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Full Length Research Paper

Productivity of energy consumption in agricultural productions: A case study of corn farmers of Ahwaz Township, Iran

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Optimum use of energy is very vital for agricultural productions section. The purpose of this research is to determine the productivity of energy consumption in corn farms of Ahwaz Township, Khouzestan Province, Iran. Linear programming was used for calculating the productivity of energy consumption, in that the mathematical technique of linear programming is instrumental in solving a wide range of operations management problems. Linear programming models consist of an objective function and constraint functions. In this research, energy productivity (EP) served as the objective function. By using Lingo software, all the analyses were conducted. Based on the results of the research, the consumption of energy in different sections such as machines, seed, irrigation, human resources and fertilizer was higher than the optimal level.

Key words: Energy consumption, mathematical technique, Lingo software.

INTRODUCTION

Agriculture requires energy as an important input to production. It uses energy directly as fuel or electricity to operate machinery and equipment, to heat or cool buildings, and for lighting on the farm, while it indirectly uses the fertilizers and chemicals produced off the farm (Schnepf, 2004). With the start of green revolution, the usage of external inputs in agriculture was increased (Ommani, 2010). Increasing the usage of external inputs in agriculture caused the increase of energy consumption in this section (Ommani, 2010).

Shakibai and Koochekzadeh (2009) show that energy consumption in Iran agricultural section will have an increasing trend as shown before and it warns the authorities that in a case where the price of energy increases in Iran, the prices will have a huge increase in the agricultural section and this has a negative effect on State competitive power. Agriculture uses energy directly for operating machinery and equipment on the farm and indirectly in the fertilizers and pesticides produced off the farm. There are multiple approaches for energy management in agriculture. All of them include (Bonner et al., 2011): reduce tillage (RT), practice good nutrient management (PGNM), save energy when drying grain (SEDG) and save energy on irrigation (SEI). For analyzing farm energy consumption, there exist three energy indicators (EIs) (Ommani, 2010):

1) Energy productivity in agriculture (EP): For calculating EP, the ratio of the output of agricultural system (Y) is used on input (E_{in}):

$$EP = Y/E_{in}$$

2) Efficiency of energy in agriculture (EE): For calculating EE, the ratio of energy output of agricultural system (E_{out}) is used on energy input (E_{in}):

$$EE = E_{out}/E_{in}$$

3) Special energy in agriculture (SE): For calculating SE, the ratio of consumption energy (E_{in}) is used on crop yield (Y):

$$SE = E_{in}/Y$$

Energy becomes a larger portion of a farmer's operating costs, in that farmers can cut input costs, maintain production, protect soil and water resources, reduce the nation's dependence on fossil fuels and save money by implementing conservation practices that promote energy conservation and efficiency (Gulkis and Clarke, 2010). Agriculture requires energy as an important input to production (Schnepf, 2004). Also, it is a major user of energy, with direct energy consumption and indirect energy use through production inputs, such as fertilizer, thereby accounting for 15% of total farm cash production expenses (USDA, 2007).

The purpose of this research is to determine the productivity of energy consumption in corn farms of Ahwaz Township, Khouzestan Province, Iran.

The research hypothesis is:

There is no difference between consumption of energy in the current situation in different sections such as machines, seed, irrigation, human resources and fertilizer with optimal level.

$H_0: \mu_1 = \mu_2$

$H_1: \mu_1 \neq \mu_2$

MATERIALS AND METHODS

Management practices often present complex problems that can be modeled by linear functions. The mathematical technique of linear programming is instrumental in solving a wide range of operations management problems. Linear programming models consist of an objective function and the constraints of that function. A linear programming model takes the following form:

Objective function:

$$\mathbf{Y = a_1x_1 + a_2x_2 + a_3x_3 + \ldots\ldots\ldots\ldots + a_nx_n}$$

Constraints:

$$b11X1 + b12X2 + b13X3 + \ldots + b1nXn < c1$$
$$b21X1 + b22X2 + b23X3 + \ldots + b2nXn < c2$$
$$\vdots$$
$$bm1X1 + bm2X2 + bm3X3 + \ldots + bmnXn < cm$$

In this system of linear equations, Z is the objective function value that is being optimized, Xi are the decision variables whose optimal values are to be found, and a_i, b_{ij}, and c_i are constants derived from the specifics of the problem.

In this research, energy productivity (EP) served as the objective function. Objective function includes:

$$Y = a_1x_1 + a_2x_2 + a_3x_3 + \ldots\ldots\ldots\ldots + a_nx_n$$

$$EP = Y/E_{in}$$

$$MaxEP = Max(Y/\sum_{i=1}^{n} E_{in_i})$$

1) Therefore, the final objective function is:

$$MinE_{in} = Min\sum_{i=1}^{n} E_{in_i}$$

2) Constraints:

$$E_{consumption} = \sum_{i=1}^{n} E_{in_i}$$

a) Irrigation energy:

$$E_{in_1} = (P.h)\ 3.6$$

b) Machine energy:

$$E_{in_2} = E.M.T/L$$

c) Seed energy:

$$E_{in_3} = RE_e$$

d) Herbicide energy:

$$E_{in_4} = HE_e$$

f) Pesticide energy:

$$E_{in_5} = PE_e$$

g) Fertilizer energy:

$$E_{in_6} = FE_e$$

h) Human resources energy:

$E_{in_7} = EI_L.T.N$ (Almasi, 2008).

