Determination of relationship between wheat farm size and energy indexes in west Azerbaijan province, Iran

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Abstract: The objective of this study was to determine the relationship between farm size and energy productivity of wheat production in west Azerbaijan province, Iran. Farmers with different farm sizes (less than two hectares, between two and five hectares and more than five hectares) were randomly selected. Questionnaires were filled by 61 farmers. Then total used energy, produced energy, energy productivity and energy ratio were calculated for each farm. Also the relationship between energy indexes and three methods of tillage and planting (combination machine, seed drill and seed spreader) and three harvesting methods (combine harvester, mower and hand tools) were calculated. The data were analyzed by SPSS software. The results showed that fertilizers (43%) and machinery (40%) was the maximum portion of total used energy on farm. There was no significant linear relationship between the farm size and energy indexes. There was no significant relationship between energy indexes and harvesting methods. But there was a significant relationship between tillage and planting methods and energy indexes. Results showed that tillage and planting methods such as combination tillage and planter machine application increases the effect of farm size on energy indexes.

Keywords: farm size, energy productivity, used energy, energy production

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1 Introduction

Crops production have been developed in recent years, but there are some environmental and soil challenges due to excessive use of resources such as water and nonrenewable fossil fuels (Esengun et al., 2007a; Esengun et al., 2007b). These problems can be reduced by management of consumption of agricultural inputs. An important portion of agricultural inputs is energy. Energy on farm can be used in two types: direct and indirect. Direct energy consists of fuel and animal energy and indirect energy consists of used energy to product and transportation of farm inputs such as chemical fertilizers, seeds, machinery and pesticides (Alam et al., 2005).

Among them, human, animal and seeds are known as renewable resources energy and fuel, electricity, pesticides, fertilizers and machinery are known as non-renewable energy ones (Ozkan et al., 2003; Ozkan et al., 2004). Energy can be used as physical (human, livestock, machinery, electric motors and fuel), chemical (chemical fertilizers and pesticides) and biological (energy of seeds and animal manure) forms (Hatirli et al., 2005).

Because energy resources are expensive and limited, improving energy productivity on farm is necessary for sustainable agriculture. Study of energy indexes in crops production can help find methods in energy consumption optimization (Alam et al., 2005).

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A factor that can affect energy indexes is farm size. There are different ideas on the effects of farm size on farm energy and costs budget. Some people believe that smaller farms need low costs and energy and have high profits, due to easy management. Unlike their opinion, some researchers believe that smaller farms are not profitable and larger farms have more energy and economical efficiency due to the application of big machines which use low energy and costs per hectare. The third group of people rejected the both ideas. They believe that both smaller and larger farm sizes which have low efficiency and the maximum productivity will be achieved on a given farm size (Assuncao and Ghatak, 2003; Erdal et al., 2007; Pender et al., 2002).

Singh et al (1976) reported that total used energy on medium farm sizes was more than small farm sizes and cost of used energy per hectare was diminished by increase in farm size. They reported that larger farms have the best conditions to maximum yield production (Singh et al., 2002).

Shahin et al (2008) calculated used energy and energy productivity of wheat production on three groups of farm sizes in Ardabil. The results showed that larger farm sizes are more efficient in energy productivity (Shahin et al., 2008).

Many studies were carried out to estimate energy indexes in different crops productions, but all of them did not develop equation between farm size and energy indexes. So this study was carried out to determine the relationship between farm size and energy indexes on wheat farms in West Azerbaijan Province in Iran. Objectives of this study were to: calculate the energy indexes and study the relationship between the indexes and farm size.

2 Materials and methods

The study was conducted in West Azerbaijan province of Iran. West Azerbaijan is located in 30°42' and 39°46' north latitude and 44°3' and 47°23' east longitude. Wheat production is nearly 3,462 tons per year in this province. The study data were collected through personal interview method. The sample size was estimated using simple random sampling method. The sample size was estimated by Equation (1) (Taki et al., 2012).

$$n = \sum N_h S_h / N^2 D^2 + \sum N_h S_h^2 \quad (1)$$

where, n is the required sample size; N is the number of total population; N_h is the number of population in the h stratification; S_h is the standard deviation in the h stratification; S_h^2 is the variance in the h stratification; D^2 is equal to $\frac{d^2}{z^2}$; d is the precision; $(\bar{x} - \bar{X})$ (5%) is the permissible error and z is the reliability coefficient. The sample size was determined as 61.

