Energy 84 (2015) 390–396

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Energy flow analysis for rice production in different geographical regions of Iran

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ARTICLE INFO

Article history:
Received 16 September 2014
Received in revised form
10 January 2015
Accepted 2 March 2015
Available online 31 March 2015

Keywords:
Energy use
Fuel
Chemical fertilizer
Input
Output
Iran

ABSTRACT

Rice (*Oryza sativa* L.) is an important primary crop in Iran. In this study, energy use pattern for rice production was analyzed and compared in different geographical regions, Golestan, Mazandaran and Guilan, northern provinces of Iran. There is a significant difference among the three provinces in respect to input energy and agronomical managements such as crop rotation, transplanting date and land preparation. Data were collected from 50 farmers using a face to face questionnaire-based survey. The data collected belonged to the production period of 2012–2013 with the following results obtained. The energy use efficiency varied from 1.39 for Golestan to 1.67 for Guilan provinces. The research results revealed the main difference between energy consumption in three provinces comes from diesel fuel, chemical fertilizers and electricity. The net energy for paddy production was approximately higher in Guilan (36,927.58 MJ ha^{-1}) than other provinces. Also, the values of energy productivity (kg MJ^{-1}) for Golestan, Mazandaran and Guilan provinces were found to be 0.064, 0.059 and 0.070, respectively. On average 84.70% of total energy input used in rice production was non-renewable, while the contribution of renewable energy was 15.30. The results showed that the total energy input for rice production in Golestan province was 64,158.78 MJ ha^{-1} which was higher than other provinces, due to high energy consumption in diesel fuel style (46.44%).

1. Introduction

In the developing countries, energy consumption has risen rapidly as a result of economic growth and with the introduction of high-yielding varieties and mechanized crop production practices. The relation between agriculture and energy is very close. Agriculture is an energy consumer and energy supplier [4,27].

Energy is one of the important elements in modern agriculture as it heavily depends on fossil and other energy resources. Energy consumption in agriculture has been increasing in response to the limited supply of arable land, increasing population, technological changes, and a desire for higher standards of living [18,34]. Agriculture uses energy directly as fuel or electricity to operate machinery and equipment, to heat or cool buildings, and for lighting on the farm, and indirectly in the fertilizers and chemicals produced off the farm [38].

In recent years, the relationship between agriculture and the environment has changed, and concerns regarding the sustainability of agricultural production systems have come to the fore. This had led to tension between production vs. conservation. Conservation systems are understood as sustainable production systems, while production first oriented practices imply production should take place, without considering the environmental and energetic effects. Conservation practices, however, balance environmental and energetic effects with production [22]. It is important to note the current agricultural production is not sufficient. Due to land limitation and environmental impacts, crop yield increase is the main source of growth in agricultural production. Thus, more agricultural inputs, mainly fertilizer, will be needed in future to increase agricultural production [35].

Many studies have been conducted to determine the energy efficiency in crop production. Eskandari et al. [14] considered the energy consuming process and factors influencing rice production in semi-mechanize and traditional systems in Mazandaran province located in north of Iran. They found irrigation and fertilizer energy use are the most energy consumers in rice production. A research was carried out byIqbal [17] to find the

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http://dx.doi.org/10.1016/j.energy.2015.03.005
0360-5442/

Table 1
Annual average of climatic variables in Golestan, Guilan and Mazandaran provinces, Iran.

Region/Variable	Precipitation (mm)	Temperature (°C)	Sunshine hours (h)	Relative humidity (%)
Golestan (Minoodasht)	450.00	18.55	2422.70	68
Guilan (Talesh)	1040.92	16.28	1571.63	77
Mazandaran (Babol)	653.40	17.40	1898.80	78

energy inputs requirement for production of rice in different categories of farms in Bangladesh. The results indicated small farms (0.61–1.00 ha) had the highest energy use efficiency in comparison with other groups. In another study [26], determined energy use efficiency by paddy crop DEA[1] technique in India. Their results disclosed that small farmers had high energy –ratio and low specific energy requirement as compared to larger ones at paddy farms. Ren et al. [33] reported that nitrogen fertilization contributed the highest proportions to the total energy consumption, as compared with the seed, labor, machinery, diesel fuel, phosphorus and potassium fertilizers, irrigation water, plastic film, and pesticides in sweet sorghum production as a bioenergy crop on coastal saline-allkine site in Sandong province, China. Results of Šarauskis et al. [37] showed that reduced tillage technology reduced working time, fuel consumption and CO_2 emission in maize cultivation. Kuswardhani et al. [20] by a case study in Indonesia found that the ratio of output to input energy was higher in greenhouse production than open field vegetable production for tomato, chili medium land and chili highland, but output–input ratio of lettuce open field production was twice as that of greenhouse vegetable production.

