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Estimate energy, energy balance and economic indices of watered farming Potato Production in North of Iran

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Abstract

One way to evaluation of sustainable developing 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 rain fed farming potato in north of Iran (Guilan province) was investigated. Data were collected from 72 farms by used a face to face questionnaire method during 2010 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 watered farming potato production in this study was calculated 3.48, showing the affective use of energy in the agro ecosystems potato production. Energy balance efficiency (production energy to consumption energy ratio) for watered farming potato production in this study was calculated 2.58, showing the affective use of energy in the agro ecosystems potato production.

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Introduction

In developing countries such as Iran, agricultural growth is Necessary to support economic development and meeting the demands of a growing population. Within 30 years of commercial agriculture replaced subsistence Agriculture as the dominant mode of agricultural production in Iran. Iran's economy has highlighted the vital agricultural sector the Iranian government's policy of self-sufficiency in food Production.

Potatoes (Solanum tuberosumL.) are grown world wide under a wide range of altitude, latitude and climatic conditions than any other major food crop. No other crop can match the potato in its production of food energy and food value perunitarea (Sieczka and Thornton, 1993). Potatoes have become increasingly important in the developing countries for both sustenance and income. The United Nationsc alled 2008 as the International Year of the potato in order to boost its plantation which has a significant role to decrease hunger of people allover the world (Anonymous, 2008). The production of potato in 2010 was about 4274490 t/yr in Iran and the cultivation land area was about 146303 ha Giulan (Anonymous, 2010).

Energy in all its forms is essential to to the improvement in people's quality of life. Energy, economics, and the environment are mutually dependent. Moreover, there is a close relationship between agriculture and energy; agriculture itself is an energy user and energy supplier in the form of bio-energy. At the present time, the productivity and profitability of agricultural productions depend upon energy consumption (Tabatabaeefar *et al.,* 2009). Energy use in agricultural production has been increasing faster than that in many other sectors of the world economy because agricultural production has become more mechanized, and the use of commercial energy inputs has increased (Karkacier *et al.,* 2006).

Efficient use of the energy resources is vital in terms of increasing production, productivity, competitiveness of agriculture as well as sustainability of rural living. Energy auditing is one of the most common approaches to examining energy efficiency and environmental impact of the production system. It enables researchers to calculate output-input ratio, relevant indicators, and energy use patterns in an agricultural activity. Moreover, the energy audit provides sufficient data to establish functional forms to investigate the relationship between energy inputs and outputs. To explain, the amount of inputs used in the production of yield, for instance, (chemicals, human labor, machinery, seed, manure, fertilizers, fuel, electricity and irrigation water) and obtained output (yield) amount are calculated per hectare then, these input data and the amount of yield are multiplied with the coefficient of energy equivalent (Rajabi Hamedani *et al.,* 2011).

Energy indicators relating energy to economic issues can be useful tools for policy makers. They provide a way to structure and clarify statistical data to give better insight into the factors that affect energy, environment, economics and social well-being. Indicators can also be used to monitor progress of past policies. All sectors of an economy agriculture, manufacturing and mining, and services require energy. These energy services in turn foster economic and social development at the local level by raising productivity and facilitating local income generation. Energy indicators provide a measure of efficiency and sustainability in economical, social, and environmental programs. Indicators of energy use are usually expressed as normalized quantities of total energy use to facilitate comparison. There are several studies on the energy use pattern and benchmarking of potato production but the authors were not concerned with the functional relationship energy input, energy balance input and yield (Mohammadi *et al.,* 2008; Zanganeh *et al.,* 2011; Rajabi Hamedani *et al.,* 2011).

The main purpose of this research was to determine energy consumption and the relationship between energy input, energy balance input and yield for potato production and to make an economic analysis of potato production in Giuan province, north of Iran.

Materials and methods

Materials

Giulan province is one of suitable areas to farming potato, due to existing climate conditions. In order to gather the required data in this research, Data on potato production was collected from the farmers by using a face to face questionnaire performed in during 2010 production year. Seventy-two farmers were randomly selected to use from the simple random sampling bottom Equation (Yamane, 1967):

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

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 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.

