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Low Carbon Agriculture and GHG Emission Reduction in China: An Analysis of Policy Perspective

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Abstract

Although agriculture is an important source of greenhouse gas (GHG) emissions, yet it has huge potentials for GHG emissions reduction. Therefore, vigorously to develop low-carbon agriculture is one of the most important means for China to achieve the targets of GHG emissions reduction. This paper uses cost-benefit analysis method to demonstrate the key factors that affect low-carbon agriculture and green agricultural product development and related policy measures. Research results indicate that, key to promoting the transition of high-carbon to low-carbon agriculture is how to create good scheme, mechanism and policy, and the most effective measures for low-carbon agriculture development are fully to play the role of market mechanism. Meanwhile, other policies, such as the improvement of agricultural inputs and land cultivation, wetland protection, carbon sink agriculture development and so forth, have to be practiced, too.

Keywords

Low Carbon Agriculture, Greenhouse Gas Emissions Reduction, Market-Oriented Mechanism, Carbon Emissions Right Trading, Carbon Sink Agriculture Development

1. Introduction

The adverse effects of climate change on socio-economy have been more and more cared by all countries around the world, while the root cause of climate change is significant emissions of greenhouse gases (GHG). The reasons of significant GHG emissions have many according to the existing research, while agriculture is one of the major sources of GHG emissions [1] [2]. However, GHG emissions caused by agriculture haven't been paid sufficient attention and the impacts of agricultural emissions tend to be underestimated. Accordingly, most of policy and technology options are aimed primarily at the GHG emissions of other sources in GHG emissions treatment, thereby reducing the effects of low-carbon-oriented policies and technologies [3].

In fact, GHG emissions from agriculture are prominent. It is estimated that, agriculture's share of total GHG emissions in global GHG emissions was about 13.5% in the mid-2000s [4]. With the development of the world's agriculture, GHG emissions from agriculture are constantly growing. Global GHG emissions from agriculture in 2010 were about 469 million tons of carbon equivalent (CE), growing 13% on 1990 level. The most common gases released from agricultural activities are methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2), respectively. Among them, methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) account for about 50%, 35% and 14% share of total agricultural emissions, respectively [3] [5]. China is a large agriculture country and agriculture's share of total GHG emissions will reach about 15% to 18% above with the increasing use of agricultural machine and inorganic agricultural materials [6]. Obviously, GHG emissions from agricultural activities cannot be ignored.

Because there is a close relation between agricultural activities and natural ecosystems, the potentials of agricultural GHG emissions reduction are enormous [7]. On the one hand, it is possible through eco-organic agriculture development to reduce agricultural consumption on fossil fuels, thereby reducing GHG emissions. On the other hand, it is possible through change in farming manners to increase carbon sequestration, through increase in the production of energy crops to replace fossil fuels, and through increase in grasslands and woodlands to absorb carbon to offset GHG emissions [8] [9] [10]. At present, China is in the stage of industrialization and urbanization development, so huge GHG emissions will be inevitable, which has to fully exert agriculture's potentials to reduce GHG emissions.

From the perspective of practice at home and abroad, key factors restricting low carbon agriculture development are technologies and policies. Agricultural technologies, including agricultural biodiversity, land farming methods, crop rotation, fallow, the use of organic amendments and the clearing of plant residues, have all an important impact on soil organics, while enriching soil biodiversity, controlling plowing tillage and reducing the clearing of plant residues may effectively avoid the decomposition and leakage of soil organics, helping to increase carbon sequestration capacity of soil [11] [12] [13] [14] [15].

Different practical ways and policies for low carbon agriculture will not only produce different policy effects, but also change the costs and benefits of different stakeholders. Therefore, effective policies and related measures for low carbon agriculture are crucial [16]. In fact, the research, development and application of low carbon agriculture technologies must be supported by the associated policies. Apparently, the core issue of China's low carbon agriculture development is the implementation of effective low carbon agriculture policies, which requires appropriate scheme and mechanism to ensure it.

