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Research Article

ANALYZING ENERGY PRODUCTIVITY IN SUSTAINABLE AND UNSUSTAINABLE FARMING SYSTEMS (CASE STUDY OF WHEAT FARMERS IN AHWAZ TOWNSHIP)

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ABSTRACT
The purpose of this research is comparative analysis of energy productivity in sustainable and unsustainable farming systems. The sample size based on Cochran formula was 280 wheat farmers. In this study was used linear programming. The mathematical technique of linear programming is instrumental in solving a wide range of operations management problems. By using Lingo software all of the analysis conducted. Also wheat farmers based on sustainability level (using hazard material and equipments) were divided into five groups. Based on the results, the difference between energy used in preparation, planting, applying fertilizers, harvesting, productivity and renewable energy in US_1, US_2, MS, S_2 and S_1 systems were found significant. The suitable system based on use of energy, productivity and renewable energy was S_1 system. Output of Lingo Software regarding current and optimum energy consumption showed that the consumption of energy in different systems was higher than optimum levels. Also the results explained the difference between current and optimum energy consumption in US1 systems higher than other systems. The suitable system found was S_1 system.

Keywords: *Energy Productivity, Sustainable Agriculture, Liner Programming*

INTRODUCTION

Sustainable agriculture is the heart of a green economy. Not only does it produce food, which is fuel for human beings, it satisfies our other basic needs, wood for construction material, medicinal herbs, biomass for fuel, paper, etc. Sustainable agriculture saves energy and carbon emissions, prevents pollution of the environment, increases biodiversity, (certainly saving our bees), yields more than chemical agriculture, produces healthier food for the nation, results in more profit for farmers, creates more jobs, and when integrated with local green energies generation, forms the green circular economy we need to replace the unsustainable economic model (Wan, 2010). Harder (2011) pointed out based on multiple studies, researchers have concluded that organic farming systems use significantly less nonrenewable energy than conventional farming. The farm energy savings for organic are often 20% or more. Energy productivity analysis has an important role in the assessment of agricultural systems sustainability. Several studies have been done to measure the level of spending on energy in tropical systems. On the other hand, some studies have shown the savings on energy achieved by the means of substitution of high-energy inputs with low-energy inputs or cultural practices (Pimental *et al.*, 1983).

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 exist three Energy Indicators (EIs) (Ommani, 2010 and 2011):

1) **Energy Productivity in Agriculture (EP):** For calculating EP is used ratio of output of agricultural system (Y) on input (E_{in}).

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

2) **Efficiency of Energy in Agriculture (EE):** For calculating EE is used ratio of energy output of agricultural system (E_{out}) on energy input (E_{in}).

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

3) **Special Energy in Agriculture (SE):** For calculating SE is used ratio of consumption energy (E_{in}) to crop yield (Y).

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

Energy becomes a larger portion of a farmer's operating costs, 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 Clark, 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, accounting 15 percent of total farm cash production expenses.

MATERIALS AND METHODS

The purpose of this research is comparative analysis of energy productivity in sustainable and unsustainable farming system of wheat production in Ahwaz township of Khouzestan province, Iran. This province is located within 29^{0}58' and 32^{0}58' north latitude and 47^{0}42' and 50^{0}39' east longitude. Khouzestan province is the second wheat producer in Iran with an average area of 261000 hectares (Ministry of Agricultural-Jihad, 2012). The population of study was 8989 wheat farmers. The sample size based on Cochran formula was 280 wheat farmers.

At this study was used linear programming. 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 on that function. A linear programming model takes the following form:

a) Objective function:

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

b) **Constraints functions**:

$$b_{11}X_1 + b_{12}X_2+b_{13}X_3 + \ldots + b_{1n}X_n < c_1$$
$$b_{21}X_1 + b_{22}X_2+b_{23}X_3 + \ldots + b_{2n}X_n < c_2$$

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$$b_{m1}X_1+b_{m2}X_2+b_{m3}X_3 + \ldots + b_{mn}X_n < c_m$$

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_n, b_{mn}, and c_m are constants derived from the specifics of the problem. At this research Energy Productivity (EP) was objective function.

