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Energy Production in Iran's Agronomy

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Abstract: Sustainable development in agricultural production is an issue of growing concern. An energy-use pattern analysis is proposed for providing parameters for estimating agricultural sustainability. Since sustainability has to be assessed over generations, the current study examines the energy use pattern of 21 field crops in Iranian agronomy for the period of 1981-2005. Total output energy (energy production), output energy per unit of area, energy per unit of weight and output energy per capita were the indices calculated and analyzed. It was found that the total output energy, total output energy per hectare and output energy per capita grew with a rate of 31.83 $PJyr^{-1}$, 2.35 $GJyr^{-1}$ and 0.25 $GJyr^{-1}$ respectively reaching the values of 669.12 PJ, 52.07 $GJha^{-1}$ and 9.66 $GJcapita^{-1}$ for the total output energy, total output energy per hectare and output energy per capita respectively. Output energy per unit of weight was calculated to be an average of 9.65 $MJkg^{-1}$ which showed no particular increasing or decreasing trend within the 24 year study period. The comparative output energy of agricultural commodities indicated that sugar beet with an output of 394.61 $GJha^{-1}$ had the highest energy output while tobacco, cucumber, lentil, chickpeas, tomatoes, beans and cotton with output energy of 24.71, 22.97, 20.52, 16.09, 15.39, 14.0 and 0.09 $GJha^{-1}$ respectively had the lowest output energy. It is suggested that besides other factors the energy output per hectare index for different crops, be taken into account when setting regional agricultural policies.

Key words: Output energy · Energy per capita · Iran agricultural

INTRODUCTION

In developing countries like Iran, agricultural growth is essential for fostering the economic development and meeting the ever higher demands of the growing population. Energy in agriculture is important in terms of crop production and agro processing for value adding. The relation between agriculture and energy is very close. At present productivity and profitability of agriculture depends on energy consumption.

Energy use in the agricultural sector depends on the size of the population engaged in agriculture, the amount of arable land and the level of mechanization.

Since 1979 and the revolution in Iran, commercial farming has replaced subsistence farming as the dominant mode of agricultural production. Some northern and western areas of Iran support rain-fed agriculture, while other areas require irrigation for successful crop production. The agricultural sector is vital in the Iranian economy highlighted by the Iranian Government policy of self-sufficiency in food production. The agricultural sector is Iran's second largest employment provider and a significant contributing sector to GDP, imports and exports. More than 33% of the total population of Iran is engaged in agriculture while the share of agriculture in GDP was 26% in 2007 [1]. The contribution of agricultural commodities in total exports is a tangible amount and in 2003, a quarter of Iran's non-oil exports were agricultural based. However, despite government incentives to farmers and support of the agricultural sector the importance of agriculture has declined in relation to the increase observed in the industry and service sectors.

Roughly one-third of Iran's total surface area is suited for farmland, but because of poor soil and lack of adequate water distribution in many areas, most of it is not under cultivation. Presently about 11 percent of the Iran's total land area of 1,636,000 km^2 is cultivated while 63% of the cultivable lands have not been used, and 185,000 km^2 of the present farms are being used with 50 to 60% capacity [1]. In 1975, the total production area

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for the major crops examined in the study was 18.5 million ha and it reached to 20.5 million ha in 2000 with an increase of 1.1%.

The wide range of temperature fluctuation in different parts of the country and the multiplicity of climatic zones make it possible to cultivate a diverse variety of crops. Cereals are of great importance in Iranian agriculture. In 2007, cereal production was nearly 23.5 million tones. Wheat takes the most important place in cereals with a share of 42.6%, barley ranks second with 3.2 million tones 25.5% and is followed by maize with a share of 7.5%. The remaining 2.5% consists of the production of other crops.

Considerable research studies have been conducted on energy use in agriculture. Singh *et al*. [2] evaluated the energy requirements of rice, maize, wheat, groundnut, sugar cane, cotton and gram in Indian conditions. This study deals with energy consumption in the productivity of these crops in different states of India. It also highlights the future energy needs to achieve desired yield levels and production targets. Finally, it was concluded that as the energy input increased, the production also increased. Hetz [3] studied the utilization of energy in the production of fruits in Chile in order to improve the efficiency of its use. Singh [4] stated that growth of crop production depends on the three sources: arable land expansion, increase in cropping intensity and yield growth. Borlaugh *et al*. [5] stated that crop production environment including the generation and transfer of

Appropriate technology must be improved to increase the fertilizer use efficiency to meet the challenge of feeding increased population. However, considerable studies have been conducted in different countries on energy flow in agriculture [6-11].