Because agro-ecological environment is an important part of natural eco-environment and directly affects total ecological environment system, GHG emissions in agricultural sectors cover a wide range including almost entire ecological system. The non-point source emissions of agriculture determine that it is impossible through a centralized governance comprehensively to achieve the targets of GHG emissions reduction [17] [18] [19] [20]. Obviously, the governance of agricultural GHG emissions involves more issues and is a complex socio-economic systematic engineering, which needs from associated scheme and policy comprehensively to guide and coordinate low-carbon agriculture development. Only in this way, it is possible to fundamentally solve the problem of GHG emissions from agricultural activities.

Different from other studies focusing on specific field of agriculture, this paper will focus on the scheme, mechanism and policy of China's low carbon agriculture and green agricultural product development and from the perspective of agricultural inputs and land use to explore the road of China's low carbon agriculture development.

2. Materials and Method

2.1. Scenario

This paper will focus on how to realize agricultural low-carbon-oriented development with the property of the combination of traditional agriculture and modern agriculture in China's main grain producing areas. In recent decades, the level of mechanization and utilization for inorganic chemicals in China's agriculture has been significantly improved, resulting in the substitution of modern inorganic agriculture for traditional organic agriculture. This not only led to a substantial increase in agricultural energy consumption, but also led to chemical pollution caused by excessive use of pesticides, fertilizers, pesticides, plastic film and other inorganic substances. However, it is impossible to make a complete return to traditional agriculture under the background of modern mass production. Therefore, it is necessary to take traditional agriculture as the foundation and make use of modern agricultural technology to reasonably transform traditional agriculture.

The basic characteristic of traditional agriculture is as follows.

a) It mainly depends on agricultural biological productivity and natural climate resources to produce agricultural products.

b) It adopts the intensive and meticulous farming mode and has more labor inputs on per unit area land.

c) It practices decentralized individual business and belongs to subsistence agriculture with low capital and technology intensity.

d) It more closely integrates planting industry with livestock industry, that is, produces crops as well as household livestock such as feeding horses, cattle, sheep and pigs.

Obviously, traditional agriculture belongs to low-input, low-output and low-pollution agriculture. However, it has not adapted to the requirements of modern productivity because of its low efficiency. The core of low carbon agriculture development is to make full use of the advantages of low investment and low pollution of traditional agriculture and at the same time to improve the efficiency of agricultural production and the quality of agricultural products as much as possible. Its ultimate goal is to realize the positive interaction and sustainable development of agricultural production system and natural ecosystem [21] [22].

2.2. The Properties of Agricultural GHG Emissions

When farmers produce agricultural production and light industrial raw materials through agricultural ecosystem, it will produce large amounts of greenhouse gases, too. Therefore, agricultural activities and agricultural ecosystem itself are one of the major sources of GHG emissions. Agricultural GHG emissions include direct and indirect emissions (see Table 1).

2.2.1. Agriculture's Direct GHG Emissions

Direct GHG emissions from agriculture are caused by agricultural plant and animal production and land use itself. CH_4 is important GHG emissions from agricultural activities, while the anaerobic decomposition of organic matters (e.g., crops, livestock's fodder and manure, etc.) and livestock enteric fermentation will produce large amounts of CH_4 emissions [23] [24]. The higher the yield

Table 1. Agricultural GHG emissions.

