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An analytical method to survey the energy input-output and emissions of greenhouse gases from Wheat and Tomato farms in Iran

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ABSTRACT: This study survived the energy use patterns and energy input-output of wheat and tomato productions in Isfahan province of Iran. The face-to-face questionnaire method was used to collect the data from 75 and 35 farmers for wheat and tomato, respectively. The results showed that total energy input for wheat and tomato production was to 46108and 115894 MJha^{-1}, respectively. Among all inputs involved, fertilizer had the highest energy value per hectare for wheat; furthermore, diesel fuel had the highest share of total energy consumption for tomato production. The value of energy ratio for cultivating wheat and tomato productions were calculated at 0.95 and 0.75, respectively. The ratio of renewable energy within the total energy in all productions is very low. The share of non-renewable energy for wheat and tomato production was 80% and 85%, respectively. The results of CO_2 emission analyzes showed that the total amount of CO_2 emission for wheat and tomato production was 1.9 and 4.7 tonesha^{-1}, respectively. In the research area, use of further energy made some environmental damages such as global warming, nutrient loading and pesticide pollution. Therefore, there is a need to develop a new policy to force producers to use all inputs on time and enough undertake more energy efficient practices.

Keywords: Energy utilization; environmental pollution; Energy ratio

INTRODUCTION

Agriculture is both a producer and consumer of energy. It uses large quantities of locally available non-commercial energy, such as seed, manure and animate energy, as well as commercial energies, directly and indirectly, in the form of diesel, electricity, fertilizer, plant protection, chemical, irrigation water, machinery etc. Efficient use of these energies helps to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living (Singh *et al.*, 2002). Energy input-output relationships in cropping systems vary with crops being grown in sequence, by type of soils, nature of tillage operations for seedbed preparation, nature and amount of organic manure, chemical fertilizer, plant protection measures, harvesting and threshing operations and, finally, yield levels (Mandal *et al.*, 2002) .

Cetin and Vardar studied on differentiation of direct and indirect energy inputs in agro industrial production of tomatoes.

Erdal *et al.*, have studied on energy consumption and economic analysis of sugar beet production. Damirjan *et al.*, studied the energy and economic analysis of sweet cherry production. Alam, *et al.*, studied the energy flow in agriculture of Bangladesh for a period of 20 years. Satori *et al.*, studied the comparison of energy consumption on two farming system of conservation and organic in Italy. In recent years, Data Envelopment Analysis (DEA) as a non-parametric method has become a central technique in productivity and efficiency analysis applied in different aspects of economics and management sciences. Although within this context, several researchers have focused on determining efficiency in agricultural units and various products ranging from cultivation and horticulture to aquaculture and animal husbandry for example: surveying the quantity of inefficient resources which are used in cotton production in Panjab in Pakistan (Shafiq and Rehman 2000), reviewing energy performance used in paddy production

(Nassiri and Singh 2009), surveying improving energy efficiency for garlic production (Samavatian *et al.*, 2009), evaluation and development of optimum consumption of energy resources in greenhouse cultivation in Tehran province (Gochebeyg *et al.*, 2009), checking the efficiency and returning to the scale of rice farmers in four different areas of Panjab state in India by using Non-parametric method of data envelopment analysis (Nassiri and Singh 2010), determination of the amount of energy consumption in wheat cultivation of Fars province with the approach of data envelopment analysis (Houshyar *et al.*, 2010). A further comparative review of frontier studies on agricultural products can be found in (Sharma *et al.*, 1999), (Iraizoz *et al.*, 2003), (Galanopoulos *et al.*, 2006), (Singh *et al.*, 2004), (Chauhan *et al.*, 2006).

The Isfahan region is one of the most important agricultural production areas in Iran. Different geographical and climatic characteristics increase the variety of crop patterns, and irrigated farms have an important economic value in the province. The farmers grow many agricultural products, such as field crops, vegetables, fruits, flowers, etc. The main objective of this research was to investigate the energy use patterns, examine the greenhouse gas emission and analyze the energy input-output in the cultivation of wheat and tomato production in this part of Iran.

MATERIALS AND METHODS

This study was conducted in Isfahan province of Iran. This province is located within 30° 42' and 34° 30' north latitude and 49° 36' and 55° 32' east longitude. Data were collected through personal interview method in a specially designed schedule for this study. The collected data belonged to the 2012/13 production year. Before collecting data, a pre-test survey was conducted by a group of randomly selected farmers. The required sample size was determined using simple random sampling method. The equation is as below (Mousavi-Avval *et al.*, 2011):

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

where n is the required sample size; s, the standard deviation; t, the t value at 95% confidence limit (1.96); N, the number of holding in target population and d, the acceptable error (permissible error 5%).

Table 1. Energy equivalences of inputs and outputs.

