4.19
Diesel fuel	L/ha	133	56.31	7489.23	41.69
Nitrogen	Kg/ha	66	69.5	4567.23	25.42
Phosphorus	Kg/ha	14	12.44	167.95	0.93
Potassium	Kg/ha	10	11.15	105.93	0.59
Poison	L/ha	3	120	360	2.00
Water	M^3/ha	1700	1.02	1734	9.65
Seed	Kg/ha	121	14.7	1906.45	10.61
Output					
Grain yield	Kg/ha	2825	15.7	44353	100
Straw yield	kg/ha	3560	12.5	44500	100

About 121 kg seed, 450 h human labor, 1700 m^3 water, 12 h machinery power and 133 L diesel fuel for total operations were used in agro ecosystems wheat production on a hectare basis. The use of nitrogen

ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

fertilizer, phosphorus and potassium were 42, 11 and 2 kg per one hectare, respectively. The total energy equivalent of inputs was calculated as 17963 MJ/ha. The highest shares of this amount were reported for diesel fuel (41.69%), nitrogen fertilizer (25.42%), seed (10.61%) and water (9.65%), respectively. The energy inputs of potassium chemicals (0.59%), Phosphorus chemicals (0.93%), and poison (2%) were found to be quite low compared to the other inputs used in production (Table-1). The average seed yield of wheat was found to be 2825 kg/ha and its energy equivalent was calculated to be 4435 MJ/ha (Table-1). The average straw yield of wheat was found to be 3560 kg/ha and its energy equivalent was calculated to be 44500 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	450	500	225000	3.69
Machinery	h/ha	12	90000	1080000	17.73
Diesel fuel	L/ha	133	9237	1228521	20.17
Nitrogen	kg/ha	66	17600	1156594.56	18.99
Phosphorus	kg/ha	14	3190	43067.87	0.71
Potassium	kg/ha	10	1600	15200	0.25
Poison	L/ha	3	27170	81510	1.34
Water	M^3/ha	1700	272.2	462740	7.60
Seed	kg/ha	121	6000	728580	11.96
Depreciation for per diesel fuel	L	111.72	9583	1070612.76	17.57

Evaluation indicators of energy in wheat production

The energy use efficiency, energy production, energy specific, energy productivity, water and energy productivity, net energy gain, and intensiveness of wheat seed production were shown in Table-3. Energy efficiency (energy output to input ratio) in this study was calculated 2.47, showing the affective use of energy in the agro ecosystems wheat production. Energy specific was 6.36 MJ/kg this means that 6.36 MJ is needed to obtain 1 kg of wheat seed. Energy productivity calculated as 0.16 Kg/MJ in the study area. This means that 0.16 kg of output obtained per unit energy. Net energy gain was 26387 MJ/ha.

The energy use efficiency, energy production, energy specific, energy productivity, water and energy productivity, net energy gain, and intensiveness of wheat straw production were shown in Table-3. Energy efficiency (energy output to input ratio) in this study was calculated 2.48 showing the affective use of energy in the agro ecosystems wheat production. Energy specific was 5.05 MJ/kg which means that 5.05 MJ is needed to obtain 1 kg of wheat straw. Energy productivity calculated as 0.20 Kg/MJ in the study area. This means that 0.20 kg of output obtained per unit energy. Net energy gain was 26535 MJ/ha.

Houshyar *et al*. (2010) analyzed the energy indices of wheat production in Iran (Fars province), and found that total input energy for wheat production were 38589.677 and 38817.823 MJ/ha with the averaged weight yield of 6813.996 and 6046.968 kg/ha in region 1 and 2, respectively. Energy output-input ratio, energy productivity and specific energy were 2.596, 0.178 kg/MJ and 5.603 MJ/kg for region 1, and 2.290, 0.162 kg/MJ and 6.186 MJ/kg for region 2, respectively. The efficiency evaluation disclosed that the number of efficient farmers was more in region 2 (16.2%) and for combined seeder (25.53%).

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 wheat production are also investigated in Table-3. The results show that the share of direct input energy was 56.25% (1015 MJ/ha) in the total energy input compared to 43.75% (7860 MJ/ha) for the indirect energy. On the other hand, nonrenewable and renewable energy contributed to 74.83% (13443 MJ/ha) and 25.17% (4522 MJ/ha) of the total energy input, respectively.