Type	The substance or link of emissions	The sources of emissions
Direct emissions	CH_4	Anaerobic decomposition of organic matter such as crops, livestock's fodder and manure and others, and livestock enteric fermentation emissions.
	N_2O	Microbial decomposition of nitrogen in soil and manure, and nitrogen-rich fertilizer use.
	CO_2	Aerobic decomposition of organic soil (e.g., moisture, peatland and marshes, etc.), crop straw burning, forest fires, and barren hill and wasteland grass burning.
Indirect emissions	Link of agricultural inputs	The use of fertilizers, pesticides, herbicides, films and machinery as well as agricultural irrigation, farmland construction, installation-agricultural development and others need all to consume a large amount of natural resources and fossil fuels, resulting in indirect GHG emissions.
	Link of agricultural outputs	The transport, storage, processing and others of agricultural products need to consume a large amount of natural resources and fossil fuels, resulting in indirect GHG emissions.
	Land use structure change	The reclamation of woodland and grassland into arable land reduces the ability of agricultural carbon reduction, indirectly increasing GHG emissions.

of crops and livestock, thereby the more CH_4 gas emissions. In particular, CH_4 gas from livestock enteric fermentation is positive proportion to the amount of livestock rearing. However, CH_4 emissions from such a field cannot be reduced, unless the amount of livestock rearing is decreased [25]. For China, because agricultural productions (especially on meat production) per capita are relatively low, CH_4 gas emissions from agriculture in the future will inevitably increase with agriculture development, which will bring pressure for the reduction of China's GHG emissions.

In agriculture's direct GHG emissions, besides CH_4 gas, there are still N_2O, CO_2 and other gases. The microbial decomposition of nitrogen in soil and manure and nitrogen-rich fertilizers used will produce large amounts of N_2O gas [26] [27], while the aerobic decomposition of organic soil (e. g., moisture, peatland and marshes, etc.), crop straw burning, forest fires and barren hill and wasteland grass burning will result in a lot of CO_2 emissions [28] [29]. In these gas emissions, some can be reduced by technical means, while others can be made through policy instruments. However, due to the complexity of agricultural production systems, to completely solve the problem of GHG emissions from agriculture is unrealistic. Therefore, CH_4, N_2O and CO_2 emissions from agriculture will continue to increase in the future and be difficult to be avoided with agriculture development [30] [31].

2.2.2. Agriculture's Indirect GHG Emissions

Agriculture's indirect GHG emissions are caused by indirect agricultural activities, including GHG emissions from agricultural inputs, agricultural outputs, land use structure change and others. In the link of agricultural inputs, the use of fertilizers, pesticides, herbicides, agricultural films and machinery as well as agricultural irrigation, farmland construction, installation-agricultural development and others need all to consume a large amount of natural resources and fossil fuels, resulting in indirect GHG emissions [32] [33]. Because China's agricultural outputs excessively rely on the inputs of chemical fertilizers, pesticides, herbicides and agricultural machinery, GHG emissions caused by agricultural inputs are enormous.

In the link of agricultural outputs, agricultural product transport, storage, processing and others need to consume a large amount of natural resources and fossil fuels, resulting in indirect GHG emissions. In the modern consumption of people, the consumption ratio of the deep processing products of agriculture is increasing, but each link including agricultural product processing, packaging, transportation, marketing and others needs to consume a large amount of natural resources and fossil fuels. With the developed traffic and transport technology, the off-site consumption of agricultural products will be increasingly common, which needs packaging, proper processing and transport for agricultural products, consuming a lot of natural resources and fossil fuels [34].

Due to the development of production, preservation and storage technology, the counter-season production and consumption of agricultural products has become increasingly common phenomenon. However, it will not only increase investment in agricultural production and storage facilities, but also consume more natural resources and fossil fuels in production, preservation and storage. Obviously, the link of agricultural outputs is another source of GHG emissions.

The change in land utility structure will lead to large amounts of GHG emissions, too. The reclamation of woodland and grassland into arable land not only reduces soil's ability to fix nitrogen and carbon, but also reduces the carbon sink ability of forests and grasslands, indirectly increasing GHG emissions [35]. If considering soil desertification, alkalization, erosion and other phenomena caused by deforestation, then GHG emissions from the improper use of land will be greater.