Schroll [12] conducted a study on the energy flow and ecological sustainability in Danish agricultural production from 1936 to 1990. His calculations included energy output (contents of energy in vegetable produce, animal produce and the part of the produce that is used for human consumption) and he found a decline in the output/input energy ration throughout the period mainly due to a large increase in the use of fertilizers, fuel and electricity. Ozkan *et al*. [13] determined the energy use in the Turkish agricultural sector for the period of 1975-2000 including 36 agricultural commodities of Turkey. He found that the total output energy rose from 38.8 to 55.8 GJ ha^{-1} in the study period. He concluded that the large increase in the use of inputs was not accompanied by the same result in the final product output energy thus leading to a less energy efficient system. Alam *et al*. [14] analyzed the flow of energy in Bangladesh agriculture for a period from 1980 to 2000 to evaluate the impact of energy input to produce output. He found that output energy was increased from 72.22 to 130.05 GJ ha^{-1} in the 20 year period also the energetic efficiency (energy output to input ratio) was declined from 11.28% to 8.1%.

The aim of this study is to provide a descriptive analysis of energy output in the agronomy sector of Iranian agriculture in the period 1981-2005. An energy flow analysis provides planners and policy makers an opportunity to evaluate the performance of agricultural system on energy use.

MATERIALS AND METHODS

The energy flow in Iranian agronomy is calculated for the period 1981-2005. In the calculation of the energy flow, output energy (energy production), output energy per unit of area, energy per unit of weight and output energy per capita were calculated and analyzed. In the study, energy equivalents of agronomy outputs were used to estimate the total output energy (Table 1).

In the study, 21 crops were taken into account to estimate output energy values. The major crops produced during the study period are wheat, barley, rice, chickpeas, dry beans, lentils cotton, tobacco, sugar beet, sugar cane, potatoes, onions, maize, tomatoes, melon, water melon, cucumbers, alfalfa, corn, white clover, and oil seeds including soy beans and canola. These crops cover more than 95 percent of the agronomy cultivated land in Iran.

The data used in the study were collected from various statistical resources including Statistical Year Books of the Agricultural Ministry of the Islamic Republic of Iran [15-19] in which data is separated for irrigated and rain fed agriculture and also data from Energy Balance Tables of Power Ministry of Islamic Republic of Iran. The study has also benefited from previous researches and studies conducted on energy analysis in agriculture.

Total output energy from agricultural lands in any one year is calculated using Eq. (1).

$$E_T = \sum_{i=1}^{n} P_i \times A_i \times ev_i \qquad (1)$$

where ET is the total output energy in agronomy sector, J; Pi is the average yield of crop i, kg/ha; Ai total land cultivated for crop i, ha; evi energy equivalent of product i, J/kg.

By using Eq. (1) output energy is calculated separately for rain fed and irrigated agriculture. In

Table 1: Energy equivalents of crops

Crops	Unit	Equivalent energy (MJ)
Cereal and pulses	kg	14.70
Sugar beet	kg	5.04
Cotton	kg	11.80
Oil seed	kg	25.00
Water melon/melon	kg	1.90
Potatoes	kg	3.60
Vegetables	kg	0.80
Olive	kg	11.80
Tobacco	kg	0.80
Onion	kg	1.60

Table 2: The total output energy of Iranian agronomy for the period of 1981-2005

	Total output energy (PG)		
Year	Irrigated	Rain fed	Total
1981	193.3861	63.20673	256.5929
1983	235.3659	63.99584	299.3617
1985	254.7898	78.91471	333.7045
1987	231.1567	83.28721	314.4439
1989	273.7873	85.59138	359.3786
1991	436.2393	82.76455	453.9610
1993	341.4341	85.85159	427.2857
1995	346.9297	84.38932	431.3191
1997	404.6783	107.0411	511.7194
1999	400.3086	74.84712	544.8102
2001	443.1337	96.24866	539.3824
2003	498.1777	105.5917	603.7694
2005	565.9457	103.1713	669.1171

Table 2 the output energy of Iranian agronomy for the period of 1981-2005 is shown.

To eliminate the effect of area in the energy production of the agronomy sector and calculate the average output energy in one hectare Eq. (2) was used.

$$E_a = \frac{E_T}{A_T} \quad (2)$$

where Ea is the average output energy in unit area, J/ha; ET is the total output energy, J; AT is the total cultivated area of the agronomy sector, ha.

Equation (2) is used to calculate the output energy per unit area for both rain fed and irrigated farming. The average output energy per hectare for the study period is shown in Table 3.

For calculation of the energy value of Iran's agronomy per unit of weight Eq. (3) was used.