VOL. 7, NO. 4, APRIL 2012 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

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

Item	Unit	Wheat
Seed		
Yield	Kg/ha	2825
Input energy	Mj/ha	17965
Output energy	Mj/ha	44353
Energy use efficiency	-	2.47
Energy specific	Mj/Kg	6.36
Energy productivity	Kg/Mj	0.16
Net energy gain	Mj/ha	26387
Water and energy productivity	$g/m^3.Mj$	0.009
Direct energy	Mj/ha	10105 (56.25%)
Indirect energy	Mj/ha	7860 (43.75%)
Renewable energy	Kg/Mj	4522 (25.17%)
Nonrenewable energy	Mj/ha	13443 (74.83%)
Straw		
Yield	Kg/ha	3560
Input energy	Mj/ha	17965
Output energy	Mj/ha	44500
Energy use efficiency	-	2.48
Energy specific	Mj/Kg	5.05
Energy productivity	Kg/Mj	0.20
Net energy gain	Mj/ha	26535
Water and energy productivity	$g/m^3.Mj$	0.012
Direct energy	Mj/ha	10105 (56.25%)
Indirect energy	Mj/ha	7860 (43.75%)
Renewable energy	Kg/Mj	4522 (25.17%)
Nonrenewable energy	Mj/ha	13443 (74.83%)

Analysis of energy balance in wheat production

The inputs used in wheat production and their energy equivalents and output energy equivalent are illustrated in Table-2. About 121 kg seed, 450 h human labor, 1700 m^3 water, 12 h machinery power and 133 L diesel fuel for total operations were used in agro ecosystems wheat production on a hectare basis. The use of nitrogen fertilizer, phosphorus and potassium were 42, 11 and 2 kg per one hectare, respectively. Also 111.72 L depreciation power in this system was used. The total energy equivalent of inputs was calculated as 6091826 MJ/ha. The highest shares of this amount were reported for diesel fuel (20.18%), machinery (20.73%), nitrogen chemical (18.99%), depreciation for per diesel fuel (17.57%) and seed (11.96) respectively. The energy inputs of potassium chemicals (0.25%), Phosphorus chemicals (0.71%), and poison (1.34 %) were found to be quite low compared to the other inputs used in production (Table-1).

The highest percent of compositions (64%), amounts (1808 kg/ha), production energy (7232000 kcal/ha) and production energy to consumption energy ratio (1.19) in wheat seed were obtained from starch as compared with protein and fat, The lowest consumption energy to production energy ratio (0.84) in wheat seed was obtained from starch as compared with Protein and fat (Table-4).

The highest percent of compositions (43.3%), amounts (1541.48 kg/ha), production energy (6165920 kcal/ha) and production energy to consumption energy ratio (1.01) in wheat straw were obtained from starch as compared with protein and fat, The lowest consumption energy to production energy ratio (0.99) in wheat straw was obtained from starch as compared with protein and fat (Table-4).

Evaluation indicators of energy balance in wheat production

The consumption energy (6091826 kcal/ha), production energy (9145938 kcal/ha), energy per unit (3238 kcal), production energy to consumption energy ratio (1.50) and consumption energy to production energy ratio (18.68) of wheat seed production were shown in Table-4. Energy balance efficiency (production energy to consumption energy ratio) in this study was calculated 1.50, showing the affective use of energy in the agro ecosystems wheat seed production.

The consumption energy (6091826 kcal/ha), production energy (7867600 kcal/ha), energy per unit (2210 kcal), production energy to consumption energy ratio (1.29) and consumption energy to production energy ratio (16.53) of wheat straw production were shown in Table-4. Energy balance efficiency (production energy to consumption energy ratio) in this study was calculated 1.29, showing the affective use of energy in the agro ecosystems wheat seed production.