Energy source	Units	MJ
1. Human power	-	
Man	h	1.96
Woman	h	1.57
2. Chemical fertilizer	-	-
N	kg	66.14
P_2O_5	kg	12.44
K_2O	kg	11.15
3. Diesel fuel	L	47.8
4. Tractor	kg	93.61
5. Agricultural machinery	kg	62.7
6. Combine	kg	87.63
7. Chemical poison	kg	-
Herbicides		238
Fungicides		216
Insecticides		101.2
8. Farmyard manure	kg	0.3
9. Nylon	kg	60
10. Seed	-	-
11. Water for irrigation	m^3	1.02
12. Electricity	kWh	11.93
Wheat (seed)	kg	15.7
Tomato (seed)	kg	1.00
13. Output	-	
Wheat	kg	14.7
Tomato	kg	0.8

Consequently calculated sample size in this study was 75 and35 for wheat and tomato, respectively. Consequently, based on the number of wheat producers and tomato greenhouses in each village the 75 field crops farmers and 35 greenhouses from the population were randomly selected. Energy is primarily used in agricultural operations for autumn tillage, seedbed preparation, sowing, planting, hoeing-weeding, bund making (ridging), irrigation, fertilizer application, spraying, harvesting-threshing and transportation. The energy equivalents given in Table 1 were used to calculate the input amounts. The production energy of tractors and agricultural machines was calculated by using the following equation (Gezer *et al.,* 2003):

$$\mathrm{M}_{\mathrm{pe}} = \frac{G \quad M_{p}}{\mathrm{TW}} \qquad \ldots(2)$$

Where Mpe is the energy of the machine per unit area, $\mathrm{MJha^{-1}}$, G is the mass of machine, kg; Mp is the energy consumption for production 1 kg of machine, $\mathrm{MJkg^{-1}}$; *T* is the economic life, *h*; and *W* is the effective field capacity, $\mathrm{hahr^{-1}}$. The Diesel energy requirement was determined on the basis of fuel consumption, $\mathrm{lha^{-1}}$. The data were converted into energy units and expressed in$\mathrm{MJha^{-1}}$. The following equation was used in the calculation of fuel consumption (Canakci *et al.,* 2005):

$$\mathrm{FC} = P_{m} \times R \times SFC \qquad \ldots(3)$$

Where *FC* is the fuel consumption, $\mathrm{lha^{-1}}$; Pm is the tractor power, kW; *R* is the loading ratio, decimal; and SFC is the specific fuel consumption ($0.300\,\mathrm{lkWh^{-1}}$).

In this study the fuel requirements of water pumps (stationary type) and combine harvesters were measured by the following method: the fuel tank of the engine was completely filled before starting the field test, and the quantity of fuel required to fill the tank after performing the field test was measured using a 1 L graduated cylinder. Thus, the fuel consumed during the test was determined (Canakci *et al.,* 2005).

Based on the energy equivalents of the inputs and output (Table 1), the energy ratio (energy use efficiency), energy productivity, specific energy and net energy gain were calculated in Table 2.

Table 2. Indices of energy in Agriculture production.

Indicator	Definition	Unit	
Energy ratio	$\frac{\text{Energy Output (MJ ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})}$	ratio	(4)
Energy productivity	$\frac{\text{Yield (kg ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})}$	$\mathrm{Kg\ MJ^{-1}}$	(5)
Specific energy	$\frac{\text{Energy input (MJ ha}^{-1})}{\text{Yield (kg ha}^{-1})}$	$\mathrm{MJ\ kg^{-1}}$	(6)
Net energy gain	Energy Output ($\mathrm{MJ\ ha^{-1}}$) - Energy Input ($\mathrm{MJ\ ha^{-1}}$)	$\mathrm{MJ\ ha^{-1}}$	(7)

The output-input energy ratio (energy use efficiency) is one of the indices that show the energy efficiency of agriculture. In particular, this ratio, which is calculated by the ratio of input fossil fuel energy and output food energy, has been used to express the ineffectiveness of crop production in developed countries. An increase in the ratio indicates improvement in energy efficiency, and vice versa. Changes in efficiency can be both short and long term, and will often reflect changes in technology, government policies, weather patterns, or farm management practices. By carefully evaluating the ratios, it is possible to determine trends in the energy efficiency of agricultural production, and to explain these trends by attributing each change to various occurrences within the industry (Unakitan *et al.,* 2010).

RESULTS AND DISCUSSION

A. Energy use pattern

The components of the energy use pattern for cultivating the wheat and tomato are shown in Table 3. As it can be seen in the Table 3, 330 kg nitrogen, 300 kg Phosphate, 300 kg potassium, 17 tons of farm fertilizer, 1000 l diesel fuel, 4150 $\mathrm{m^3}$ water, 9.2 kg chemical spraying agents, 5710 h human power, 48 h machinery, 1170 Kwh electrical energy per hectare are used for the production of tomato in Isfahan province of Iran. The average tomato output were found to be 130000 kg $\mathrm{ha^{-1}}$ in the enterprises that were analyzed. The energy equivalent of this is calculated as 104000 $\mathrm{MJha^{-1}}$.