Rice (*Oryza sativa* L.) is an important primary crop in the world. About 3 billion people, nearly half of world's population, depend on rice for survival. In Asia as a whole, much of the population consumes rice in every meal. In many countries, rice accounts for more than 70% of human caloric intake [29,41]. Rice is an important annual crop in Iran. Based on ministry of Jihad-e- Agriculture of Iran statistics, Iran produced about 2.7 million tones of rice in 2011. Guilan, Mazandaran, and Golestan provinces are the main canters of rice cultivation in north of Iran; about 78.4% from total of paddy production in Iran is provided from these provinces [21]. However, few studies have been published on the energy analysis of paddy production in Iran [1,14,29]. An important aspect of this investigation was the comparison of energy use efficiency of paddy production in different regions of Iran. Therefore, this study was undertaken with the following objectives: to examine the quantity of energy used for rice production in three main provinces of rice production in north of Iran, and the comparison of energy use pattern in these regions.

2. Material and methods

2.1. Site details

The study was carried out in the north of Iran, Golestan (Minoodasht township), Mazandaran (Babol township) and Guilan (Talesh township) provinces. These regions are not the same, in terms of the precipitation rate, temperature, sunshine hours and relative humidity (Table 1). The soil properties of the three regions were display in Table 2. Golestan province is located within 36° 30′ and 38° 08′ Lat. N, 53° 57′ and 56° 22′ Lon. E. In this region, rice is sown in the spring and summer during the months of June and July. The crop is harvested during September and October, after which a canola crop is sown as the second crop in rotation cropping system.

[1] Data Envelopment Analysis (DEA).

Mazandaran province is located between 35° 46′ and 36° 58′ Lat. N and between 50° 21′ and 54° 08′ Lon. Guilan province is also located in the south of the Caspian see, within 36° 34′ and 38° 27′ Lat. N and 48° 53′ and 50° 34′ Lon. E. In two later provinces, rice is sown in the spring and summer during the months of May and July. This crop is harvested during August and October, after which canola or faba bean are sown as the second crop in rotation cropping system. Wheat, barley, soybean, maize, and dry bean are other crops grown in the regions.

2.2. Energy analysis

Data were collected from farmers using a face to face questionnaire performed and statistical yearbooks [21] in Feb and Aug 2013. In this study, 50 farms were selected randomly. The average size of the studied fields has been found to amount to 2 ha. All data detail information of the questionnaire were averaged and arranged. First, all inputs and outputs for rice production were determined, quantified and entered into Microsoft Excel spreadsheets (var. 2007), and then transformed into energy units and expressed in MJha^{-1}.

The energetic efficiency of the agricultural system has been evaluated by the energy ratio between output and input. Human labor, machinery, diesel fuel, chemical fertilizers, chemicals and seed amounts and output yield values of rice crop have been used to estimate the energy ratio. Energy equivalents shown in Table 3 were used to estimate the input and output energy. The quantity of inputs in three provinces is demonstrated in Table 4. The sources of mechanical energy used on the selected farms included tractor, power tiller and this included energy for manufacturing, for repairs and maintenance and energy for transportation. The diesel energy was computed on the basis of total fuel consumption (L ha^{-1}) in different operations such as land preparation, nursery preparation and irrigation. Based on the total energy equivalents of the inputs and output (Table 3), the energy use efficiency (energy ratio), net energy, energy productivity and specific energy were calculated using following equations (1)–(4) [11,39,45]:

$$\text{Energy use efficiency} = \text{Energy Output (MJ ha}^{-1}\text{)/Energy Input (MJ ha}^{-1}\text{)} \quad (1)$$

$$\text{Net energy} = \text{Energy Output (MJ ha}^{-1}\text{)} - \text{Energy Input (MJ ha}^{-1}\text{)} \quad (2)$$

$$\text{Energy productivity} = \text{Grain output (kg ha}^{-1}\text{)/Energy Input (MJ ha}^{-1}\text{)} \quad (3)$$

$$\text{Specific energy} = \text{Energy Input (MJ ha}^{-1}\text{)/Grain output (kg ha}^{-1}\text{)} \quad (4)$$

The energy output for each region was obtained by multiplying grain and straw yields by their energy equivalents. Energy contents of 14.7 MJ ha^{-1} for paddy rice and 12.5 MJ ha^{-1} for straw were used (Table 3). The direct energy input is the energy consumption of physical energy resources for physical work during field operations. Field operations consume significant amounts of energy in agricultural production, with most being fuel usage [7]. The input energy was divided into direct, indirect, renewable and non-