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Experience and Ways of Low-carbon Agriculture Development

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Abstract Firstly, the status quo of low-carbon agriculture development in China was analyzed, and then advanced experience of developed countries in low-carbon agriculture development was introduced, finally ways of developing low-carbon agriculture in China were put forward.

Key words Low-carbon agriculture, Greenhouse gas, Climate change

Agricultural production is closely related to global climate change, and agriculture is the second biggest source of greenhouse gases. Low-carbon agriculture plays an important role in slowing down and adapting climate change, so developing low-carbon agriculture has become an urgent priority. Low-carbon agriculture means to popularize energy-saving and emission-reduction technology and develop biomass energy in agriculture, so as to maintain global ecological security and improve global climatic conditions, and it is a new kind of agriculture with new characteristics of "low energy consumption, low emissions and low pollution" and multiple functions of "agricultural production, safety esurience, climate adjustment, ecological conservation and rural finance". As rapid growth of economy, excessive increase of population and so-called "modernization" of human mode of production and lifestyle, more and more CO₂ and other greenhouse gases have been discharged into the atmosphere, so that greenhouse effect has become increasingly serious and led to global warming and depletion of energy resources all over the world. Moreover, agriculture is the main source of greenhouse gases. It is estimated that CH₄ and N₂O discharged by agriculture in quantity account for 50% and 60% of their total emissions related to human activity. If effective measures are not adopted, their emissions will increase by 60% and 35%–60% compared with those in 2005^[1]. Therefore, slowing down greenhouse gases from agriculture is important to control of global climate change, so low-carbon agriculture emerges at a historic moment.

1 Status quo of low-carbon development in China

Practice activities about low-carbon agriculture are very active in each region of China, and many models have been developed. Meanwhile, rich experience has been accumulated. In April 2009, Asia-Pacific Environmental Protection Association awarded Asia-Pacific (International) Low-carbon Agriculture Award to He-

heng Village, Shengao Town, Jiangyan City. For along time, Henghe Village has insisted on developing green economy, low-carbon agriculture, rural ecological tourism and conduct production and processing according to green industry standards, and representative agricultural products, like "Heheng" rice, "Santai" pickle, "Ruchun" egg and so forth, are highly praised by consumers.

1.1 Ecological agriculture In the 1980s, agricultural ecological environment and production conditions had worsened gradually, so Ministry of Agriculture put forward the general idea of ecological agricultural development and built a series of eco-agricultural pilot projects. To develop ecological agriculture, 51 pilot counties were built in 1993 and obtained obvious economic, environmental and social benefits. The 51 pilot counties' GDP, total output value of agriculture and per capita net income of farmers increased by 2.2%, 0.6% and 1.5% every year compared with the national average in the same period; 73.4% and 60.5% of soil suffering erosion and desertification were controlled; forest coverage improved by 3.7%; comprehensive production capacity of agriculture enhanced greatly^[2].

Ecological agriculture is the major mode of low-carbon agriculture in China. Ministry of Agriculture collected and chosen ecological agricultural modes in 2002, and began to popularize ten typical ecological agricultural modes and supporting technology in 2003, which has played good exemplary roles in low-carbon development. As the development of ecological agriculture, pollution-free and green agriculture have developed. Up to August 2007, there were 28 600 pollution-free agricultural products and 24 600 accredited regions producing pollution-free agricultural products in China with an area of 2 107 hm²; 5 315 enterprises had the right to use symbol of green food and produced 14 339 products with total weight of 72 million tons, and there were 10 million hm² of accredited regions producing green food; there were 539 national standard agricultural demonstration districts, 100 standard agricultural demonstration counties (farms), and about 3 500 provincial standard agricultural demonstration districts, with a planting area of above 33.33 million hm²^[3]. At the end of 2010, 6 391 enterprises used symbol of green food effectively and produced 16 748 products, which increased by 5.1% and 4.4% compared with

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2009. Moreover, 99.2% of tested green products met the national standard. In 2010, annual sales of green products in China reached 282.38 billion yuan, and the exports totaled 2.31 billion dollars. The area of monitored regions producing green food reached 16 million hm^2 ^[4].

