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Energy use and economical analysis of potato production in Iran a case study: Ardabil province

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ABSTRACT

The purpose of this study is to determine energy consumption of input and output used in potato production, and making an economical analysis in Ardabil, Iran. For this purpose, the data were collected from 100 potato farms in Ardabil, Iran. Inquiries were conducted in a face-to-face interviewing November–December 2006 period. Farms were selected based on random sampling method. The results indicated that total energy inputs were 81624.96 MJ ha^{-1}. About 40% of this was generated by chemical fertilizers, 20% from diesel oil and machinery. About 82% of the total energy inputs used in potato production was indirect (seeds, fertilizers, manure, chemicals, machinery) and 18% was direct (human labor, diesel). Mean potato yield was about 28453.61 kg ha^{-1}, it obtained under normal conditions on irrigated farming, and taking into account the energy value of the seed, the net energy and energy productivity value was estimated to be 20808.03 MJ ha^{-1} and 0.35, respectively, and the ratio of energy outputs to energy inputs was found to be 1.25. This indicated an intensive use of inputs in potato production not accompanied by increase in the final product. Cost analysis revealed that total cost of production for one hectare of potato production was 3267.17 $. Benefit–cost ratio was calculated as 1.88.

1. Introduction

Potatoes (*Solanum tuberosum* L.) are grown worldwide under a wider range of altitude, latitude, and climatic conditions than any other major food crop—from sea level to over 4000 m elevation. No other crop can match the potato in its production of food energy and food value per unit area [1]. It is also high in Vitamin C, niacin and Vitamin B6. Yet, the potato plant has one of the heaviest production demands for fertilizer inputs of all vegetable crops, i.e., its nitrogen (N), phosphorus (P) and potassium (K) requirements are, respectively, 100, 100 and 33% greater than that required for tomato or pepper plant production [2]. Being a temperate crop, potato growth and yield are highly affected by higher temperature, especially a mean temperature above 17 °C [3]. Tuberization occurs at low temperatures and is delayed or even inhibited at higher temperatures, tubers rarely being formed above 30 °C. As a result, potato is grown in countries where the prevailing mean air temperature is around 15–18 °C during the growing season and rainfall or irrigation provides ample water [4–8]. Recent publications have shown the importance of the potato as a global food crop, ranking fourth among other crops with an overall annual production of nearly 327 million tonnes and about 19 million ha planted. China, Russian Federation, India, United States, Ukraine and Germany are the main potato producer countries. The potato is also cultivated in Poland, Netherlands, France, United Kingdom, Iran, and Canada [9]. Based on FAO statistics [9], Iran, produced about 4,830,120 tonnes of potato in 2005, more than 15% of which is produced in Ardabil province [10]. Potatoes are the single most important agricultural commodity in Ardabil province. In 2005, for example, the crop was planted in 25,503 ha. Potatoes are grown throughout Ardabil, Iran under irrigated conditions [10].

The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bio-energy [11]. Energy use in agriculture has developed in response to increasing populations, limited supply of arable land and desire for an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labor-intensive practices, or both [12]. Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction [13]. Application of integrated production methods are recently considered as a means to reduce production costs, to efficiently use human labor and other inputs and to protect the environment (often in conjunction with high numbers of tourists present in the area). Energy budgets for agricultural production can be used as building blocks for life-cycle assessments that include agricultural products, and can also serve as a first step towards identifying crop production processes that benefit most from increased efficiency [14]. Many

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Nomenclature

N	required sample size	d	precision $(\bar{x} - \overline{X})$
N	number of holdings in target population	z	reliability coefficient (1.96 in the case of 95% reliability)
N_h	number of the population in the h stratification	D^2	d^2/z^2
S_h^2	variance of h stratification		

researchers have studied energy and economic analysis to determine the energy efficiency of plant production, such as sugarcane in Morocco [15], wheat, maize, sugar beet, sunflower, grape, olive, almond, barley, oat, rye, orange, lemon, apple, pear, peach, apricot and plum in Italy [16], rice in Malaysia [17], sweet cherry, citrus, apricot, stake-tomato, cotton, sugar beet, greenhouse vegetable and some field crops and vegetable in turkey [18–24], wheat in Iran [25], soybean, maize and wheat in Italy [26], soybean based production system, potato in India [27,28], maize and sorghum in United States [29], cotton and sunflower in Greece [30,31], winter oilseed rape in Germany [32]. However, no studies have been published on the energy and economical analysis of potato production in Iran.

