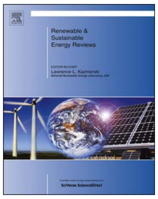
Renewable and Sustainable Energy Reviews 70 (2017) 836–844

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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



Trends in the economic return on energy use and energy use efficiency in China's crop production

Shen Yuan, Shaobing Peng*

National Key Laboratory of Crop Genetic Improvement, MOA Key Laboratory of Crop Ecophysiology and Farming System in the Middle Reaches of the Yangtze River, College of Plant Science and Technology, Huazhong Agricultural University, Wuhan, Hubei 430070, China

ARTICLE INFO

Keywords:
China
Crop production
Economic return on energy use
Energy use efficiency

ABSTRACT

This study examines trends in energy input and output in China's crop production. Trends are also observed in energy use efficiency and economic return on energy use from 1991 to 2012. The results indicate that energy input increased from 3647.1 PJ to 7919.5 PJ and energy output increased from 7222.0 PJ to 10954.0 PJ between 1991 and 2012. Given the growth in the sowing area, energy input and output per unit of area sown also increased during this period. Energy use efficiency was estimated at 1.98 in 1991 and 1.38 in 2012, with an average annual decrease of 1.69%. The economic return on crop production in China increased from 1991 to 2012 whereas agricultural labor input decreased; consequently, the economic return on energy use, sowing area, and labor all increased stably. Given a larger growth rate and higher production of high-value and low-energy crops when compared with low-value and high-energy crops, an increase in the economic return on energy use occurred but so did a decline in energy use efficiency. This phenomenon indicates the need to increase investments in technological development and technological innovation, adopt new policies to optimize China's crop production structure, and establish sustainable production systems.

1. Introduction

Crop production depends on energy inputs, and the efficient use of resources is a key part of efficient and sustainable production [1]. Recently, however, energy use in agriculture has been increasing in response to a growing population, limited supply of arable land, and desire for higher standards of living [2]. Continuous demand for increasing food production has resulted in intensive use of diesel, electricity, human labor, farm machinery, fertilizers, pesticides, and agricultural plastics-based energy resources in both developed and developing countries [3].

In transitioning countries such as China, agricultural growth is essential for promoting economic development and meeting the ever-growing demands of a growing population. Indeed, China must feed 20% of the global population using approximately 5% of the planet's water resources and 7% of its arable land [4]. Thus, China has spared no effort in pursuing national food security as a means of advancing economic development and maintaining social stability. Consequently, the output of grain increased from 277.1 million tons (MT) in 1978 to 552.7 MT in 2013; the output of beans increased from 12.5 MT in 1991 to 16.0 MT in 2013; tuber crop production increased from 9.8 MT in 1949 to 33.3 MT in 2013; cotton production climbed from 0.4 MT in 1949 to 6.3 MT in 2013; oilseed production increased from 2.6 MT in 1949 to 35.2 MT in 2013; sugar beet output increased from 2.9 MT in 1949 to 137.5 MT in 2013; tea production increased from 0.3 MT in 1978 to 1.9 MT in 2013; tobacco production increased from 0.5 MT in 1970 to 3.4 MT in 2013; vegetable production climbed from 204.1 MT in 1991 to 735.1 MT in 2013; and fruit output increased from 21.8 MT in 1991 to 250.9 MT in 2013 [5–7]. Meanwhile, during the period 1978–2012, the nominal economic return on crop production increased at an average annual growth rate of 9.3%, whereas the real economic return (REcR) (based on 1978 constant prices) on crop production increased at an average annual growth rate of 3.9% [8]. This marked achievement can largely be attributed to growth in agronomic inputs, namely, the use of chemical fertilizers, electricity, and total agricultural machinery power, which increased by factors of 5.68, 32.33, and 7.82, respectively, from 1978 to 2013. Meanwhile, the consumption of diesel, pesticides, and agricultural plastic film increased by factors of 1.43, 1.36, and 2.83, respectively, from 1991 to 2012 [5,7,8]. However, intensive energy input can harm public health and the environment. For example, overuse of chemical fertilizers often results in decreased economic return on crop production [9], significant acidification of major croplands [10], greenhouse gas emissions [11], and damage to water quality and aquatic ecosystems [12].

---

* Corresponding author.
E-mail address: speng@mail.hzau.edu.cn (S. Peng).

http://dx.doi.org/10.1016/j.rser.2016.11.264
Received 10 June 2015; Received in revised form 14 May 2016; Accepted 29 November 2016

Energy input in agriculture is very intensive and directly and indirectly uses large quantities of energy. Therefore, the availability of natural resources has rapidly decreased, whereas the level of contamination has increased. Energy input has been discussed given its effect on carbon emissions [13–15], biological diversity [16,17], and human health [18,19]. The best way to lessen the environmental threat posed by energy use is to increase energy use efficiency (EUE). The efficient use of energy in agriculture helps increase production and productivity, provides financial savings, minimizes negative environmental impacts, helps protect natural resources, and promotes the sustainable development of agricultural ecosystems [20,21]. Agriculture and energy have very close relationship: agriculture both produces and consumes energy, and agriculture and energy use are complementary and mutually affect one another [22,23].