In a word, agricultural activities not only directly produce a large amount of GHG emissions, but also indirectly bring about a large amount of GHG emissions from associated activities, taking a multiplier growth with the development of inorganic agriculture. Because agriculture is closely related to natural ecosystem and has a fundamental impact on natural ecosystem, it has a fundamental role in low carbon development to some extent. Therefore, from the perspective of responsibility, agriculture must reduce itself GHG emissions to make a great contribution for curbing the greenhouse gas effects.

2.3. The Possibilities and Potentials of Agricultural GHG Emissions Reduction

Agriculture has really huge potentials for GHG emissions reduction (see **Table 2**). In the link of agricultural inputs, if comprehensively to promote the transformation of existing inorganic agriculture to organic ecological agriculture, then it may not only reduce the large-scale use of fertilizers, pesticides, herbicides and other chemicals, but also improve the quality of agricultural products [36]. In fact, China's traditional farming techniques put great emphasis on the use of organic fertilizers, biological pest control and other energy-saving agricultural technologies. If associated policies and measures are appropriate, then future development space of organic ecological agriculture in China is enormous. In addition, comprehensively to reduce dependence on installation-agriculture and to improve the efficiency of agricultural machinery may contribute to GHG emissions reduction, too [37].

Agricultural production itself has great potentials for GHG emissions reduction, too. For example, to promote shallow plowing and no-plowing techniques and to implement fallow and rotation tillage system [38]; to practice micro-irrigation and smart irrigation technology and to develop water-saving agriculture; to implement land use and conservation combination, and comprehensively to protect land resources and reduce soil desertification and alkalization phenomenon; to build effective three-dimensional agro-ecological chain and realize agriculture's structural rationalization and agro-biodiversity [21]; to practice plant residues back to farmland system and increase soil organic matters and so forth, have all huge potentials for GHG emissions reduction.

Table 2. The possibilities and potentials of emissions reduction from agriculture.

Emissions reduction field	Emissions reduction means
Input link	To minimize the use of chemical fertilizers, pesticides, herbicides, agricultural film and other chemicals, to increase the use of bio-organic fertilizer and promote biological pest control technology; to improve the efficiency of agricultural machinery; to reduce dependence on installation-agriculture; actively to use clean and renewable energy.
Production process	To promote shallow plowing and no-plowing techniques and implement fallow and rotation tillage system; to practice micro-irrigation and smart irrigation technology and develop water-saving agriculture; to implement land use and conservation combination, comprehensively to protect land resources and reduce soil desertification and alkalization phenomenon; to build effective three-dimensional agro-ecological chain and realize agriculture's structural rationalization and agro-biodiversity; to practice plant residues back to farmland system and increase soil organic matters.
Consumption link	To minimize agricultural processing link and increase the consumption of primary agricultural products; to reduce waste in agricultural consumption process; to practice the localized and seasonal consumption of agricultural products.
Agricultural carbon sink	To put an end to deforestation phenomenon and vigorously to carry out afforestation activities; fully to promote desert control, sand fixation and sealing and silviculture activities, and actively to develop desert agriculture and tourism agriculture; vigorously to protect wetlands and wildlife habitat and restore biodiversity to improve self-healing capacity of agro-ecological system.

Scientific and rational consumption is an important thing to reduce GHG emissions. With the development of agricultural product processing, transportation and storage technology, people consume more deep processing, counter-seasonal and non-local agricultural products. In fact, the consumption of primary or simple processing and seasonal and local agricultural products may not only save a lot of resources and energy consumed in processing, packaging, transport, storage and others, but also be beneficial to people's health [39]. Therefore, the state may take effective policies and measures to guide and encourage people to contribute to the reduction of GHG emissions.