Table 3: The output energy in unit area for the period of 1981-2005 in Iranian agronomy

	Output energy in unit area (GJ ha^{-1})		
Year	Irrigated	Rain fed	Total
1981	40.93739	10.79808	24.25845
1983	45.05471	10.80897	26.86153
1985	45.05146	12.58036	27.97568
1987	45.73716	12.12928	26.37809
1989	47.26828	12.71882	28.70046
1991	75.45275	11.96086	40.86246
1993	60.25704	12.98986	34.80824
1995	60.37772	12.76350	34.90270
1997	67.80790	17.20629	41.98187
1999	72.86236	15.91724	46.60077
2001	75.29850	15.74415	44.95481
2003	80.56109	17.31011	49.15148
2005	85.42608	16.57388	52.07173

Table 4: Energy production per capita and average energy value for 1 kg of agronomy product for the study period

Year	Average output energy in unit weight (MJ/kg)	Average energy production per capita (GJ/capita)
1981	8.836217	6.258362
1983	8.816264	6.881878
1985	8.873521	7.010599
1987	11.07733	6.202049
1989	10.30616	6.755237
1991	9.682422	8.106429
1993	9.940505	7.431055
1995	9.549508	7.285795
1997	9.628506	8.320641
1999	10.64442	8.593061
2001	9.287786	8.172460
2003	9.386925	8.984664
2005	9.412641	9.655367

$$E_w = \frac{E_T}{\sum_{i=1}^{n} P_i \times A_i} \quad (3)$$

where Ew is the average energy value per unit weight, J/kg; ET is the total output energy, J; Pi is the average yield of crop i, kg/ha; Ai total land cultivated for crop i, ha.

By dividing the total yearly agronomy energy by the total population of the same year, energy produced by the agronomy sector per capita (output energy per capita) is calculated. Energy production per capita and average energy value for 1 kg of agronomy product for the study period is shown in Table 4.

Statistical analysis was done applying the analysis of regression and variance by using the SPSS 12.0 (Version, 2003) computer software.

RESULTS AND DISCUSSION

Total grain equivalent of selected crops are 23075 × 103 tons for cereal, 11668 × 103 tons for sugar beet and cane, 2468.3 × 103 tons for vegetables, 14813 × 103 tons for feed crops, 5064.5×103 tons for tomato, 4218.5 × 103 tons for potato, 2038.3×103 tons for onion, 1938.4 × 103 tons for cucumber, 1367.3 × 103 tons for melon and water melon, 615.1 × 103 tons for oil seed, 283.6 × 103 tons for cotton and 15.4 × 103 tons for tobacco in 2005. Total grain production rose from 29038.7 × 103 tons in 1981 to 71087.1 × 103 tons in the year 2005. In 1981, the production value of cereals had the highest ratio with 32.6% followed by sugar beet and sugar cane with 19.6% and feed crops with 15.1%. The shares of cereals, sugar beet and cane and feed crops in 2005 were 32.4, 16.4 and 20.8 percent respectively. The most significant increase over the study period was in tomato production with a 2.3 fold increase. The production increases are 1.6% for vegetables, 1.4% for oil seeds and 1.38% for feed, while cereal, potato, onion and cucumber production was stagnant in the period under study.

Energy equivalents of examined crops were calculated by using equivalent value of each crop. The results showed that the total output energy equivalent is estimated to be 256.6 ×1015 J in 1981 and it has increased 669.11 ×1015 J in 2005 and this increase is realized as 261%.

Total output energy is influenced by weather, yield, price and technology. Weather conditions influence output energy level and yield. Output energy increased over the 24 year study period. Output energy level is adversely affected by changes in commodity price in terms of farmer preferences to choose the crop sown for the next growing period. New technologies have also affected energy output. Newly developed seed varieties have increased the yield, but not at desired levels because of the use of old growing systems.

Total output energy pattern in Iranian agronomy for the period 1981-2005 is shown in Fig. 1. Linear regression with a correlation coefficient of R^2=0.957 shows that output food energy the Iranian agronomy has risen by a rate of 31.83(PJ/year).

The growing rate of output energy is due to the increase in cultivated area and an increase in the yield. To analyze the increase in the yield, energy equivalent of the