1.2 Organic agriculture Different from ecological agriculture, organic agriculture needs to be certified by the third party strictly and has a strict standard system, which lays the foundations for market premium of organic agricultural products. In recent years, with the continuous increase in the demand of consumers for health and environmental protection, the requirement for organic products has risen obviously, and more and more organic products have been produced and consumed. At the end of 2011, China had issued 9 337 certificates about organic product certification, and two million hm^2 of land producing organic products had been certified^[5]. However, China had paid more attention to production of organic rice, coarse cereals, vegetable and other primary products, so it is difficult to meet diversified demands of the market. As the continuous enhancement of people's food safety and environmental protection awareness as well as their increase of diversified demands, Chinese organic agriculture will develop rapidly; products will be diversified, and proportion of livestock and aquatic products will increase; production of organic agriculture in China will rank first in the world in next ten years^[6].

2 Advanced experience of developing low-carbon agriculture in developed countries

With global warming and depletion of energy resources, western developed countries have put forward a strategy to develop low-carbon agriculture, which is the key to the new round of industry, technological and economic growth competition in the world. Advanced technology, management measures, systematic methods and strategies of developed countries can promote implementation of strategies to develop low-carbon agriculture in China to reduce greenhouse gases discharged from agriculture in quantity.

2.1 Innovating cropping system and conducting farmland management In Canada, emissions of greenhouse gases have decreased obviously after its cropping system was reformed. Protective farming measures adopted by some regions can reduce emissions of greenhouse gases obviously as well as invested fossil energy and operating cost. Afforestation system is carried out to make full use of forest system to reduce emissions of greenhouse gases, such as decreasing deforestation to save carbon, enlarging reforestation to increase carbon storage capacity, producing biomass energy to counteract consumption of fossil energy. In America, using improved crop varieties (especially perennial crops that can fix more carbon) and implementing suitable crop rotation system and protective tillage can increase crop yield and carbon fixed by soil. Nitrogen fertilizer can be applied to crops lacking nutrition to promote the ability of soil to fix carbon, but more N_2O may be released from soil and more CO_2 may be released during fertilizer production.

2.2 Carrying out fallow plan to conduct nutrition management As the development of weed control methods and agricultural machinery farming, fallow plan has been implemented in the world and has improved the ability of land to store carbon obviously. America adopts protective tillage and fallow measure in farmland with long-term tillage and weathered soil to absorb and store organic carbon again. Afterwards, surface of the fallow farmland is covered by vegetation again, which can increase the storage capacity of organic carbon in soil. In the southeast, decrease of farmland tillage in magnitude and intensity can reduce the physical disturbance to soil, improve soil stability, and increase the proportion of stable organic matter in soil. In France, crops needing nitrogen are planted in farmland, and inorganic nitrogen fertilizer is applied to improve storage capacity of organic carbon in soil. In addition, animal compost is applied in some regions for a long term to improve the storage effect of organic carbon in soil. Meanwhile, pasture is planted in farmland instead of crops. Based on the accurate estimation of fertilizer needed by crops, Australia adjusts use ratio of fertilizer and applies slow-release fertilizer in different farms or various nitrification inhibitors to crops when loss of nitrogen fertilizer is the minimum, and fertilizer should be applied in a suitable position where it could be absorbed by crop most easily. Moreover, nitrogen fertilizer should not be applied when the demand of crops for nitrogen was excess.

2.3 Adjusting and controlling animal husbandry development and managing animal manure Many countries abroad have reduced the use nutrient supplements to avoid overgrazing and adopted various ways to feed different livestock to decrease CH_4 emissions from livestock. For instance, Australia adopts concentrated feed and alternative feed to reduce CH_4 emissions. Besides, to reduce CH_4 emissions, we can add oil or oilseeds to feed, improve forage quality (especially in underdeveloped areas) and optimize protein intake. Through breeding and better management, Japan reduces CH_4 emissions from livestock. America utilizes anaerobic effluent to change CH_4 into renewable energy. To reduce emissions of greenhouse gases by 25% in next ten years, America will change waste milk into renewable energy to supply it to farmland^[7]. Moreover, anaerobic digester is used to transform waste like manure, and methane produced from animal manure can be used as fuel.

3 Ways of developing low-carbon agriculture in China

3.1 Popularizing low-carbon technology and developing low-carbon mode of production According to a previous study, the improvement of ruminant nutrition by ammoniated straw can decrease CH_4 emissions from a beef by 15% – 30%, and implementation of paddy intermittent irrigation can reduce CH_4 emissions from an unit area of paddy by 30%, while developing biogas project and improving ways to collect and store manure can also decrease CH_4 emissions from manure^[8]. Therefore, it is imperative to develop low-carbon mode of production in agriculture. In Chi-

na, there are five modes of production in low-carbon agriculture at present.