Method to calculate the energy

The amount of inputs used in agricultural production practices (human labor, machinery, diesel fuel, chemical fertilizers, poison fertilizers, farmyard manure, water and seeds) were calculated per hectare and then, these data were converted to forms of energy to evaluate the output-input analysis. In order to calculate output and input energy, these input data and amount of output yield were multiplied with the coefficient of energy equivalent. Energy equivalents of inputs and output were converted into energy on area unit. The previous researches (table 1) were used to determine the energy equivalents' coefficients (Azarpour and Moraditochaee, 2013; Mohammadi *et al.,* 2008; Zanganeh *et al.,* 2011; Rajabi Hamedani *et al.,* 2011).

In this research, energy indices (energy use efficiency, energy specific, energy productivity and net energy gain) were calculated according to bottom equations (Azarpour and Moraditochaee, 2013; Mohammadi *et al.,* 2008; Zanganeh *et al.,* 2011; Rajabi Hamedani *et al.,* 2011).

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

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

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

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

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

For the growth and development, energy demand in agriculture can be classified into direct energy (DE), indirect energy (IDE), renewable energy (RE) and non-renewable energy (NRE) (Ozkan *et al.,* 2004, Yilmaz, 2005). The IDE includes energy embodied in seeds, fertilizers, farmyard manure (FYM), chemicals, machinery while the DE covers human labor, water and diesel fuel used in the potato production. The NRE includes diesel, chemicals, fertilizers and machinery, and the RE consists of human labor, seeds, water and FYM.

In order to calculate energy balance indices, these input data and amount of output yield were multiplied with the coefficient of energy balance equivalent. Energy balance equivalents of inputs and output were converted into energy on area unit. The previous researches (table 2) were used to determine the energy balance equivalents' coefficients (Azarpour and Moraditochaee, 2013; Eizadkhahe Shishvan *et al.,* 2010). Energy balance input include human labor, machinery, diesel fuel, chemical fertilizers, poison fertilizers, machinery depreciation for per diesel fuel, farmyard manure, water and seeds and output include yield of potato.

Method to calculate the economic

In the last part of the research, the economic analysis of potato production was investigated. Net profit, gross profit, productivity and benefit to cost ratio were calculated using the following equations (Mohammadi *et al.,* 2008; Zanganeh *et al.,* 2011).

$$\text{Gross value of production}\,(\$\,\text{ha}^{-1}) = \text{Yield}\,(\text{kg ha}^{-1}) \times \text{Sale price}\,(\$\,\text{kg}^{-1})$$

$$\text{Net return}\,(\$\,\text{ha}^{-1}) = \text{Gross value of production}\,(\$\,\text{ha}^{-1}) - \text{Total cost of production}\,(\$\,\text{ha}^{-1})$$

$$\text{Productivity}\,(\text{kg/\$}) = \frac{\text{Yield (kg/ha)}}{\text{Total cost of production (\$/ha)}}$$

$$\text{Benefit to cost ratio} = \frac{\text{Gross value of production}\,(\$\,\text{ha}^{-1})}{\text{Total cost of production}\,(\$\,\text{ha}^{-1})}$$

Result and discussion

Analysis of input–output energy use in potato production

Table 1 showed inputs used in potato production and their energy equivalents and output energy equivalent are illustrated. Results show that, about 1267 kg seeds, 3500 L water, 1 L chemical poison, 658 h human labor, 14 h machinery power and 127 L diesel fuel for total operations were used in agro ecosystems potato production on a hectare basis. The use of nitrogen fertilizer, phosphorus fertilizer and potassium fertilizer and farmyard manure were 29, 17, 5 and 6487 kg per one hectare respectively. The total energy equivalent of inputs was calculated as 21733 MJ/ha. Figure 2 showed the energy use pattern in the surveyed farms. The highest shares of this amount were reported for diesel fuel (32.91%), seeds (20.99%), water (16.43%) and chemical fertilizer (10.20%). The energy inputs of farmyard manure (8.95%), human labor (5.93%), machinery (4.04%) and chemical poison (0.55%) were found to be quite low compared to the other inputs used in potato production. The average yield of potato was found to be 21000 kg/ha and its energy equivalent was calculated to be 75600 MJ/ha (table 1).