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

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

I) Therefore, final objective function was:

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

II) 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:
$E_{in_4} = HE_e$

e) Pesticide Energy:
$E_{in_5} = PE_e$

f) Fertilizer Energy:
$E_{in_6} = FE_e$

g) Human Resources Energy:
$E_{in_7} = EI_L.T.N$

h) Manure Energy:
$E_{in_8} = ME_e$

i) Energy for Biological Control:
$E_{in_8} = BE_e$

By using Lingo software all of the analysis conducted (Ommani, 2011). Also wheat farmers based on sustainability level (using hazard material and equipments) divided in to five groups:
1- Non adopter sustainable agriculture (Unsustainable$_1$-US$_1$): Chemical fertilizer +pesticide+ herbicide + plowing (using moldboard plow) + seed planter
2- Non adopter sustainable agriculture (Unsustainable$_2$-US$_2$): Chemical fertilizer +pesticide+ herbicide + Plowing (using moldboard plow) + disking + seed planter
3- Non adopter sustainable agriculture (Moderate Sustainable-MS): Manure fertilizer +chemical fertilizer + pesticide+ herbicide + Combined chisel harrow and roller + seed planter
4- Adopter sustainable agriculture (Sustainable$_2$-S$_2$): Manure fertilizer +chemical fertilizer + pesticide+ herbicide + combined seeder (tiller + seeder)
5- Adopter sustainable agriculture (Sustainable$_1$-S$_1$): Manure fertilizer+ Biological control+ combined seeder (tiller + seeder)

RESULTS AND DISCUSSION

Energy using and productivity status of wheat production (MJ/ha) in different systems were explained in Table 1. Based on the results the different between energy using in preparation, planting, fertilizers, harvesting, productivity and renewable energy in US1, US2, MS, S2 and S1 systems were significant. The suitable system based on energy using, productivity and renewable energy was S1 system.
Output of Lingo Software regarding current and optimum energy consumption in US1, US2, MS, S1, S2 systems were explained in table 2, 3, 4, 5, 6. Based on the results of research the consumption of energy in different systems were higher than optimum levels. Also the results explained the different between current and optimum energy consumption in US1 systems is higher than other systems. The suitable system was S1 system.

Table 1: Energy use and productivity status of wheat production (MJ/ha)

Inputs	US1	US2	MS	S2	S1	F	Sig
Preparation	1764.8	1734.6	1456.4	1459.9	1121.3	12.67	0.000***
Planting	1432.9	1324.8	1121.9	1109.9	998.5	8.21	0.000***
Fertilizers	6145.4	5673.9	4429.9	4192.9	619.9	32.56	0.000***
Harvesting	6732.8	6654.9	6342.8	6129.3	5876.9	7.23	0.000***
Energy productivity	0.128	0.149	0.184	0.210	0.287	5.43	0.000***
Renewable energy	812.9	981.8	1061.8	1121.6	2876.7	8.23	0.000***

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

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Table 2: Output of Lingo Software regarding current and optimum energy consumption in US1 system

Inputs	Current energy consumption	Optimum energy consumption	Percent of reduce
Preparation	1764.8	1447.14	18
Planting	1432.9	1160.65	19
Fertilizers	6145.4	4547.60	26
Harvesting	6732.8	5318.91	21

Table 3: Output of Lingo Software regarding current and optimum energy consumption in US2 system

Inputs	Current energy consumption	Optimum energy consumption	Percent of reduce
Preparation	1734.6	1474.41	15
Planting	1324.8	1112.83	16
Fertilizers	5673.9	4539.12	20
Harvesting	6654.9	5523.57	17

Table 4: Output of Lingo Software regarding current and optimum energy consumption in system MS

Inputs	Current energy consumption	Optimum energy consumption	Percent of reduce
Preparation	1456.4	1267.07	13
Planting	1121.9	987.27	12
Fertilizers	4429.9	3809.71	14
Harvesting	6342.8	5645.09	11

Table 5: Output of Lingo Software regarding current and optimum energy consumption in S2 system

Inputs	Current energy consumption	Optimum energy consumption	Percent of reduce
Preparation	1459.9	1343.11	8
Planting	1109.9	1032.21	7
Fertilizers	4192.9	3857.47	8
Harvesting	6129.3	5761.54	6

Table 6: Output of Lingo Software regarding current and optimum energy consumption in S1 system

Inputs	Current energy consumption	Optimum energy consumption	Percent of reduce
Preparation	1121.3	1054.02	6
Planting	998.5	958.56	4
Fertilizers	619.9	582.71	6
Harvesting	5876.9	5700.59	3

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Table 7: Analysis discriminant function regarding multiplicity model