In this study, the first 61 farmers were randomly selected from Azerbaijan wheat producer farmers, and the data were collected by filling questionnaires by the selected farmers. Then energy input, production and productivity indexes were calculated as follows:

2.1 Energy input (used)

Energy input was calculated according to kinds of inputs materials (Table 1).

2.1.1 Human energy

Human energy consists of used energy by machine operators and farm labors. Human energy of manual operations was calculated by Equation (2).

$$E_{L1} = \sum_{i=1}^{n} E_{Li} = \sum_{i=1}^{n} \frac{1.96}{A} N_{Li} \times T_{Oi} \times D_{Oi} \times N_{Oi} \quad (2)$$

where, E_{L1}: Human energy in manual operations, MJ/ha; T_{Oi}: Daily working hours for operation 'i', hr/day; D_{Oi}: Work days that are needed in each repetition of operation 'i', day; N_{Li}: Number of labors required to complete the farm in each repetition of operation 'i'; N_{Oi}: Operation repetition per year; A: Farm size, ha.

The second portion of human energy consists of energy that are used by machine operators. Operator energy was calculated as Equation (3).

$$E_{L2} = 1.96 \times \sum_{i=1}^{n} \frac{N_{Oi}}{Ca_i} \quad (3)$$

where, Ca_i: Capacity of machine for i operation, ha/hr; E_{L2}: used energy by operators, MJ/ha.

Capacities of machines were calculated by Equation (4) (Hunt, 2001). Average of proper traveling speed for each mechanical operation was used as V value in Table 2.

$$Ca = \frac{W \times V \times \eta}{10} \quad (4)$$

where, W: working width of machine, m; V: Traveling speed of machine, km/hr; η: Field efficiency of machine, decimal.

Table 1 Energy equal to inputs

Kind of energy	Unit	Equal energy (MJ/unit)	Reference
Energy input			
Human	hour	1.96	(Ozkan et al., 2004)
Machinery	hour	62.7	(Erdal et al., 2007)
Diesel	Liter	56.31	(Singh et al., 2002)
Chemical fertilizer			
N	kg	66.24	(Yilmaz et al., 2005)
P_2O_5	kg	12.44	(Esengun et al., 2007b)
K_2O	kg	11.15	(Esengun et al., 2007b)
pesticide	Liter	0.3	(Esengun et al., 2007b)
seed	kg	14.7	(Demircan and Ekinci, 2006)
Products			
Wheat	kg	14.7	(Ozkan et al., 2004)
Straw	kg	12.5	(Ozkan et al., 2004)

Table 2 Averages of proper traveling speeds and filed efficiencies of machines (Hunt, 2001)

Machine type	Proper traveling speed, km/hr	Field efficiency, decimal
Tillage	6	0.81
Disk	8	0.83
Land leveler	8	0.8
Fertilizer spreader	8	0.67
Seed spreader	8	0.68
Sprayer	8	0.7
Seed drill	7	0.73
Combination tillage and planter machine	5	0.75
Mower	8	0.68
Combine harvester	5	0.77

2.1.2 Fuel energy

Tractor fuel consumption varies depending on type of tractor (maximum power), kind of operation (load factor) and work rate (machine capacity). Fuel consuming rate was calculated by Equation (5) (Hunt, 2001).

$$Q_i = SFCV \times P_t \quad (5)$$

where, Q_i: Rate of fuel consumption, L/hr; P_t: Total used power equal to PTO power, kW; $SFCV$: Specific fuel consumption, L kw^{-1} hr^{-1}.

Specific fuel consumption was determined by Equation (6) for each mechanical operation.

$$SFCV = 3.91 + 2.64X - 0.203\sqrt{173 + 738X} \quad (6)$$

X is Load factor and consists of proportion of total used power by machine to maximum power of tractor. Since there are 56.31 MJ energy per liter of diesel (Table 1), used energy as fuel was calculated by Equation (7).

$$E_{fuel} = \frac{56.31 \times Q_i}{Ca} \quad (7)$$

where, E_{fuel}: Used energy as fuel, MJ/ha.

2.1.3 Machinery energy

Since an hour operation of machine consists of 62.7 MJ energy (Table 1), machinery operation time (hour) was multiplied by 62.7 to determine total input energy as machinery.

$$E_M = 62.7 \times \sum_{i=1}^{n} \frac{1}{Ca_i} \quad (7)$$

where, E_M: Machinery energy.