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

Parameter	Unit	Quantity per hectare	Energy equivalents	Total energy equivalents	Percent
			Inputs		
Water	M3/ha	3500	1.02	3570.00	16.43
Human labor	h/ha	658	1.96	1289.68	5.93
Machinery	h/ha	14	62.7	877.80	4.04
Diesel fuel	L/ha	127	56.31	7151.37	32.91
Nitrogen	Kg/ha	29	66.14	1947.16	8.96
Phosphorus	Kg/ha	17	12.44	214.22	0.99
Potassium	Kg/ha	5.0	11.15	55.75	0.26
Poison	L/ha	1	120	120.00	0.55
Farmyard manure	Kg/ha	6487	0.3	1946.10	8.95
Seed	Kg/ha	1267	3.6	4561.20	20.99
			Output		
Yield	Kg/ha	21000	3.6	75600	100

Rajabi Hamedani *et al.* (2011) showed that the rates of other inputs in the total amount of energy such as fertilizers application, diesel fuel, seeds, water and other inputs in potato production were 46.6%, 21%, 14.9%, 7.5%, 10%, respectively. Total energy input and Total energy output in this research were calculated 92296.3 MJ/ha and 103009.2 MJ/ha respectively.

Mohammadi *et al.* (2008) showed that the rates of other inputs in the total amount of energy such as fertilizers application, diesel fuel, seeds, water and other inputs in potato production were 39.74%, 15.80%, 13.64%, 13.93%, 16.89%, respectively. Total energy input and Total energy output in this research were calculated 81624.96 MJ/ha and 102432.99 MJ/ha respectively.

Evaluation of energy indices in potato production

Energy indices (energy use efficiency, energy production, energy specific, energy productivity, net energy gain and water and energy productivity) of potato production were showed in table 3. Energy efficiency (energy output-input ratio) in this study was calculated 3.48; showing the affective use of energy in the agro ecosystems watermelon production. Energy specific was 1.03 MJ/kg this means that 1.03 MJ is needed to obtain 1 kg of watermelon. Energy productivity calculated as 0.97 Kg/MJ in the study area, this means that 0.97 kg of output obtained per unit energy. Net energy gain was 53867 MJ/ha. Water and energy productivity was 0.28 g/M3.Mj.

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

Parameter	Unit	Quantity per hectare	Energy balance equivalents	Total energy balance equivalents	Percent
			Inputs		
Water	M3/ha	3500	272.7	954450	11.61
Human labor	h/ha	658	500	329000.00	4.00
Machinery	h/ha	14	90000	1260000.00	15.33
Diesel fuel	L/ha	127	9237	1173099.00	14.27
Nitrogen	kg/ha	29	17600	518144.00	6.30
Phosphorus	kg/ha	17	3190	54931.80	0.67
Potassium	kg/ha	5.0	1600	8000.00	0.10
Poison	L/ha	1	27170	27170.00	0.33
Farmyard manure	kg/ha	6487	303.1	1966209.70	23.91
Seed	kg/ha	1267	717	908439.00	11.05
Depreciation for per diesel fuel	L	106.68	9583	1022314.44	12.43

Direct-indirect energy forms used in potato production are also investigated. Percentages of these energy forms are illustrated in figure 3. The results show that the share of direct input energy was 55.27% (12011 MJ/ha) in the total energy input compared to 44.73% (9722 MJ/ha) for the indirect energy.

renewable- non-renewable energy forms used in potato production are also investigated. Percentages of these energy forms are illustrated in figure 4. The results show that the share of renewable input energy was 52.30% (11367 MJ/ha) in the total energy input compared to 47.70% (10366 MJ/ha) for the non-renewable energy.

Table 3. Analysis of energy indices in potato production.

Item	Unit	Potato
Yield	Kg/ha	21000
Input energy	Mj/ha	21733
Output energy	Mj/ha	75600
Energy use efficiency	-	3.48
Energy specific	Mj/Kg	1.03
Energy productivity	Kg/Mj	0.97
Net energy gain	Mj/ha	53867
Water and energy productivity	g/M3.Mj	0.28

Mohammadi *et al.* (2008) showed that share of direct input energy was 17.65% (14407.69 MJ/ha) in the total energy input compared to 82.35% (67217.27 MJ/ha) for the indirect energy. Also, share of renewable input energy was 25.73% (20994.36 MJ/ha) in the total energy input compared to 74.27% (60630.60 MJ/ha) for the non-renewable energy. In this research that Energy use efficiency, energy productivity, specific energy and net energy gain were 1.25, 0.35 kg/MJ, 3.59 MJ/kg, 208080.03 MJ/ha respectively.

Table 4. Analysis of energy balance indices in potato production.