Vigorously to develop the agriculture of carbon sink is an important part to full play to the role of agriculture's GHG emissions reduction, as it may effectively remove GHG (especially CO_2) in atmosphere. In fact, no matter how advanced the technology is, GHG emissions are inevitable. If greenhouse gases produced in atmosphere can be cleared promptly, then it will reduce the accumulation of greenhouse gases in atmosphere, thereby reducing or eliminating the impact of GHG on climate [40] [41] [42]. Moreover, China has great potentials on the development of carbon sink agriculture, especially on the improving of forest green rate. As we know that, forest's carbon sink is one of the agricultural fields that have the biggest potentials of GHG emissions reduction for China.

2.4. Cost-Benefit Analysis Method Based on the Whole Life Cycle of Agricultural Production

This paper makes use of cost-benefit analysis method based on the whole life cycle of agricultural production to demonstrate conditions and policy measures for low-carbon agriculture development. The agents of economic activity of low carbon agriculture always try to obtain maximum profit with minimum costs for the pursuit of profit maximization. Only when the costs resulted from the adoption of low carbon agriculture technology and production mode are less than the benefits, the farmers will take low carbon production. Otherwise, original agricultural production mode will be taken.

Cost-benefit analysis process includes the following three steps:

a) The reasonable definition of relevant costs and benefits of the project.

b) The measure and calculation of relevant costs and benefits.

c) The comparison of relevant costs and benefits in the whole life cycle of agricultural production project and final choice for the project.

For low carbon agricultural projects, the biggest difficulty is the reasonable definition and accounting of costs and profits, especially the reasonable definition and calculation of the costs. This paper only gives an intuitive comparison and analysis to explain policy implications.

3. Results and Discussion

3.1. Results

3.1.1. Benefits

a) Quality improvement benefits (QB) (+)

Different from traditional agricultural products, low carbon agriculture product is green organic agricultural products, which will significantly improve the quality of agricultural products. From the perspective of market demand, the price of green organic agricultural products is significantly higher than that of ordinary agricultural products. Therefore, it can increase the sales income of agricultural products.

b) Ecological benefits (EB) (+/−)

Low carbon agriculture is essentially organic ecological agriculture, which will significantly improve the quality and efficiency of natural ecosystem. Although the ecological benefits are social benefits, which will not bring the actual benefits to farmer (namely, its short-term value is negative), the improvement of agriculture's ecological environment will be beneficial to improve the efficiency of agricultural production for farmer in the long term (namely, its long-term value is positive).

3.1.2. Costs

a) Input costs of inorganic chemicals (IC) (−)

Because of the extensive use of organic fertilizer and pest control of biological treatment, the inputs of inorganic chemicals (e.g., fertilizers, pesticides, herbicides and agricultural films, etc.) will be significantly reduced. At present, the inputs of these inorganic chemicals account for about 30% of total cost of agricultural production. Therefore, the reduction of these inputs will be conducive to a significant cut in the cost of low carbon agriculture production.

b) Additional costs (AC) (+)

Low carbon agriculture development will generate additional costs, such as R&D costs, production mode conversion costs, production environment reconstruction costs, associated facilities construction costs, learning costs, and so forth. These costs are bound to happen. They are the key factors that restrict the development of low carbon agriculture.

3.1.3. Net Benefits (NB)

Net benefits from low carbon agriculture are the benefits brought by low carbon agriculture minus the corresponding costs. That is,

$$\mathrm{NB_t} = \left(\mathrm{QB_t} + \mathrm{EB_t}\right) - \left(-\,\mathrm{IC_t} + \mathrm{AC_t}\right) \tag{1}$$

As ecological benefits ($\mathrm{EB_t}$) are social benefits, so in the short term it is negative for farmer. Then, formula (1) will become,

$$\mathrm{NB_t} = \mathrm{QB_t} + \left(-\mathrm{EB_t}\right) + \mathrm{IC_t} - \mathrm{AC_t} \tag{2}$$

To ensure that net income is greater than zero (*i.e.*, $\mathrm{NB_t} > 0$), it is necessary to make $\mathrm{QB_t} + \left(-\mathrm{EB_t}\right) + \mathrm{IC_t} \geq \mathrm{AC_t}$. Because of high additional costs ($\mathrm{AC_t}$) especially in early stage, the best way is to transfer agriculture ecological benefits ($\mathrm{EB_t}$) to agricultural producers through subsidies or agricultural tax cuts to ensure this inequality.