The aim of the present paper is to study the energy input and output per hectare for the production of potato, and to make a cost analysis in Ardabil, Iran. It also identifies operations where energy savings could be realized by changing applied practices in order to increase the energy ratio, and propose improvements to reduce energy consumption for potato production.

2. Material and methods

The study was carried out in 100 potato producer in Ardabil, Iran. Twelve villages were chosen to represent the whole study area. The province is located in the northwest of Iran, within 34° 04′ and 39° 42′ north latitude and 47° 02′ and 48° 55′ east longitude. The total area of the Ardabil province is 1,795,200 ha, and the farming area is 718,614 ha, with a share of 40.03%. Data were collected from the growers by using a face-to-face questionnaire performed in November–December 2006. The data collected belonged to the production period of 2005–2006. The secondary material used in this study was collected from the previous studies and publications by some institutions like FAO.

Farms were randomly chosen from the villages in the area of study. The size of each sample was determined using Eq. (1) derived from Neyman technique [33].

$$n = \frac{(\sum N_h S_h)}{N^2 D^2 + \sum N_h S_2^h} \quad (1)$$

where n is the required sample size; N is the number of holdings in target population; N_h is the number of the population in the h stratification; S_h is the standard deviation in the h stratification, S_h^2 is the variance of h stratification; d is the precision $(x - X)$; z is the reliability coefficient (1.96 which represents the 95% reliability); $D^2 = d^2/z^2$.

The permissible error in the sample size was defined to be 5% for 95% confidence, and sample size was calculated as 100 farms. For the growth and development, energy demand in agriculture can be divided into direct and indirect, renewable, and non-renewable energies [11]. The energetic efficiency of the agricultural system has been evaluated by the energy ratio between output and input. Human labor, machinery, diesel oil, fertilizer, pesticides and seed amounts and output yield values of potato crops have been used to estimate the energy ratio. Energy equivalents shown in Table 1 were used for estimation. The sources of mechanical energy used on the selected farms included tractors and diesel oil. The mechanical energy was computed on the basis of total fuel consumption (L ha^{-1}) in different operations. Therefore, the energy consumed was calculated using conversion factors (1 L diesel = 56.31 MJ) and expressed in MJ ha^{-1} [30].

Basic information on energy inputs and potato yields were entered into Excel spreadsheets, SPSS 15 spreadsheets. Based on the energy equivalents of the inputs and output (Table 1), the energy ratio (energy use efficiency), energy productivity and the specific energy were calculated [18,26].

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy input (MJ ha}^{-1})} \quad (2)$$

$$\text{Energy productivity} = \frac{\text{Potato output (kg ha}^{-1})}{\text{Energy input (MJ ha}^{-1})} \quad (3)$$

$$\text{Specific energy} = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Potato output (t ha}^{-1})} \quad (4)$$

$$\text{Net energy} = \text{Energy output (MJ ha}^{-1}) - \text{Energy Input (MJ ha}^{-1}) \quad (5)$$

Indirect energy included energy embodied in seeds, fertilizers, manure, chemicals, machinery while direct energy covered human labor and diesel used in the potato production. Non-renewable energy includes diesel, chemical, fertilizers and machinery, and renewable energy consists of human labor, seeds, manure. In the last part of the research, economic analysis of potato production was investigated, and net profit and benefit–cost ratio was calculated. The net return was calculated by subtracting the total cost of production from the gross value of production per hectare. The benefit–cost ratio was calculated by dividing the gross value of production by the total cost of production per hectare [18,19].

Table 1
Energy equivalent of inputs and outputs in agricultural production

Particulars	Unit	Energy equivalent (MJ unit^{-1})	Ref.
A. Inputs			
1. Human labor	h	1.96	[19,21,34]
2. Machinery	h	62.7	[22,34,35]
3. Diesel fuel	L	56.31	[22,34,35]
4. Chemical fertilizers	kg		
(a) Nitrogen (N)		66.14	[12,21,36]
(b) Phosphate (P_2O5)		12.44	[12,21,36]
(c) Potassium (K_2O)		11.15	[12,21,36]
(e) Sulphur (S)		1.12	[12,37]
(d) Zinc (Zn)		8.40	[38,39]
5. Farmyard manure	kg	0.30	[18,19,34]
6. Chemicals	kg	120	[24,27,35]
7. Water for irrigation	m^3	1.02	[40,41]
9. Seeds (potato)	kg	3.6	[42]
B. Outputs			
1. Potato	kg	3.6	[42]

3. Results and discussion

3.1. Socio-economic structures of farms

Average farm size was 5.08 ha and potato production occupied 27.66% of total farm lands. The other vegetables grown besides