2.1.4 Electrical energy

On some farms, electric motors are used to supply water by pumps. For this, used electrical energy was calculated by Equation (9).

$$E_e = \frac{N_I \times T_I \times D_I \times P_e \times e_I \times 3.6}{A \times 100} \quad (9)$$

where, E_e: Used electrical energy, MJ/ha; N_I: Irrigation repetition annually; T_I: Working time, hr/day; D_I: Work days that are needed for each irrigation operation; P_e: Electromotor power; kW; e_I: Portion of supplied water that was used on the given farm, %.

2.1.5 Other energy inputs

To determine used energy as inputs materials such as fertilizers, pesticides (chemicals) and seed, the amount of each used input material was multiplied by equal energy (Table 1).

2.2 Energy output

Products on wheat farms consist of wheat grain and straw. Energy output was calculated by multiplying amounts of each product by equal energy (Table 1).

2.3 Energy indexes

Farms were classified in three groups (less than two hectares, between two and five hectares and larger than five hectares). Averages of input and output energy in each group were calculated. Then energy ratio (E_R) and productivity (E_P) indexes were calculated by Equations (10) and (11) (Demircan and Ekinci, 2006; Sartori et al., 2005).

$$E_R = \frac{Energy_{Output}\,(\text{MJ ha}^{-1})}{Energy_{input}\,(\text{MJ ha}^{-1})} \quad (10)$$

$$E_P = \frac{Yield\ (\text{kg ha}^{-1})}{Energy_{input}\,(\text{MJ ha}^{-1})} \quad (11)$$

Linear regressions were used to determine the relationships between farm size and energy indexes.

Three methods of tillage and planting and three methods of harvesting operations were selected as follows. Tillage and planting methods include use of combination tillage and planter machine (A); conventional tillage and seed drill (B); and conventional tillage and seed spreader (C). Combination tillage and planter machine method (A) was selected as the basic method in tillage and planting methods.

Methods of harvesting operations, include combine harvester (a) mower and thresher (b) and hand tools and thresher (c). Combine harvester method (a) was selected as a basic method in harvesting methods.

3 Results and discussion

Energy produced and consumed energy indexes are shown in Table 3 in three groups of farm sizes.

The minimum of total used energy occurred on small farm sizes (21.3 GJ/ha) is 5.9% less than the average of total farms. The maximum total used energy (23.7 GJ/ha) occurred on moderate fields that is 4.9% higher than average of total farms used energy. The result is inconsistent with that reported by Singh et al (2002). This might be due to increase of use of fuel, fertilizers and machinery.

Labor, machinery, and electrical energy decrease and pesticide energy increases when farm size increases (Table 3).

Since most of the operations were completed by labors and use of machinery is difficult and slow on small farms, used energy was the maximum.

Since small machines were used on small farms, operation time per hectare increased then machinery used energy increased.

Fertilizer and fuel accounted for the maximum portion of total energy used. While the results of Shahin et al. (2008) showed that the minimum of total used energy as fertilizer occurred on medium farm size (Shahin et al., 2008). Also the result of study of the Yilmaz et al. (2005) showed that the minimum of labor and fertilizer used energy occurred on medium farm size. They reported that total energy used on cotton farms was increased by increasing of farm size (Yilmaz et al., 2005).

