An Analysis of Current Energy Consumption in China's Agricultural Production

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Abstract Energy consumption is one of the important symbols of modern agriculture, and it is also an important input in modern agricultural production. The study on the agricultural energy consumption not only has a positive significance to agricultural energy saving, emission reduction and ecological environment protection, but also can greatly reduce the cost of agricultural production and improve the economic benefit of farmers. Through the analysis of the national statistical data about energy consumption for agriculture production from 2005 to 2012 year, the results show that the amount of energy consumption for agricultural production in China has increased year by year since 2005. Because of the continued growth of the total energy consumption in China, the proportion of energy consumption for agricultural production to the total energy consumption of China has declined slightly since 2005. At present, the energy consumption structure for agricultural production in China is diesel fuel, coal, electric power, gasoline, and indirect energy consumption. With the rapid development of the agricultural technology in recent years, the total agricultural output value in China has increased greatly, the direct and indirect agricultural energy consumption per unit of agricultural output value in China has decreased year by year, and the efficiency of energy consumption for agricultural production has increased consequently.

Key words Agricultural production, Energy consumption, Current situation, Analysis

1 Introduction

With the rapid growth of the world population and people's increasing living standards, improving food production on dwindling arable land has become a common challenge for the world agriculture[1-2]. Due to increased mechanization and widespread use of pesticides and fertilizers, agricultural production has been greatly developed, and food production has been also greatly improved. Modern agriculture has thus become the main measure to ease global food supply pressure and eradicate famine, contributing to the first boom of modern agriculture on a global scale in human history from developed to developing countries[3]. However, with increasing depletion of global oil resources, soaring oil prices and prominent environmental protection and climate change issues, it is increasingly recognized that the intensive agriculture featured by high investment and high energy consumption not only exacerbates the world's energy crisis, but also leads to lack of natural resources, environmental pollution and ecological imbalance[4]. China is a large agricultural country with 7% of the world's land to feed 20% of the world's population, and China's agriculture has made remarkable achievements over the past decades. According to *China Statistical Yearbook*[5], China's grain output increased from 430.67 million t in 2003 to 589.57 million t in 2012, an increase of 36.9%. What gives no cause for optimism is the excessive dependence of grain yield on chemical fertilizers, pesticides, plastic sheeting and other production inputs which not only consume large quantities of fossil fuels but also bring serious pollution of soil and groundwater[6]. Through 20 years of rapid economic development, energy shortage and environmental pollution have increasingly become the major factors restricting China's economic development and people's living standards improvement, agricultural non-point source pollution has become the main reason for China's environmental pollution[7]. Currently, the energy consumption and environmental protection issues in agricultural production have captured more and more attention of domestic and foreign researchers. Peng Ke *et al.* used the final consumption of coal, oil and electricity for agricultural production in China's 30 provinces (autonomous regions and municipalities) during 2000 - 2008, to calculate the standard amount of annual average agricultural production energy consumption in major provinces, and employ fixed effects model to find that the main factors influencing energy consumption in agricultural production are agricultural economic growth, number of agricultural workers, mechanization level and spending habits in the past[8]. Zhu Lizhi *et al.* predicted that 2010 - 2020 will be a stage of substantial increase in agricultural production energy consumption in China, and China's energy consumption in agricultural production will still show unreasonable structure in a long time[9]. These studies described the current situation and trend of energy consumption in agricultural production, but they lacked a further analysis on sources and classification of energy consumption in agricultural production, energy consumption structure and consumption efficiency. In this paper, we firstly expounded the sources and classification of energy consumption in agricultural production, then analyzed the current situation and characteristics of energy consumption in agricultural production in China during 2005 - 2012, and finally discussed the China's agricultural energy consumption structure and consumption efficiency.