In this research, different data were gathered for calculating energy consumption. A questionnaire was designed for this regard. The validity of the questionnaire was obtained by a panel of experts, while the reliability was determined by Cronbach alpha. However, all the items were over 0.70. The different sections of the questionnaire include:

a) Knowledge regarding energy consumption.
b) Knowledge regarding energy productivity.
c) Knowledge regarding energy efficiency.
d) Personal, economical, social and farming characteristics of farmers.
e) h = total time of irrigation (hr/ha).
f) t = total time of using machines (hr/ha).
g) R = seed (Kg/ha).
h) H = herbicide (Kg/ha).
i) P = pesticide (Kg/ha).

Table 1. Farmer's knowledge regarding energy management in farming system.

Level of knowledge	f	%	Cum%
Very low	16	13.33	13.33
Low	15	12.5	25.833
Moderate	45	37.5	63.33
High	23	19.17	82.5
Very high	21	17.5	100
Sum	120	100	

Table 2. Farmer's knowledge regarding each item of energy management.

Factors	Number of items	Mean*	sd
KEC	6	2.987	1.03
KEP	7	2.901	1.07
KEE	7	2.672	0.98

1 = Very low, 2 = low, 3 = moderate, 4 = high, 5 = very high; KEC = Knowledge regarding energy consumption; KEP = knowledge regarding energy productivity; KEE = knowledge regarding energy efficiency.

j) F = fertilizer (Kg/ha).
k) T = total work time of labor (hr/ha).
l) N = number of labors.

A random sample of Ahwaz township corn farmers of Khouzestan province, Iran (n = 150), was selected for participation in the study. The method used for sampling was cluster sampling. The research question is:

Is there any difference between the consumption of energy in the current situation in different sections such as machines, seed, irrigation, human resources and fertilizer with optimal level?

By using SPSS and Lingo software, all of the analyses were thus conducted.

RESULTS

For assessment of the farmer's knowledge regarding energy management in farming system, 3 subsystems of energy management and farmer's knowledge were used regarding each item that was analyzed in the Likert domain:

KEC = Knowledge regarding energy consumption
KEP = Knowledge regarding energy productivity
KEE = Knowledge regarding energy efficiency

According to results, 46% of farmers had moderate knowledge regarding energy management (Table 1). Also, the mean rank and standard deviation of farmer's knowledge include:

M1 = 2.987, sd1 = 1.03, M2 = 2.901, sd2 = 1.07., M3 = 2.672, sd3 = 0.98 (Table 2).

Furthermore, to identify the correlation between the selected independent variables with the dependent variable (farmer's knowledge regarding energy management), spearman correlation coefficient was used. In this study, there was a significant relationship between the farmer's knowledge regarding energy management with access to communications channels, level of education, income, crop yield, size of farm, social participation, and level of participation in extension classes (Table 3). However, level of education, income, crop yield, size of farm, social participation and level of participation in extension classes may well explain 42% (R^2 = 0.424) changes in farmer's knowledge regarding innovation management (Table 4).

This relationship of variables is described in the following formula:

$$Y = A + b1X1 + b2X2 + ...$$
$$Y = 1.223 + 0.610x_1 + 0.423x_2 + 0.645x_3 + 0.445x_4 + 0.521x_5 + 0.371x_6 + 0.356x_7$$

The output of Lingo software regarding current and optimum energy consumption is explained in Table 5. Based on the results of the research, the consumption of energy in different sections, such as machines, seed, irrigation, human resources and fertilizer was higher than the optimum level.

DISCUSSION AND CONCLUSION

Agriculture requires energy as an important input to

Table 3. Correlation between selected variables.

Variable	r	p
Access to communication channels	0.715	0.000***
Crop yield	0.664	0.000***
Size of farm	0.532	0.000***
Social participation	0.712	0.000***
Income	0.522	0.000***
Participation in extension	0.612	0.000***
Level of education	0.514	0.000***

*: p<0.05; **: p<0.01; ***: p<0.001.

Table 4. Linear regression results for predicting changes in knowledge of farmers.

Variable	B	SE B	Beta	T	Tsig
Crop yield	0.610	0.422	0.542	2.654	0.000
Size of farm	0.423	0.365	0.543	2.653	0.000
Social participation	0.645	0.564	0.512	3.154	0.000
Income	0.445	0.413	0.465	3.643	0.000
Extension classes	0.521	0.433	0.261	2.490	0.000
Level of education	0.371	0.323	0.434	4.457	0.000
Access to communication channels	0.356	0.332	0.251	3.223	0.000
Constant	1.223	0.912	-	4.238	0.000

F = 11.445; Signif F = 0.000; R^2 = 0.424.

Table 5. Output of Lingo software regarding current and optimum energy consumption.

Inputs	Current energy consumption	Optimum energy consumption	Percent of reduction (%)	p
Irrigation	34712	32116	7.479	0.000
Machines	66542	58765	11.688	0.000
Seed	2323	1982	14.679	0.000
Fertilizer	2775	2187	21.189	0.000
Herbicide	6547	5427	17.107	0.000
Pesticide	4366	3971	9.047	0.000
Human	4675	3451	26.181	0.000

production (Schnepf, 2004). Also, it is a major user of energy, with direct energy consumption and indirect energy use through production inputs, such as fertilizer, accounting for 15% of the total farm cash production expenses (USDA, 2007).

Optimum use of energy is very vital in agricultural productions section. For calculating the productivity of energy consumption, linear programming was used. The mathematical technique of linear programming is instrumental in solving a wide range of operations management problems. Linear programming models consist of an objective function and constraint functions. In this research, energy productivity (EP) served as the objective function.

By using Lingo software, all the analyses were conducted. Based on the results of the research, the consumption of energy in different sections, such as machines, seed, irrigation, human resources and fertilizer was higher than the optimal level. By implementing conservation practices that promote energy conservation and efficiency, consumption of energy must be reduced. However, the findings of Shakibai and Koochekzadeh (2009), Farahmandpur et al. (2008) and Asakereh et al. (2010) supported this result.

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