Omid *et al.*, concluded that the input energy for cucumber production was to be 152908 MJha^{-1} and the Similar results have been reported in the literature that the energy input of diesel fuel and chemical fertilizers has the biggest share of the total energy input in agricultural crops production (Erdal *et al.*, 2007, Bahrami *et al.*, 2011, Monjezi *et al.*, 2011, Taki *et al.*, 2012).

For the wheat crop, the total energy requirement consumed in various energy sources was calculated to average inputs energy consumption was highest for diesel fuel, total chemical fertilizer and electricity.

be 46108MJha^{-1}. The fertilizer application was found to be the highest energy source in total inputs. It was followed by diesel fuel and water for irrigation. All of the field operations are performed using agricultural implements. So, the share of human power usage remained at the lowest level. Also, seeds and chemical energies were found to be low. The average yield of the wheat crop was determined to be 3700kg ha^{-1}.

Table 3. The physical inputs used in the production of tomato and wheat and their energy equivalences.

Inputs	Wheat			Tomato		
	Amount	Unit	MJ	Amount	Unit	MJ
1. Chemicals	20	kg	4760	9.2	kg	1697
Herbicides	20	kg	4760	3.5	kg	833
Fungicides		-	-	2.5	kg	540
Insecticides		-	-	3.2	kg	324
2. Human power	185	h	362	5710	h	11192
3. Machinery	85	h	5330	48	h	3010
4. Fertilizer	350	kg	12371	930	kg	28904
Nitrogen fertilizer	150	kg	9921	330	kg	21827
Phosphate	170	kg	2115	300	kg	3732
Potassium	30	kg	335	300	kg	3345
5. Manure	-	-	-	17	ton	5100
6. Seed	270	kg	4239	0.1	kg	0.1
7. Diesel fuel	200	l	9560	1000	l	47800
8. Electricity	-	-	-	1170	kWh	13958
9. Water	9300	m^3	9486	4150	m^3	4233
Total energy input		-	46108	-	-	115894
Yield	3700	kg	54390	130000	kg	104000

B. Energy indices in field crops and vegetables

The energy ratio (energy use efficiency), energy productivity, specific energy, net energy gain and the distribution of inputs used in the production of wheat and tomato production according to the direct, indirect, renewable and non-renewable energy groups, are given in Table 4.

Table 4. **Energy output–input ratio and type of energy forms for crop field and vegetables productions.**

Items	Unit	Tomato	Wheat
Energy ratio	-	0.75	0.95
Energy productivity	kgMJ^{-1}	0.94	0.06
Specific energy	MJkg^{-1}	1.06	17
Net energy	MJha^{-1}	-27894	-2008
Direct energy [a]	MJha^{-1}	77183	19408
Indirect energy [b]	MJha^{-1}	38711	26700
Renewable energy [c]	MJha^{-1}	16292	9202
Non- renewable energy [d]	MJha^{-1}	99602	36906
Total energy input	MJha^{-1}	115894	46108
Energy output	MJha^{-1}	88000	44100

[a]include human power, fuel, water for irrigation and electricity power, [b]include the Chemical poisons, fertilizers, seeds and machinery, [c]include human power, seeds and manure fertilizers, [d]include fuel, electricity, Chemical poisons, water for irrigation, fertilizers and machinery.

The ratio of renewable energy including the energies of human power, seed and farm fertilizer inputs, within the total energy in all productions is very low. Renewable energy resources (solar, hydroelectric, biomass, wind, ocean and geothermal energy) are inexhaustible and offer many environmental benefits over conventional energy sources. Each type of renewable energy also has its own special advantages that make it uniquely suited to certain applications Taki *et al.*, 2012).

The use of renewable energy offers a range of exceptional benefits, including: a decrease in external energy dependence; a boost to local and regional component manufacturing industries; promotion of regional engineering and consultancy services specializing in the use of renewable energy, decrease in impact of electricity production and transformation; increase in the level of services for the rural population; creation of employment, etc Miguez *et al.*, 2006). Within the enterprises that were analyzed, the share of non-renewable energy for wheat and tomato production was 80% and 85%, respectively. Several researchers have found similar results that the share of non-renewable energy is greater than that of renewable energy consumption Kaya *et al.*, 2006).