Item	Percent of compositions	Energy per gram (kcal)	Amounts (kg/ha)	production energy (kcal/ha)	Production energy/ Consumption energy	Consumption energy/ Production energy
Protein	2	4	420	1680000	0.20	4.89
Fat	1	9	210	1890000	0.23	4.35
Starch	21	4	4410	17640000	2.15	0.47
Item	Yield (kg/ha)	Consumption energy (kcal/ha)	Production energy (kcal/ha)	Energy per unit (kcal)	production energy/ Consumption energy	Consumption energy/ Production energy
	21000	8221758	21210000	1010	2.58	9.71

Analysis of energy balance in potato production

Table 2 showed inputs used in potato production and their balance energy equivalents and output balance energy equivalent are illustrated. Results show that, about 1267 kg seeds, 3500 L water, 1 L chemical poison, 658 h human labor, 14 h machinery power and 127 L diesel fuel for total operations were used in agro ecosystems potato production on a hectare basis. The use of nitrogen fertilizer, phosphorus fertilizer and potassium fertilizer and farmyard manure were 29, 17, 5 and 6487 kg per one hectare respectively. Also 106.68 L depreciation power in this system was used. The total energy balance equivalent of inputs was calculated as 8221758 MJ/ha. Figure 5 showed the energy balance use pattern in the surveyed farms. The highest shares of this amount were reported for farmyard manure (23.91%), machinery (15.33%), diesel fuel (14.27%), machinery depreciation for per diesel fuel (12.43%), water (11.61%) and seeds (11.05%). The energy inputs chemical fertilizer (7.07%), human labor (4%), and chemical poison (0.33%) were found to be quite low compared to the other inputs used in potato production.

Eizadkhahe Shishvan *et al.* (2010) showed that the rates of other inputs in the total amount of energy such as fertilizers application, water, seeds, machinery, diesel fuel, and other inputs in potato production were 30.17%, 24.09%, 19.72%, 8.97%, 8.31%, 8.74%, respectively.

Table 5. Economic analysis of potato.

Cost and return components	
Yield (kg/ha)	21000
Sale price ($/kg)	0.12
Gross value of production ($/ha)	2520
Total cost of production ($/ha)	1699
Net return ($/ha)	821
Benefit to cost ratio	1.48
Productivity (kg/ha)	12.36

The highest percent of compositions (21%), Amounts (4410 kg/ha), production energy (17640000 kcal/ha) and production energy to consumption energy ratio (2.15) in potato were obtained from starch as compared with protein and fat, The lowest consumption energy to production energy ratio (0.47) in potato was obtained from starch as compared with protein and fat (table 4).

Eizadkhahe Shishvan *et al.* (2010) showed that the highest percent of compositions (21%), Amounts (735000 kg/ha) and production energy (29400000 kcal/ha) in potato were obtained from starch as compared with protein and fat.

Fig.1. Location of the study area.

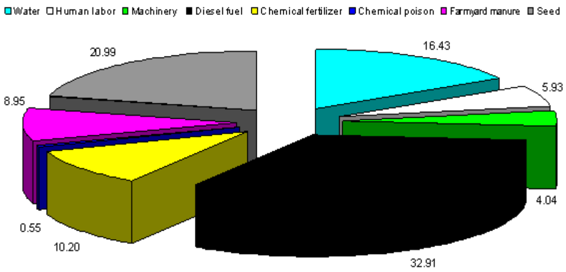

Fig. 2. The share (%) production inputs in potato (energy).

Direct-indirect energy balance forms used in potato production are also investigated. Percentages of these energy balance forms are illustrated in figure 6. The results show that the share of direct input energy balance was 29.88% (2456549 MJ/ha) in the total energy balance input compared to 70.12% (5765209 MJ/ha) for the indirect energy balance.

renewable- non-renewable energy forms used in potato production are also investigated. Percentages of these energy balance forms are illustrated in Figure 7. The results show that the share of renewable input energy balance was 50.57% (4158099 MJ/ha) in the total energy balance input compared to 49.43% (4063659 MJ/ha) for the non-renewable energy.

Eizadkhahe Shishvan *et al.* (2010) showed that share of direct input energy was 44.43% (27005.74 MJ/ha) in the total energy input compared to 55.57% (33777.50 MJ/ha) for the indirect energy. Also, share of renewable input energy was 46.96% (28534.16 MJ/ha) in the total energy input compared to 53.06% (32249.08 MJ/ha) for the non-renewable energy.