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2 Energy consumption in China's agricultural production

The energy consumption in agricultural production is the consumption of energy for farming, forestry, animal husbandry and fishery activities related to agricultural production[9], which can be divided into two categories, direct energy consumption and indirect energy consumption. The direct energy consumption, occurring within the farm, is the energy consumption in direct relation to agricultural production. The indirect energy consumption, occurring outside the farm, is the energy consumption with no direct relation with agricultural production, and it is mainly the energy consumption for the production of chemical fertilizers and pesticides[10]. Table 1 lists the direct and indirect energy consumption in the major agricultural production process. Compared with industry, transport, commerce and other energy-consuming industries, agriculture has lower energy consumption. For example, the agro-energy consumption in United States accounted for less than 2% of national total energy consumption during 2001 – 2011. The estimated 1.5 quadrillion Btu of total energy was used by the United States agricultural sector in 2011, with direct energy consumption accounting for 63% and indirect energy consumption accounting for 37%[11]. Thus, the energy consumption in agricultural production has not a great impact on national total energy consumption, but energy consumption is one of the major inputs to agricultural production, having an enormous impact on agricultural production efficiency. According to the agricultural production costs estimation report released by USDA in 2011[12], for the four major crops in the United States (except soybeans), the energy consumption for the production of corn, wheat and cotton accounted for 22% to 27% of total agricultural production costs; the energy consumption for the production of soybeans only accounted for 14% of total production costs; the energy consumption for the production of rice, barley and peanuts accounted for 29% to 30%. Thus, it can be found that the study of agricultural energy-saving technologies can not only promote energy conservation and environmental protection in agriculture, but also greatly reduce crop production costs and improve farmers' economic benefits.

Table 1 Different energy consumed by the main activities of agricultural production

Category	Agricultural production activities	Main energy consumption
Direct energy consumption	Tractor operation in the field	diesel fuel
	Field transport, such as large trucks and vans	diesel fuel, gasoline
	Farm machinery and agricultural processing machinery, such as irrigation, plant protection, heating and grinding equipments; agricultural facilities and breeding facilities, such as greenhouses, barn temperature regulators and incubators.	diesel fuel, gasoline, electricity, natural gas, coal
	Farm management, such as lights and electric appliances	Electricity
Indirect energy consumption	Fertilizer production	Natural gas, coal, oil
	Pesticide production	Natural gas, oil

3 Current situation of energy consumption in agricultural production in China

At present, the survey and calculation methods vary for the energy consumption of China's primary, secondary and tertiary industries. The energy consumption of agriculture is calculated based on the consumption of related energy types in *Intermediate Consumption of Farming*, *Forestry*, *Animal Husbandry and Fishery* of National Bureau of Statistics, and it is mainly the energy consumption of goods and services in the farming, forestry, animal husbandry and fishery production process, including energy consumption of fuel, electricity consumption and production services as well as energy consumption of fertilizers, pesticides and other agricultural materials[13]. Fuel is calculated by the product of average consumption quota of mechanical fuel and the number of mechanical operations; electricity consumption for agricultural production is obtained from the agricultural electricity consumption data of power supply branch; energy consumption of production services is obtained from the survey data on rural households; the indirect energy consumption of chemical fertilizers and pesticides for agricultural production is obtained from the company statistics[14]. We can get the total energy consumption in agricultural production in China from *China Energy Statistical Yearbook*. In addition, we can also get the consumption of primary fuel and electricity as direct energy. The difference between total energy consumption in agricultural production and consumption of fuel and electricity can be seen as indirect energy consumption in agricultural production. The energy consumption in agricultural production in China during 2005 – 2012 is shown in Table 2[15]. As can be seen from Table 2, during 2005 – 2012, China's energy consumption in agricultural production increased year by year, from 60.711 million tce in 2005 to 67.844 million tce in 2012, an increase of 11.7%. From Table 2 and Fig. 1, it can be also found that since the growth rate of China's total energy consumption was higher than that of energy consumption in agricultural production, the proportion of energy consumption in agricultural production to total energy consumption declined slightly from 2.6% in 2005 to 1.9% in 2012.