The energy ratio in Table 4 was calculated as 0.95 and 75for wheat and tomato production. The higher value of energy ratio for wheat in this region can be explained by the efficiency of irrigation kennel and optimization of chemical fertilizer that affect in total energy consumption. The results of Table 4 showed that the energy ratio was low for vegetable production in Isfahan Province. The reason of low energy ratio in this research in comparison with other researches may be including: low yield, using high energy inputs consumption, not being insulate for roof and walls, etc. It is clear that the use of renewable energy in this region is very low, indicating that tomato and cucumber production depends mainly on fossil fuels. By raising the crop yield, decreasing energy inputs consumption, insulate the roof and walls, use of renewable energy and optimization of energy consumption the energy ratio can be increased. Other authors reported similar results for vegetable production such as 0.69 (Ozkan *et al.*, 2004), 0.76 (Heidari and Omid 2011), and 0.64 (Mohammadi and Omid 2010),

Energy productivity for wheat and tomato production was calculated 0.06 and 0.94 MJkg^{-1}, respectively. The net energy of wheat and tomato were negative. In literature, similar results have been reported (Mandal *et al.*, 2002, Erdal *et al.*, 2007). Pishgar Komleh *et al.*, studied energy efficiency, energy productivity, specific energy and net energy for corn silage which amount of above indices were reported as 2.27, 0.28 kgMJ^{-1}, 3.76 MJ kg^{-1}and 79452 MJ ha^{-1}, respectively.

C. Greenhouse gas emission for field crops and vegetable productions

In this research GHG emissions were the scope of this analysis and the corresponding amount was calculated. The diesel fuel combustion can be expressed as fossil CO_2 emissions with equivalent of 2764.2 gL^{-1}. Also, the machinery and fertilizer supply terms can be expressed in terms of the fossil energy required to manufacture and transport them to the farm with CO_2 equivalents of 0.071 TgPJ^{-1} and 0.058 TgPJ^{-1} for machinery and chemical fertilizers, respectively.

Table 5 shows the CO_2 emission for wheat and tomato production in actual energy use. Results of this table indicated that vegetable productions are mostly depending on diesel fuel sources. Diesel fuel had the highest share (58% for tomato) followed by chemical fertilizer and machinery. As it can be seen in Table 5, the total amount of CO_2 emission was 4.75 and 1.92 tones ha-1 for tomato and wheat, respectively. Finally, Table 5 showed that the CO_2 emission for vegetable productions is more than field crops.

Table 5. Amount of greenhouse gas emission for wheat and tomato production.

Input		Amount of energy usage (MJ/ha)		Quantity of CO_2 emission (kg/ha)	
Inputs	Equivalent (Tg (CO_2) PJ^{-1})	Wheat	Tomato	Wheat	Tomato
Diesel fuel	0.0578	9560	47800	553	2763
Machinery	0.071	5330	3010	379	214
Chemical fertilizer and poison	0.058	17071	30601	990	1775
Total	-	31961	81411	1922	4752

Using ethanol and biodiesel as biofuel is essential in the 21st century to reduce the high GHG emissions. Field operations with minimum machinery use (especially tillage operation) and machinery production are needed to be considered to reduce the amount of CO_2. Eady *et al.,* 2011 applied the Life cycle assessment modeling of complex agricultural systems with multiple food and fibre co-products. They reported that amongst the crops, estimates of emissions for the cereal grains averaged 202 kg CO_2-e/tonne grain, canola 222 kg CO_2-e/tonne and lupins 510 kg CO_2-e/tonne, when modeled to include the benefits of the mixed farming system. Gunady *et al.,* used the Life Cycle Assessment for evaluating the global warming potential of the fresh produce supply chain for strawberries, romaine/cos lettuces and button mushrooms in Western Australia. Results showed that the life cycle GHG emissions of strawberries and lettuces were higher than mushrooms due to intensive agricultural machinery operations during the on-farm stage. Mushrooms, however have significantly higher GHG emissions during pre-farm stage due to transport of peat, spawn, and compost.

CONCLUSION

Based on the results of this paper it can be stated that:

1. The total energy requirements for cultivating the wheat and tomato were found 46108 MJ ha^{-1} and 115894MJha^{-1} respectively. In energy sources, fertilizer had the maximum energy values for wheat and diesel fuel had the highest share of total energy consumption for tomato production.
2. The values of the energy ratio for cultivating the wheat and tomatowere0.95 and 0.75, respectively. Also, the values of specific energy consumption for wheat and tomato cultivation were found to be 17and 1.06 MJkg^{-1} respectively.
3. In this research the ratio of renewable energy within the total energy in all productions is very low. The share of non-renewable energy for wheat and tomato production was 80%, and 85%, respectively.
4. The results of CO_2 emission analyzes showed that the diesel fuel had the highest share of total CO_2 emission for tomato production. The total amounts of CO_2 emission were 4.7 and 1.9 tonha^{-1} for wheat and tomato, respectively.

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