Abdollahpour and Zaree (2009) analyzed the energy balance indices of wheat production in Iran (Kermanshah province), and found that Energy value of used inputs of this type cultivation was 6130900 kcal/ha and output (production) energy of value of wheat grain yield and straw were 5018000 kcal/ha and 4316000 kcal/ha, respectively. Also, energy efficiency value was 1.521 and that of grain and straw separately was 0.818 and 0.703, 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 wheat 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	13	4	367.25	1469000	0.24	4.15
Fat	1.75	9	49.44	444937.50	0.07	13.69
Starch	64	4	1808	7232000	1.19	0.84
Item	**Yield** (kg/ha)	**Consumption energy** (kcal/ha)	**Production energy** (kcal/ha)	**Energy per unit** (kcal)	**Production energy/ consumption energy**	**Consumption energy/ production energy**
	2825	6091826	9145938	3238	1.50	18.68
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	4.3	4	153.08	612320	0.10	9.95
Fat	3.4	9	121.04	1089360	0.18	5.59
Starch	43.3	4	1541.48	6165920	1.01	0.99
Item	**Yield** (kg/ha)	**Consumption energy** (kcal/ha)	**Production energy** (kcal/ha)	**Energy per unit** (kcal)	**Production energy/ consumption energy**	**Consumption energy/ production energy**
	3560	6091826	7867600	2210	1.29	16.53

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 wheat 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 wheat in Guilan province.

REFERENCES

Abdollahpour Sh Zaree S. 2009. Evaluation of Wheat Energy Balance under Rain fed Farming in Kermanshah. Sustainable Agriculture Science. 20(2): 97-106.

Hatirli SA, Ozkan B and Fert C. 2006. Energy inputs and crop yield relationship in greenhouse tomato production. Renewable Energy. 31(4): 427-438.

Houshyar E, Sheikh Davoodi MJ and Nassiri SM. 2010. Energy efficiency for wheat production using data envelopment analysis (DEA) technique. Journal of Agricultural Technology. 6(4): 663-672.

Hulsbergen K, Feil J and Diepenbrock W. 2002. Rates of nitrogen application required to achieve maximum energy efficiency for various crops: Result of a long- term experiment. Field Crops Research. 77: 113-135.

Karkacier O and Gokalp Goktolga Z. 2005. Input-output analysis of energy use in agriculture. Energy Conversion and Management. 46(9-10): 1513-1521.

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

Ma H, Oxley L, Gibson J and Kim B. 2008. China's energy economy: Technical change, factor demand and interfactor/interfuel substitution. Energy Economics. 30: 2167-2183.

Mandel KG, Saha KP, Ghosh PK, Hati KM and Bandyopadhyay KK. 2002. Bio energy and economic analysis of soybean based crop production systems in central India. Biomass Bioenergy. 23: 337-345.

Mani I, Kumar P, Panwara SG and Kanta K. 2007. Variation in energy consumption in production of wheat maize with varying altitudes in hilly regions of Himachal Pradesh. India Energy. 32(12): 2336-2339.

Mohammadi A and Omid M. 2010. Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. Applied Energy. 87: 191-196.

Mohammadi A, Tabatabaeefar A, Shahin S, Rafiee S and Keyhani A. 2008. Energy use and economical analysis of potato production in Iran a case study: Ardabil province. Energy Convers. Manage. 49(12): 3566-3570.

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.

Nagesha N. 2008. Role of energy efficiency in sustainable development of small-scale industry clusters: an empirical study. Energy Sustain. Develop. 12(3): 34-39.

Outlaw JL, Collins KJ and Duffield JA. 2005. Agriculture as a producer and consumer of energy. Wallingford, Oxford shire, UK; Cambridge, MA: USA. CABI Pub.

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

Ozkan B, Akcaoz H and Karadcniz F. 2003. Energy requirement and economic analysis of citrus production in Turkey. Energy Conversion and Management. 44: 46-56.

Rafiee S, Mousavi Avval SH and Mohammadi A. 2010. Modeling and sensitivity analysis of energy inputs for apple production in Iran. Energy. 35(8): 3301-3306.

Safa M, Samarasinghe S and Mohssen M. 2011. A field study of energy consumption in wheat production in Canterbury, New Zealand. Energy Conversion and Management. 52(7): 2526-2532.

Sauerbeck DR. 2001. CO_2 emissions and C sequestration by agriculture e perspectives and limitations. Nutrient Cycling in Agroecosystems. 60: 253-266.

Smil V. 2008. Energy in nature and society: general energetic of complex systems. Cambridge, Mass: The MIT Press.

Taheri Garavand A, Asakereh A and Haghani K. 2010. Investigation Energy and Economic Analysis of Soya Bean Production in North of Iran. American-Eurasian J. Agric. and Environ. Sci. 7: 648-651.

Yilmaz I, Akcaoz H and Ozkan B. 2005. An analysis of energy use and input costs for cotton production in Turkey. Renewable Energy. 30: 145-155.