3.1.1 Implementing minimum tillage and no-tillage and returning straw to farmland. During process of agricultural production, soil tillage frequency should be minimized to greatly reduce material and energy inputs. Returning straw to farmland can improve soil fertility, because crop straw contains large quantities of nutrients. In a dry season, straw on the surface of soil can reduce soil water evaporation. Besides, crop straw can obviously restrain weed from growing, thereby promoting growth and development of crops. In a word, returning straw to farmland is an important low-carbon agricultural technology.

3.1.2 Intercropping, mixed cropping, relay intercropping and crop rotation. Intercropping, mixed cropping and relay intercropping are essential parts of traditional agricultural technology in China, and they can form low-carbon agro-ecosystems with a high resource utilization rate, productive forces and resistance, high benefit, strong functions and stable ecosystem. At present, there are many intercropping, mixed cropping and relay intercropping patterns suitable for promotion, such as corn + soybean, peanut + corn, cotton + vegetable, rape × radish, winter wheat/rape and so forth (" + " stands for intercropping; " × " means mixed cropping; "/" refers to relay intercropping). In addition, crop rotation can improve physical, chemical and biological properties of soil, remove toxic and hazardous substances in soil, and make crop away from diseases, pests and weeds, thereby improving crop yield and farmland economic benefit.

3.1.3 Light cultivation and water-saving irrigation. At present, light cultivation technology saving labor and cost has developed rapidly. The light cultivation technology of wheat and rape includes free (less) tillage cultivation techniques of wheat and rape, free tillage transplanting and direct sowing techniques of rape and so on. The light cultivation technology has generated and developed with the shifting of large numbers of rural labor forces, and it has been applied more widely due to its advantages of saving labor and cost as well as mature supporting technology. On the whole, this light cultivation technology is beneficial to realization of energy conservation and emission reduction in agriculture, but the use of herbicide should be decreased in practice. Implementing water-saving irrigation in farmland can reduce emissions of greenhouse gases, and conducting "intermittent and wetting irrigation" in farmland can effectively decrease CH₄ emissions, thereby promoting development of low-carbon agriculture in China.

3.1.4 Methane utilization and waste reuse. Methane, one of important greenhouse gases, is an important rural energy and links farming and aquaculture. Making full use of methane can not only reduce emissions of greenhouse gases and slow down global warming, but also save energy resources, optimize rural ecological environment and improve people's living standard and quality of life. Among the utilization patterns of rural methane, the pattern "pig – methane – farmland" has been applied widely in China and obtained remarkable economic, ecological and social benefits. It

is clear that the application of this mode in China's low-carbon agriculture will play an important role in the increase of grain yield, farmers' income and agricultural benefit as well as environmental protection. Waste reuse means to save energy, reduce emission, control environment and optimize ecosystem. During the development of low-carbon agriculture, all kinds of waste should be reused as much as possible in different ways, such as industrial "three wastes", waste produced during agricultural production (crop straw, livestock manure, residue of chemicals and toxic and hazardous substances), garbage and sewage.

3.1.5 Disaster reduction in ecological ways. In tradition, farmers used pesticide and herbicide to control plant diseases, insect pests and weed which can be reduced within a certain period and in a certain range, but it is difficult to prevent environment and agricultural products from being polluted. During the development of low-carbon agriculture, it is necessary to adopt ecological methods to reduce plant diseases, insect pests and weed, so as to realize the increase of grain yield, farmers' income and agricultural benefit as well as environmental protection.

3.2 Developing carbon conservation and fixation technology

3.2.1 Reducing application of high-carbon energy and fertilizer. Presently, rural life and agricultural production in China still depend on fossil energy. As the implementation of rural construction and development of modern agriculture, energy consumed during rural life and agricultural production has increased gradually, and CO₂ emissions have risen year by year. Therefore, it is necessary to optimize rural energy structure and make full use of biomass energy. To realize low-carbon growth of agriculture, it is needed to adjust energy structure of rural life and agricultural production, reduce the use of high-carbon energy in agriculture, and increase methane and other alternative energy.

3.2.2 Improving plant varieties fixing carbon. China is weak in breeding crops with functions of "climate protection" and "carbon fixation" and has paid less attention to breeding of new varieties for coping climate change and food shortage. An American expert has pointed out that we make great efforts to breed flood-control and drought-resistant crops, but crops which can grow at a high temperature and increase carbon absorption and storage have been neglected. To adapt to and cope globe climate change, China ought to breed or introduce crop varieties which can grow in extreme climates and have resistance to plant diseases and insect pests, and improve production of agriculture and animal husbandry in a new ecological environment and increase carbon absorption.