Table 3 Used and produced energy (MJ/ha) for Wheat production

Objects	Farm size groups			Average	
	<2 ha	2-5 ha	>5 ha	Value	Percent
Human	194.78	99.14	58.84	117.59	0.52
Tillage	12.89	11.26	7.09	10.41	
Seed planting	10.77	1.27	1.39	4.48	
Fertilizer application	33.79	3.29	1.15	12.7	
Spraying	12.82	0.93	1.11	4.95	
Irrigation	90.16	79.59	46.41	72.05	
Harvesting	34.33	2.78	1.68	12.93	
Machinery	1334.34	929.41	541.44	935.06	4.14
Tillage	412.59	360.35	226.78	333.24	
Seed planting	22.09	40.9	44.49	35.83	
Fertilizer application	15.04	35.6	37.04	29.228	
Spraying	338.45	29.8	35.57	134.61	
Harvesting	546.16	462.73	197.55	402.15	
Fuel	7076.47	8592.44	8429.76	8032.89	35.56
Tillage	4598.73	5197.04	4480.27	4758.68	
Disk	895.03	824.25	806.8	842.03	
Seed drill	197.92	403.17	309.89	303.66	
Seed spreader	11.88	0	0	3.96	
Combination machine	851.19	0	571.51	190.5	
Land leveler	117.53	1003.93	980	945.04	
Fertilizer spreader	0	282.5	292.88	230.97	
Spraying	126.92	236.59	281.00	214.84	
Mower	95.98	116.84	65.32	92.71	
Combine harvester	181.29	528.11	642.07	450.49	
Fertilizer	8845.52	10473.15	10023.32	9780.66	43.3
Urea	8064.07	9528.39	8993.02	8861.82	
Phosphor	661.98	649.04	616.82	642.61	
potash	119.46	295.72	413.48	276.22	
Pesticides	347.14	396.52	482.5	408.72	1.8
Electricity	575.58	349.35	334.02	419.66	1.85
Seed	2887.5	2850.52	2940	2892.67	12.8
Total used energy (input)	21261.35	23690.54	22809.9	22587.26	100
Produced energy (output)	84747.74	94191.72	103273.8	94071.1	-
Energy ratio	4	3.99	4.69	4.23	-
Energy productivity (kg/MJ)	0.19	0.19	0.22	0.2	-

Since big machines were used on large farms, on the other hand, on small farms most of operations were completed by labor (handle) and mechanical operations were less than other farm sizes, used diesel on both farm size (small and large) were minimum.

On large farms, due to application of large machines, machinery traffic was reduced then fuel and machinery energy will be less than medium farm size. The maximum amount of the energy consumption indirectly in the field is related to the production of fertilizers. The Percent used energy related to all kinds of fertilizer include: nitrogen (39.2%), phosphate (2.84%) and potassium (1.22%).

The relationship between farm size and used energy is illustrated by nonlinear (polynomial) Equation (12) that is not a significant relationship (F=2.6). First, used energy increases then decreases when farm size increases (Figure 1). The maximum used energy occurred on medium farm size (zone 2).

$$Y=19954-2.387X^3-112.31X^2+1438X \qquad (12)$$

$$F=2.6 \quad R^2=0.119$$

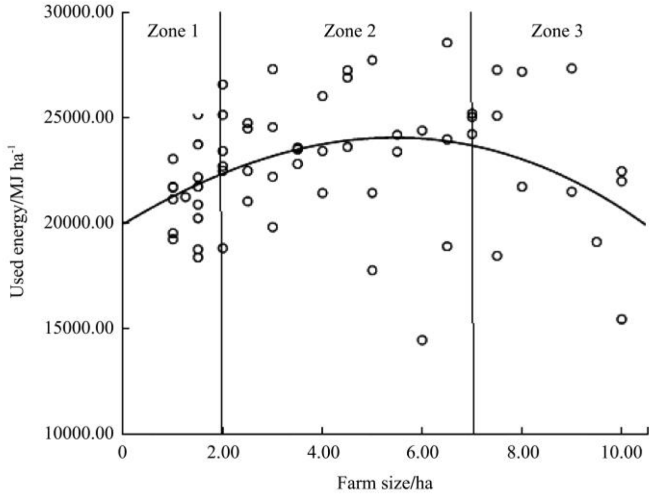

Figure 1 Relationship between used energy and farm size

Nonlinear (power) relationship between energy production and farm size is illustrated in Equation (13) that was significant at 1% level (F=50.43**). Energy production increases with increase in the farm size (Figure 2), but the rate of increasing first is high and then will be low as farm size increases. The value of R^2 (0.457) indicates that the equation occurs for nearly 45 percent of the statistical population.

$$Y=e^{(11.59-0.348/x)} \qquad (13)$$

F=50.43 (significant at 1% level) R^2=0.457

Also the relationship between farm size and energy productivity (Equation (14)) was nonlinear (polynomial) and was significant at 5% level (F=3.7*). Energy productivity increased when farm size increased but R^2=0.12 that is low (Figure 3).

$$Y=158-0.004X^2+0.025X \qquad (14)$$

$$F=3.7^* \quad R^2=0.117$$

Since the type of operated machine on farm affects used energy; farm size variation and machinery methods together will significantly affect energy indexes.