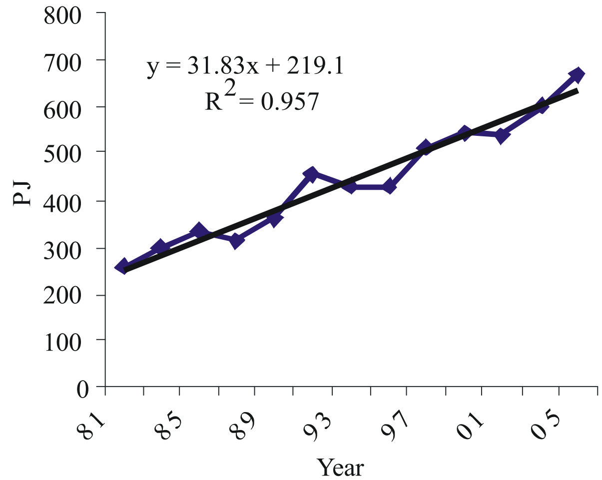

Fig. 1: Total output energy trend in Iranian agronomy for the period 1981-2005

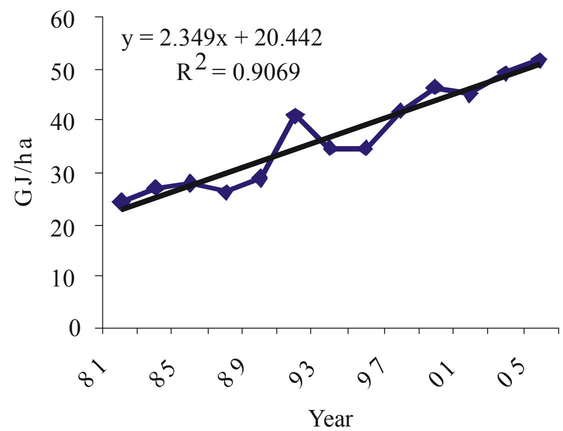

Fig. 2: Average output energy pattern in unit hectare for the period 1981-2005 in Iranian agronomy

products are used, the increasing pattern for the studied period can be seen in Fig. 2. The linear regression of Fig. 2 with R^2=0.907 shows that the average agronomy output energy per hectare has risen by a rate of 2.35 GJ/year.

Average output energy per kilogram of agronomy products between years 1981-2005 has shown no growing or declining pattern. This means in the past 24 years the agricultural policy of Iran has not moved towards more energy efficient products. On average equivalent energy per kilo of agronomy output has been 9.65 MJ/kg for the study period.

The agronomy section of Iran has witnessed a 31.83 PJ/year increase in the output energy but the country has also had a significant rise in population.

Table 5: Comparison analysis of the average output energy per hectare

Crops	Output energy (GJ ha^{-1})	Crops	Output energy (GJ ha^{-1})	Crops	Output energy (GJ ha^{-1})
Sugar cane	394.61a	Rice	57.03de	Cotton	24.71ghi
Clover	141.32b	Soy beans	50.87def	Dry beans	22.97ghi
Sugar beet	138.84b	Onions	43.64efg	Tomatoes	20.52ghi
Alfalfa	125.34b	Water melon	41.26efg	Chickpeas	16.09hi
Maize	84.22c	Wheat	40.88efg	Lentils	15.39hi
Potatoes	70.75cd	Barley	37.73efgh	Cucumbers	14.00hi
Canola	70.63cd	Melon	27.18fgh	Tobacco	0.97i

The means with minimum common letter are not significantly different (P<0.05) according to Duncan's multiple ranges test

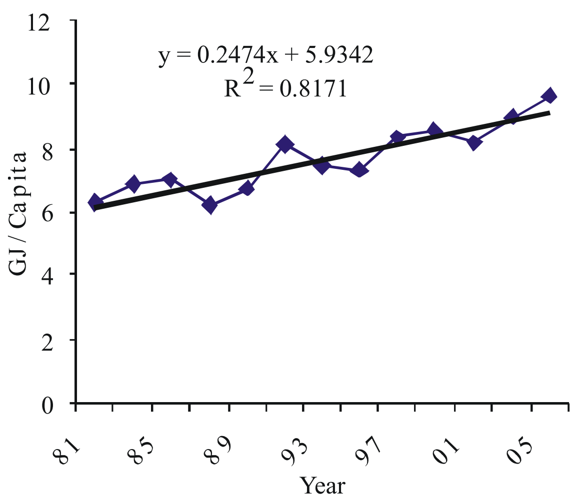

Fig. 3: Output energy pattern per capita in Iranian agronomy for the period 1981-2005

Figure 3 shows the output energy growth per capita. Energy production per capita has grown with R^2=0.82. Taking into consideration the population increase, the agronomy sector has managed to maintain a growing rate of 0.25 GJ/year energy output per capita. In developing countries like Iran, food deficiency is always a threat and a large portion of the average family's income is spent on food product. This has resulted energy deficiency in average population's diet.

Energy output of different products differs and some agronomy products have higher output energy.

Comparative analysis of the average output energy per hectare using Duncan method at 5% significance level is shown in Table 5. This Comparison divides Iran's agronomy products into 8 groups with sugarcane having the highest output energy. Tobacco, cucumber, lentil, tomatoes, beans, and cotton had the lowest output energy respectively.

The government policy to make up for the energy deficiency in agricultural products should move towards a focus on producing crops with higher energy. This can however not be totally implemented due to different factors. For instance environmental factors prevent certain products to be cultivated in different climatic conditions. Furthermore the society's need for a variety of food products does not allow for such a policy to fully implement.

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