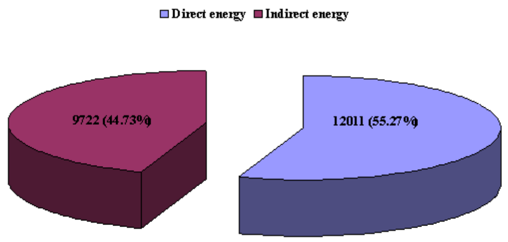

Fig. 3. Percentage of total energy input in the form of direct and indirect for potato production.

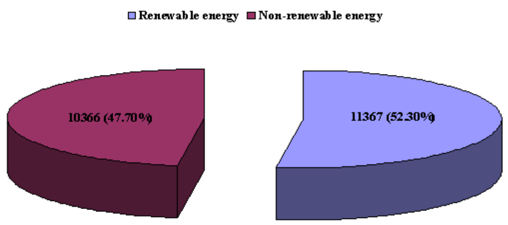

Fig. 4. Percentage of total energy input in the form of renewable- non-renewable for potato production.

Evaluation of energy indices in potato production

Energy indices balance in this research was showed in table 4. Consumption energy, production energy, energy per unit, production energy to consumption energy ratio and consumption energy to production energy ratio in potato production were 8221758 kcal/ha, 21210000 kcal/ha, 1010 kcal, 2.58, 9.71 respectively. Energy balance efficiency (production energy to consumption energy ratio) in this research was calculated 2.58; showing the affective use of energy in the agro ecosystems potato production.

Eizadkhahe Shishvan *et al.* (2010) showed that consumption energy, production energy, production energy to consumption energy ratio in potato production were 60783.21, 148268.12, 2.44 respectively.

Economic analysis of watermelon production

The Economic analysis of potato production were calculated and shown in table 5. In the research area, the potato sale price (0.12 $/kg), gross value of production (2520 $/ha), total cost of production (1699 $/ha), productivity (12.36 kg/ha) and net return (821 $/ha) were calculated. Results showed the benefit to cost ratio in the studied farms was calculated to be 1.48. Therefore potato production was a cost effective business based on the data of the 2010 season of potato production under watered farming in north of Iran. This means economic success increased by using high level of farming technology.

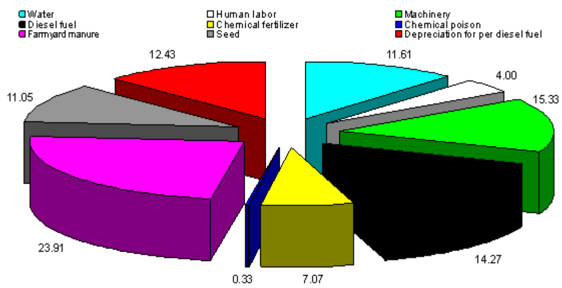

Fig. 5. The share (%) production inputs in potato (energy balance).

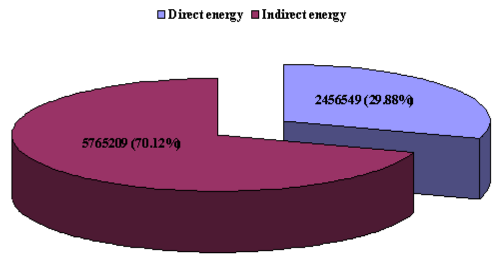

Fig. 6. Percentage of total energy balance input in the form of direct and indirect for potato production.

Mohammadi *et al.* (2008) concluded that for potato production were gross value of production (6130.64 $/ha), total cost of production (3267.17 $/ha), net return (2863.47 $/ha), and benefit to cost ratio (1.88).

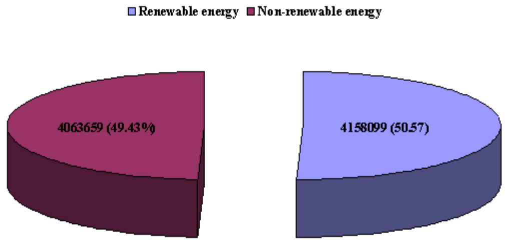

Fig. 7. Percentage of total energy balance input in the form of renewable- non-renewable for potato production.

Conclusion

In the last part of the research, 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 potato 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 watered farming potato in north of Guilan province.

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