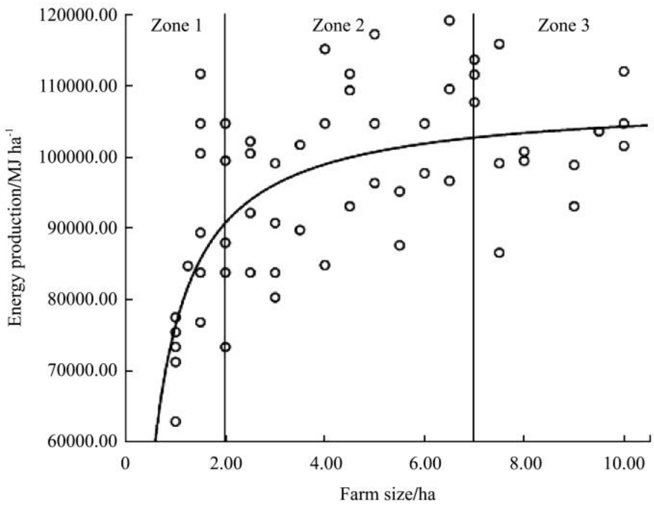

Figure 2 Relationship between produced (output) energy and farm size

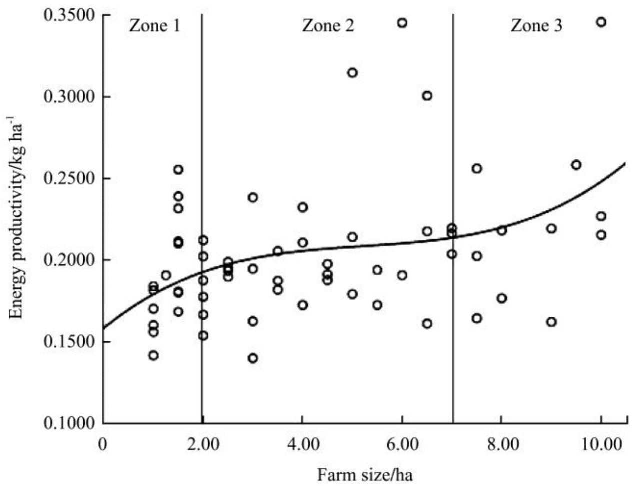

Figure 3 Relationship between energy productivity and farm size

Linear relationships between independent variables (different methods of soil preparation, planting and harvesting operations) and farm size and dependent variable (energy indices) were calculated as Equations (15), (16) and (17).

$$Y(input)=15283.9+361.18X+6858.01B+5789.24C \qquad (15)$$

$$R^2=0.45$$

Equation (15) shows that used energy varies with tillage and planting method and changes of farm size. Because method (A) is the basic of tillage and planting methods, energy used in method (A) is minimum and (C) is less than (B) as is shown in Equation (15). Equation (15) is significant at 1% level and this equation covers 45% of population. The comparison between Equations (12) and (15) shows that the relationship between farm size and used energy is more significant when planting methods is added to equation as independent variables. The relationship between used energy and harvesting methods was meaningless.

$$Y(output) = 88551.5 + 1942.56X - 13117.8C \quad (16)$$

$$R^2=0.38$$

Equation (16) shows the relationship between energy production (dependent variable) and farm size, tillage and planting methods (dependent variable). This equation shows a significant effect of (A) and (C) method and non-significant effect of (B) Method.

The highest energy production is related to (A) method in farms.

$$Y(EP) = 0.292 - 0.098B - 0.121C \quad (17)$$

$$R^2=0.59$$

The relationship between dependent variable (energy productivity) and independent variables (tillage and planting methods) are shown in Equation (17). This equation shows that tillage and planting method effect is significant at 1% level on energy productivity but the farm size effect is meaningless. Energy productivity in method (A) is the highest and method (B) is more than (C). Also the relationship between energy productivity and harvesting methods was not significant. Comparison between Equations (14) and (17) shows that tillage and planting method effect is more significant than farm size on energy productivity.

4 Conclusion

Attending to high used energy as fertilizers, it is recommended that fertilizers be properly used to increase energy productivity and reduce energy consumption. The variable rate technology can be the best solution.

Because of the relationship between energy productivity and planting methods was significant, use of combination tillage and planter machines which consume low energy is better than other methods in tillage and planting operation. The results showed that selection of a proper tillage and planting method is better than increasing of farm size to increase energy productivity.

Energy productivity increased with increase in the farm size together with using of combine machines and variable rate technology.

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