From the energy consumption structure, the major energy consumed for China's agricultural production includes indirect energy, diesel fuel, electricity, coal and gasoline. As can be seen from Fig. 2, during 2005 – 2012, the consumption of coal, electricity and indirect energy for China's agricultural production increased year by year; the consumption of diesel fuel first declined and then increased after 2008; the consumption of gasoline was less volatile. In 2012, the total energy consumption in agricultural

production was 67.844 million tce, and the consumption of diesel fuel and indirect energy had the greatest proportion, accounting for 29% of total energy consumption in agricultural production; the consumption of coal and electricity accounted for 19% and 18%, respectively; the consumption of gasoline accounted for only 4%; the consumption of charred coal, kerosene and other fuels accounts for only 1% (Fig. 3). From the efficiency of energy consumption in agricultural production, with the improvement of agricultural production technology, the total agricultural output value in China was also rising, having a great impact on the efficiency of energy consumption in China's agricultural production. According to *China Statistical Yearbook*[5], the total agricultural output value increased from 3.94509 trillion yuan in 2005 to 8.9453 trillion yuan in 2012, an increase of 127%; the direct and indirect energy consumption per unit of agricultural output value in 2005 was 10670.3 and 4718.6 tce/billion yuan, respectively, but it decreased to 5361.6 and 2222.7 tce/billion yuan in 2012, respectively, suggesting that the direct and indirect energy consumption per unit of agricultural output value in 2005 was 2.0 and 2.1 times that in 2012, respectively. It can be seen from Fig. 4 that the direct and indirect energy consumption per unit of agricultural output value decreased year by year during 2005 – 2012, indicating that the efficiency of agricultural energy consumption was increased annually.

Table 2 Energy consumption for agricultural production in China during 2005 – 2012 **Unit: 10^6 t of standard coal equivalent (tce)**

Year	National total energy consumption	Total energy consumption in agricultural production	Raw coal	Gasoline	Diesel	Other fuels	Electric power	Indirect energy consumption
2005	2359.967	60.711	10.813	2.348	18.743	0.650	9.541	18.615
2006	2386.763	63.307	10.733	2.468	19.897	0.574	10.164	19.470
2007	2805.079	62.284	10.854	2.542	17.762	0.584	10.802	19.739
2008	2914.483	60.131	10.876	2.361	16.012	0.556	10.902	19.425
2008	3066.472	62.512	11.301	2.473	16.526	0.459	11.551	20.202
2010	3249.392	64.773	12.222	2.488	17.583	0.484	12.001	19.994
2011	3480.017	67.586	12.548	2.737	18.533	0.565	12.449	20.754
2012	3617.320	67.844	12.615	2.838	19.460	0.604	12.444	19.883

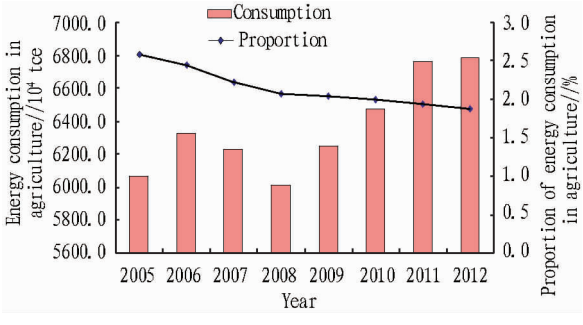

Fig. 1 Energy consumption in China's agricultural production and its proportion during 2005 – 2012

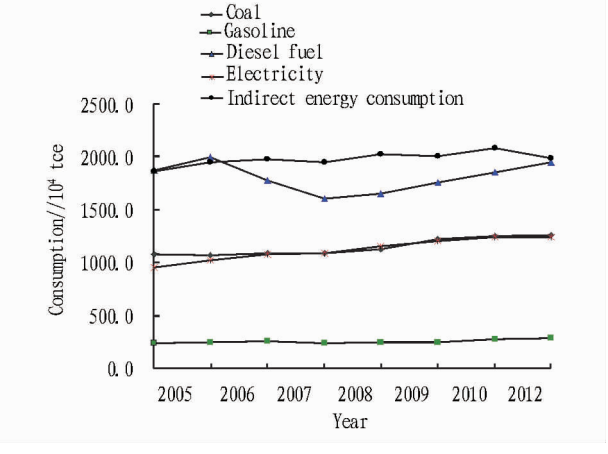

Fig. 2 The consumption of major energy in China's agricultural production during 2005 – 2012

