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Letter to the Editor

Energy comparison of two rice cultivation systems

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ABSTRACT

The current experiment, conducted in Ramhormoz, Iran, compared the energy consumption of two rice cultivation systems: direct seeded rice and transplanting cultivation systems. In the transplanting system, rice is grown by hand-transplanting thirty-day-old nursery seedlings into standing water in the main field. The direct cultivation system has no nursery or tillage operation. Instead, rice is cultivated in the main field using a cereal seeder. In this study, data was collected from 185 rice producers, 125 of whom used transplanting and 60 of whom used direct seeding as their rice growing system. The results indicated that the energy input of the two cultivation systems was significantly different in the use of diesel fuel, pesticide, electricity, irrigation, human labor, and total energy. Herbicide usage was higher in the direct seeding system than in the transplanting system, but other energy inputs were found to be higher in the transplanting system. The energy output of the transplanting system was higher than that of the direct seeding system. The energy input of the direct seeding system was lower than that of the transplanting system, resulting in a higher energy ratio, which suggests that the direct seeding system would increase energy efficiency and sustainability in rice production.

Contents

1. Introduction

Energy is considered to be fundamental in national development and providing critical services for humans. Per criteria, energy consumption is introduced as a factor for evaluating the social and economical development of a country [18,22]. In developing countries, energy consumption is greatly increased by economical development [8]. Population increase, limited arable lands, and rising living standards result in increased energy inputted into agricultural systems to maximize yield production and minimize cultivation operations carried out with human intervention [24].

The increase of energy consumption is higher in agriculture than in other economical sectors due to mechanized cultivation operations and the utilization of soil nutritive materials, particularly fertilizers [14]. Agricultural fields are, in fact, energy consuming ecosystems, and the amount of energy consumed depends on the level of mechanization [18]. There is concern that in coming years, agriculture will not be able to meet the demands for food of humans and domesticated animals. Additionally, high energy consumption in agriculture will compromise food security for future generations [9]. Thus, the efficient utilization of energy resources is of high importance for sustainable improvement.

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In Ramhormoz, Iran, rice, the third most important crop after wheat and maize, is grown in two different cultivation systems, transplanting and direct seeding systems. In the transplanting system, rice is grown by transplanting seedlings from the nursery into standing water in the main field. High amounts of water loss are expected because of the puddling process, surface evaporation, and percolation and result in high energy consumption for irrigating the rice plants [5]. Transplanting operations are usually performed by human labor. Direct seeded rice has no nursery, and seeds are sown directly into the main field. This cultivation system avoids puddling and maintains continuous moist soil conditions; therefore, the overall water demand is reduced. The direct seeding system is more mechanized than the transplanting system. Admittedly, it has been remarked that productivity is often lower in the direct seeding cultivation system than in the transplanting system [23]. In order to save water and labor and to promote conservation agriculture through energy conservation, the hypothesis that transplanting can be replaced with the direct seeding system needs more investigation.

Finite resources of nonrenewable energies clarify the necessity for optimal energy utilization. Thus, this research was aimed to analyze the energy use and relationship between the energy inputs and outputs of two rice production systems in order to introduce the most energy efficient system.

2. Materials and methods

This research was carried out during the 2011–2012 growing season in Ramhormoz, Iran (46°36′N, 31°16′E, altitude 150 m a.s.l). The soil texture of the experimental site was silt loam. The research field was located in a semi-arid region, where summers are hot and dry and winters are cool and rainy. In order to attain an overview of energy consumption in rice production, the energy consumption of two rice cultivation systems, direct seeding and transplanting, were compared during all cultivation stages. Data was collected from 185 rice producers (125 used transplanting and 60 used direct seeding). The total number of rice producers in the experimental site was 350 (240 transplanters and 110 direct producers). The sample size was determined using Eq. (1) [1]:

$$n = \frac{[Nt^2s^2]}{\left[Nd^2 + t^2s^2\right]} \tag{1}$$

where n is the required sample size, N is the number of rice producers (statistical community), s^2 is the variance of the trait, t is the coefficient of confidence in normal distribution (considered to be 1.96), and d is the difference between actual ratio of the trait in the community and the estimation (0.05 was considered the maximum difference). The collected data were obtained from two sources including farmers and direct observations of fields. The farmers were asked to provide the accurate information about their rice production systems with completing the questionnaires. The type of used machineries, technical specification of machineries including motor capacity and diesel fuel consumption, total land area, planting and harvesting method, crop yield per unit area, irrigation method, irrigation duration, water flow rate, number of workers, the amount of seed, type and amount of fertilizer and pesticides were asked in the questionnaires. During cultivation period, the recent information was checked again with direct views of fields.