Energy analysis of agricultural production systems is a promising approach to study and investigate trends in energy input, EUE, and long-term sustainability [24,25]. In recent decades, China has made remarkable strides toward increasing crop production and enhancing food security. Furthermore, the Chinese government has introduced a series of polices to adjust its crop production. From 1985 to 1998, the Chinese government attempted to promote the marketing of agricultural products [26]. Subsequently, the central government withdrew from managing national cereal production and storage from 1999 to 2003 [27] and started to encourage crop production by introducing the first nationwide direct subsidies for farmers in 2004, including subsidized seed and machinery purchases, and increased spending on rural infrastructure. The policy was very important in reducing agricultural production costs, increasing food farmers' income and promoting food production [28]. Another visible measure was the elimination of agricultural taxes in 2006 [29], China has had an agricultural tax throughout its recorded history. Typically, Chinese farmers were assessed an agricultural tax on the basis of each family's allotted land area and historical average price and yield before 2006 [30]. Patterns and trends in crop production were studied within particular social and economic environments; however, given the availability and quality of the statistical data and the level of concern for yields as opposed to energy, no study has yet evaluated patterns and trends in energy input, energy output, and EUE in China's agriculture sector from 1991 to 2012.

Many studies have undertaken an energy and economic analysis to examine energy output-input relationships and to investigate the processes involved with production of certain crops, such as wheat, cotton, beans, and potatoes in India [31–33], wheat, maize, and beans in Italy [34], rice and wheat in Bangladesh [35–37], cotton, sugar beet, and apricots in Turkey [38–40], and rice in Iran [41], the Philippines [42], and China [43]. In addition, several studies have focused on EUE in crop production systems in India [20,44], Turkey [45], and Greece [46].

As such, this study aims to investigate the interactions among energy input, energy output, EUE, and economic output in China's crop production system. Using a series of indicators, we seek to reveal the relationships between them and to: (1) analyze levels and trends in energy input and output in China's crop production system from 1991 to 2012; (2) identify the trend in economic return on energy use within this system in the study period; and (3) evaluate trends in EUE, energy productivity (EP), and net energy(NE) in China's crop production.

2. Materials and methods

2.1. Data

The analysis focuses on calculating the amount of inputs used for the production of agricultural crops and crop yields per year from 1991 to 2012. The investigation starts in 1991 with the availability of national-level data on input amounts. The data used were obtained from the China Statistical Yearbook [47], the China Agricultural Yearbook [5], the China Agriculture Statistical Report [6], the New China's agricultural statistics for 60 years [7], and the databases of National Bureau of Statistics (NBS) [8] and Ministry of Agriculture (MOA) [48]. The study also benefited from previous research and studies on energy analysis in agriculture.

2.2. Data analysis methods

The energy input in crop production system was divided into direct and indirect energy [49]. Direct energy includes diesel, electricity, and human labor [50], whereas indirect energy consists of the energy embedded in the manufacturing processes for farm machinery, fertilizers, pesticides, and agricultural plastic film [51]. Energy requirements in agriculture could also be divided into two groups, renewable and nonrenewable. In terms of the renewability of electricity, the electricity used in China's crop production mainly comes from hydroelectric and thermal sources. The shares of hydroelectricity and thermal electricity in electricity production were 20% and 80%, respectively, during the study period [47]. Nonrenewable energy includes diesel, thermal electricity, and energy consumed to manufacture farm machinery, fertilizers, pesticides, and agricultural plastic film, whereas renewable energy consists of human labor and hydroelectricity [52]. Energy output is calculated from statistics on the total production of cereals, beans, tubers, cotton, oilseeds, sugar beet, tea, hemp, tobacco, vegetables, and fruits (including all major crops grown in China). To calculate energy input, output and other energy indicators, the data were converted into energy input and output levels using equivalent energy values for each commodity. Table 1 provides the energy equivalents for inputs and outputs.

2.3. Key indicators

Energy systems drive the development of crop production systems, and crop production can also provide raw materials for energy production. Thus, many researchers have explored the relationship between the energy system and the crop production system [45], with some indicators adopted to investigate the relationship. These indicators serve two different purposes: structural indicators aim at clarifying the management and conversion of inputs into outputs for a given crop or cropping system, and efficiency indicators aim at evaluating the

Table 1
Energy equivalents for different inputs and outputs in crop production.

Item	Unit	Energy equivalent MJ Unit^{-1}	Reference
Inputs			
Nitrogen (N)	kg	66.14	[70,71]
Phosphorus (P_2O_5)	kg	12.44	[70,71]
Potassium (K_2O)	kg	11.15	[72]
Compound fertilizer	kg	12.83	[73]
Human labor	h	2.20	[73]
Diesel	L	56.31	[74,75]
Pesticide	kg	303.80	[76]
Electricity	kWh	3.60	[77]
Plastic film	kg	79.00	[78]
Machinery	kW	4.93	[73]
Outputs			
Cereals and pulses	kg	14.70	[45]
Oilseed	kg	25.00	[45]
Sugar beet	kg	5.04	[45]
Beans	kg	14.70	[79]
Tubers	kg	3.60	[45]
Cotton	kg	11.80	[45]
Vegetables	kg	0.80	[45]
Fruits	kg	1.90	[45]
Tobacco	kg	0.80	[45]
Hemp	kg	18.50	[80]
Tea	kg	0.80	[45]