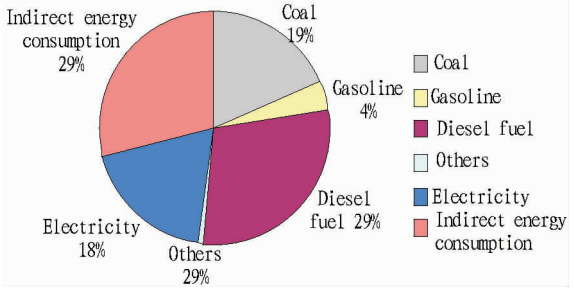

Fig. 3 The structure of energy consumption in China's agricultural production in 2012

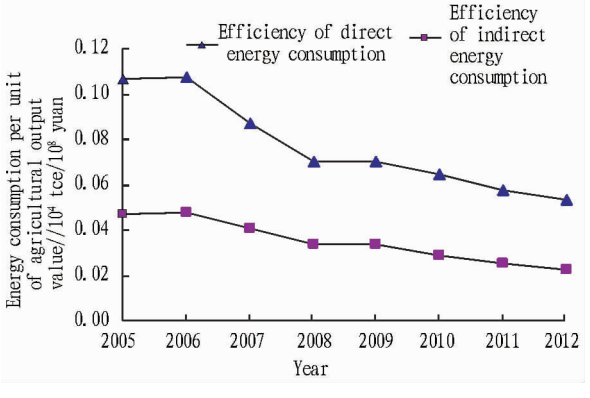

Fig. 4 The efficiency of agricultural energy consumption in China during 2005 – 2012

4 Conclusions

(i) The energy consumption in China's agricultural production is

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clear and there is no pertinent subsidy standard. Commonly used electricity is alternating current, while photovoltaic power generation is direct current. Most agricultural machines use alternating current. Thus, it is necessary to transform current agricultural machinery. This is a difficult problem. Besides, the construction cost is high and payback period is long, so it is not suitable for small scale operation. Due to transparency, the requirement for plants is high and it is still to be further studied on application of light loving plants. At present, the construction of photovoltaic agriculture is still in the period of beautiful planning and small area pilot. There are many problems to be solved by government and scientific researchers.

Photovoltaic agriculture is a huge industry chain and it needs joint effort and cooperation of industry, schools and research institutions. In view of setback in foreign market, it is recommended to actively popularize application of photovoltaic products in agricultural fields, exploit domestic market, improve environmental quality using photovoltaic technology, and make the masses obtain benefit. As to photovoltaic agriculture, China should take it as an integral part of agricultural modernization, as a mark of realizing beautiful China and beautiful countryside, organize multi-disciplinary scientists to solve technical problems in connection of photovoltaic and traditional agricultural facilities and devices, improve solar cell performance, reduce costs, and study adaptation of crops to photovoltaic facilities. Besides, government should encourage photovoltaic enterprises to research and develop, and produce photovoltaic agricultural facilities and products, and increase financial subsidies standing at the height of saving energy and protecting environment. As a large agricultural country, combination of photovoltaic agriculture and ecological civilization construction has become a completely new model of modern agriculture. Photovoltaic agriculture is an engine for solving long term problem of modern agricultural development, inevitable choice for further developing rural economy and improving people's livelihood, and also the trend of transformation of agricultural production mode.

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divided into direct and indirect consumption. The direct energy for consumption mainly includes diesel fuel, electricity, coal and gasoline, while the main indirect energy for consumption is natural gas. (ii) During 2005 -2012, China's energy consumption in agricultural production increased year by year, from 60.711 million tce in 2005 to 67.844 million tce in 2012, an increase of 11.7%. (iii) In terms of energy consumption structure, the main energy consumed for China's agricultural production includes fertilizers and pesticides, diesel fuel, electricity, coal, and gasoline. (iv) The direct and indirect energy consumption per unit of agricultural output value decreased year by year during 2005 -2012, indicating that the efficiency of agricultural energy consumption was increased annually.

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