Energy consumed by machinery in the field was calculated as follows:

$$EM = \frac{[E \times M \times T]}{N} \tag{2}$$

Table 1
Energy equivalent of input and output of rice production system.

System input	Energy equivalent	Unit	Refs.
Rice seed	14.70	MJ kg^{-1}	[6]
Rice residue	12.50	MJ kg^{-1}	[6]
Machineries	62.50	MJ kg^{-1}	[22]
Diesel fuel	56.30	MJ l^{-1}	[26]
Nitrogen fertilizer (N)	66.14	MJ kg^{-1}	[16]
Phosphorus fertilizer (P_2O_5)	12.44	MJ kg^{-1}	[16]
Potassium fertilizer (K_2O)	11.15	MJ kg^{-1}	[16]
Liquid herbicides	102.00	MJ l^{-1}	[7]
Solid herbicides	120.00	MJ kg^{-1}	[7]
Human labor (men)	1.96	MJ h^{-1}	[1]
Human labor (women)	1.57	MJ h^{-1}	[1]
Electricity	3.6	MJ kw^{-1}	[6]

where EM (MJ ha^{-1}) is energy consumed by machinery, E (MJ kg^{-1}) is energy of machinery (per unit), M (kg) is weight of machinery, T (h ha^{-1}) is time of machinery usage (hour) and N is efficient lifetime of machinery (h).

The mean of fuel consumed by diesel machinery (tractor or combine) per hour was calculated using the following equation [11]:

$$MF = \ddot{E} \qquad a \times P_{pto} \tag{3}$$

in which MF is the mean of the fuel consumed by diesel motor (l ha^{-1}); $\acute{a}$ is the 0.223 l hp-h; P_{pto} is the power of *P.T.O.* used in cultivation operations (hp).

Fuel consumption (l ha^{-1}) was calculated by multiplying Eq. (2) with machinery work time (h ha^{-1}) and, as a result, energy consumption (MJ ha^{-1}) was achieved by multiplying consumed fuel by the energy equivalent of fuel (Table 1).

Crop irrigation resulted in direct and indirect consumption of energy. Indirect consumed energy, known as energy of irrigation, included energy consumed for dam building, production of raw materials, and the production and transportation of all factors relating to crop irrigation. Since the precise calculation of these energy related factors is difficult, 20% of direct energy was considered to be indirect energy.

Energy used for pumping water was considered to be direct energy. The power needed for pumping water was achieved using the equation:

$$P = \frac{[\lambda \times Q \times h]}{1000 \times e_m \times e_p} \tag{4}$$

where P (w) is consumed power, λ (N m^{-3}) is water density, Q (m^3 s^{-1}) is the flow rate of the water pump, h (m) is total dynamic charge, and e_m and e_p are motor and pump efficiency, respectively.

Energy consumption of the water pump (kW ha^{-1}) was calculated by multiplying Eq. (4) by total irrigation time (hour) per hectare and then dividing by one thousand. In order to change the unit of water pump energy consumption into MJ ha^{-1}, it was multiplied by 3.6 (Table 1).

Based on the energy equivalents of input and output (Table 1), energy consumption of the two rice cultivation systems was calculated for the two states of utilization and no utilization of straw using the following equations [12]:

$$\text{Energy ratio} = \frac{\text{energy output}}{\text{energy input}} \tag{5}$$

$$\text{Energy productivity} = \frac{\text{yield produced (rice output)}}{\text{energy input}} \tag{6}$$

$$\text{Net output energy} = \text{energy output} - \text{energy input} \tag{7}$$