3.2.3 Popularizing carbon fixing technology in agriculture. Popularizing carbon fixing technology in agriculture is the key to the development of low-carbon agriculture. In recent years, the development and application of biological carbon fixation technology have been widely conducted internationally. The first one is to protect current carbon sinks, that is, management of agriculture, forestry, animal husbandry and fishery industry should be strengthened through manage technology of ecosystem to maintain long-term ability of ecosystem to fix carbon. The second one is to

enlarge carbon sinks to increase carbon fixed, that is, carbon fixation capacity can be enhanced through change of land use type, seed selection, breeding and planting technology. The third one is to produce biological varieties sustainably, and biological energy can be used to replace fossil energy.

3.2.4 Developing agricultural circular economy. Low-carbon agriculture places emphasis on a key field of agricultural circular economy, namely energy and CO₂ emissions, and it is a deepened form of agricultural circular economy. Developing agricultural circular economy is to organize agricultural economic activities into a circular mode "agricultural resources – agricultural products – renewable resources" to realize agricultural production with low exploitation, high utilization, low emission and pollution, which can not only expand growing space of crops but also increase yield of agricultural products.

3.3 Establishing benefit coupling mechanism

3.3.1 Studying and connect with international carbon sink trading mechanism. Carbon trading is a measure to reduce carbon emissions that generates based on clean development mechanism (CDM), and it has been adopted by many countries and regions at present. Moreover, several carbon trading activities have been conducted in international market, and carbon trading market is developing and being improved continuously. To speed up marketization of carbon trading and master pricing power of carbon trading, the first batch of trade organizations of environmental rights and interests, the Beijing Environmental Exchange and Shanghai Environment and Energy Exchange, were set up in Beijing and Shanghai respectively in August 2008^[9]. As one of sellers' markets with great potential of carbon emission trading, China faces the fact that the development of carbon sink projects is blank. It is because that there is no platform for carbon trading market and carbon sink trading mechanism, and enough supply and demand information can not be provided for buyers and sellers. Thus, it is urgent for China to study and connect with international carbon sink trading mechanism, set up a platform for carbon trading market to sell carbon emission quota publicly, and establish carbon sink trading mechanism to promote growth of carbon sink economy.

3.3.2 Developing carbon finance FAO has put forward that the scale of low-carbon agriculture in a developing country may increase 30 billion dollars every year. However, to implement the measures to reduce carbon emissions and increase grain yield, expense of up-front investment needs to be solved, and parts of funds for development of low-carbon agriculture can be collected from carbon trading market. Moreover, forest carbon sink, biogas project and recycling of rural livestock manure can be transformed into CDM project to absorb international funds and technology to develop low-carbon agriculture.

3.3.3 Establishing farmers' benefit sharing mechanism In low-carbon agriculture, farmers' income can be increased by carbon sink project, and reasonable farmers' benefit sharing mechanism is an important guarantee for the successful implementation of agri-

cultural carbon sink project. After signing an order of carbon sink project, farmer special cooperative economic organization needs to assign the direct benefit obtained from carbon trading to farmers to improve farmers' enthusiasm. In addition, ecological agriculture can promote development of rural tourism, and agricultural circular economy can produce large quantities of green products and organic food with great market competitiveness. These economic benefits are also assigned to farmers.

3.4 Strengthening government support and improving laws and regulations To realize the transformation of traditional agriculture into low-carbon agriculture in China, the government ought to provide full support, improve laws and regulations, and provide technology and services^[10]. Firstly, government support should be enhanced. Realization of economic benefit can ensure sustainable development of low-carbon economy, and low yield and high cost have hindered development of low-carbon agriculture in the early period, so it is necessary to ensure economic benefit of agricultural producers through tax revenue and transfer payment. Secondly, it is needed to change agricultural growth pattern. Since the reform and openness, yield increase has been realized by high investment and energy consumption, and the development mode is not sustainable. It is necessary to guide agricultural economy to develop towards high efficiency, low energy consumption and emission, and high carbon sink. Thirdly, science and technology investment should be increased to promote growth of low-carbon economy through scientific and technological progress. Low-carbon agriculture is a modern agriculture based high technology. Fourthly, low-carbon agriculture should be popularized greatly to make people take part in it. Lifestyle and habits have certain effects on development of low-carbon economy, and guiding consumers to buy low-carbon products is the basis for the long-term development of low-carbon agriculture. In a word, low-carbon agriculture is not only a technology choice but also a social choice.

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erty alleviation through in-depth interview, expert opinions, exploratory factors and confirmatory analysis, to make subsequent research findings reliable, comparable and testable.

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