Variables	Structure Matrix	Mean		Pooled Within-Group Correlation Matrix													
		G_1	G_2	Sign	CY	I	FS	ML	LV	Age	EL	OSA	AOS	OSK	AI	SP	SS
CY	0.49	6.11	4.45	0.000	1.00												
I	1.08	91.3	61.3	0.000	0.48	1.00											
FS	0.11	11.4	6.3	0.000	0.24	0.43	1.00										
ML	0.30	52.2	34.3	0.000	0.44	0.65	0.41	1.00									
LV	0.21	11.2	4.8	0.000	0.37	0.42	0.37	0.31	1.00								
Age	-031	42.4	51.7	0.000	0.15	-0.29	0.35	-0.31	0.21	1.00							
EL	0.22	3.4	1.5	0.000	0.59	0.39	0.48	0.53	0.35	-0.67	1.00						
SA	0.30	47.3	27.4	0.000	0.36	0.57	0.46	0.54	0.16	-0.53	0.45	1.00					
ASA	0.91	43.7	35.5	0.000	0.25	0.46	0.55	0.46	0.56	-0.65	0.56	0.55	1.00				
SAK	0.78	54.3	36.6	0.000	0.64	0.34	0.44	0.54	0.34	-0.43	0.64	0.43	0.61	1.00			
AI	0.43	20.4	11.2	0.000	0.36	0.65	0.45	0.55	0.38	-0.32	0.52	0.23	0.44	0.43	1.00		
SP	0.24	44.4	23.3	0.000	0.33	0.53	0.35	0.46	0.65	-0.43	0.33	0.54	0.43	0.33	0.23	1.00	
SS	0.24	25.3	14.2	0.000	0.22	0.42	0.28	0.31	0.32	0.11	0.21	0.33	0.37	0.47	0.34	0.41	1.00

CY=*Crop Yield* ***I***= *Income* ***FS***= *Farm Size* ***ML***= *Mechanization Level* ***LV***=*Loan Value* ***EL***=*Education Level* ***SA***= *Sustainability Awareness* ***ASA***= *Attitude to Sustainable Agriculture* ***SAK***= *Sustainable Agriculture knowledge* ***AI***=*Access to Information* ***SP=*** *Social Participation* ***SS***= *Social Status*

Table 8: Grouping adapters and non-adapters of sustainable system based multiplicity model

Group	Number of Cases	Predicted Group Membership	
		Adopters	Non-adapters
Adopters	54	47	7
		87.03%	12.97%
Non-adapters	226	28	198
		12.39	87.61

Not: 92.5% of the original cases was correctly classified

Analysis Multiplicity Model Regarding Adoption of S_1 and S_2 System

Based on multiplicity model, different variables such as income, crop yield, farm size, mechanization level, loan value, age, education level, on-farm sustainable agriculture awareness, attitude to sustainable agriculture, on-farm sustainable agriculture knowledge, access to information, social participation, and social status were analyzed. For predicting adoption behavior of farmers regarding S_1 and S_2 system the discriminant analysis was used. Based on results a discriminant function is:

D = 1.045 Income + 0.495 Crop yield + 0.653 Mechanization level + 0.244 Loan value + 0.235 Education level -0.334 Age + 0.311 Awareness + 0.435 Attitude + 0.742 knowledge + 0.454 Access to information + 0.246 Social participation+ 0.208 Social status

Wilks' lambda = 0.566 Chsquare = 155.765 Sig = 0.000

Eigenvalue = 0.965 Cannonical Correlation = 0.863

Wilks' lambda is used to test the significance of the discriminant function as a whole and the eigenvalue reflects the ratio of importance of the dimensions which classify cases of the dependent variable. The proportion of variance unexplained was 56.6% (Wilks' lambda = 0.566). The eigenvalue of 0.965 indicates that the discriminant function can explain 0.965 times as much as is not being explained. Also the degree of association between the groups and the discriminant scores was expressed as a canonical correlation of 0.863. The Table 8 shows that the adapters are the more accurately classified with 87% of the cases correct. For the non-adapters 87.61% of cases were correctly classified. Overall, 92.5% of the original cases were correctly classified.

Conclusion

The analysis of energy productivity is an important approach in the assessment of farming systems, because it represents a complement of the economical and financial analysis. This energy analysis suggested that the S1 system has a high productivity, which is important for the sustainability of the farming systems. 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 (Asskereh *et al.,* 2010; Farahmandpur *et al.,* 2008, Ommani, 2010; Shakibai and Koochekzadeh, 2009) supported this result.

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