In fact, in the early stages of low carbon agriculture development, the quality improvement benefits ($\mathrm{QB_t}$) and the inorganic chemicals input reduction costs ($\mathrm{IC_t}$) are limited. This is an important reason for government to make subsidies or tax cuts in the early stage of low carbon agriculture development.

As time passed, low carbon agriculture production technology and mode will be increasingly mature, and green agricultural products will be widely recognized by consumers, too. At this time, both increase in quality improvement benefits ($\mathrm{QB_t}$) and decrease in inorganic chemicals input costs ($\mathrm{IC_t}$) will be significant, while early social ecological benefits will also be partly internalized, that is, ecological benefits ($\mathrm{EB_t}$) will become positive for farmers. All these will ensure that agricultural producers have a substantial net gain.

3.2. Objective and Policy Orientation

The basic objective of low carbon agriculture development is to promote the transformation of high carbon agriculture characterized with high-inputs, high-consumption, high-emissions and high-pollution to low carbon agriculture with organic, ecological and efficient property. It aims at the followings.

a) Vigorously to develop organic eco-agriculture. Its core is to realize the organic integration of agricultural economy system with ecosystem to take full advantage of the natural forces and the biological productivity of agriculture to produce pollution-free green and organic agricultural products [43] [44].

b) To minimize the inputs of inorganic and hazardous chemicals (e.g., fertilizers, pesticides, herbicides and agricultural film, etc.) to fully reduce their adverse effects, including residual chemical contamination in agricultural products, agricultural nonpoint source pollution, soil degradation and so forth [45].

c) Significantly to improve the use efficiency of agricultural irrigation water, comprehensively to promote water-saving irrigation techniques and vigorously to develop water-saving agriculture [21].

d) Actively to promote and apply energy-saving agricultural technologies such as new tillage technology [46], modern planting and breeding technology, efficient agricultural machinery use, the advanced processing and storage technology of agricultural products, the construction and use of nature-oriented agricultural facilities and comprehensively to cut energy consumption in agriculture.

e) Vigorously to develop circular economy in agriculture and comprehensively to promote the recycling and reuse of planting and breeding waste and agricultural product processing waste and the recycling use of agricultural internal resources between different agricultural departments [47] [48].

f) Greatly to improve the energy efficiency of agriculture [10] and actively to develop and use clean and renewable energy sources in rural areas, especially biomass energy closely related to agriculture (e.g., straw power generation, straw gasification and biogas, etc.) and renewable energy (e.g., hydro, wind and solar power, etc.) [49].

g) With a great effort to increase forest coverage rate, urban greening rate and rural community greening rate, positively to develop tourism agriculture, and comprehensively to promote the development of agricultural carbon sink projects combining with desertification and soil erosion control and green engineering [50].

To achieve these goals above, it is necessary to take appropriate policies and measures to promote low carbon agriculture development. From the policy-oriented perspective, the core of low carbon agriculture policies is to promote agricultural technology and system innovation, as the power of low carbon agriculture development comes from the comparative interests of agricultural producers, while comparative advantage comes from agricultural system and technology innovation [51] [52]. To begin with, low carbon agriculture is essentially a major agriculture with a high performance, while agricultural system innovation (especially the innovation of agricultural management and production mode) is conducive to large-scale, specialized and intensive management of agriculture to greatly cut agricultural costs [53].

Secondly, the fundamental driving force of low carbon agriculture development comes from agricultural technology innovation, as the improvement of agricultural production and management efficiency is based on agricultural technology innovation [54]. Because low carbon technologies involve modern installation-agricultural technology, agricultural biotechnology, farming and irrigation techniques, fertilization techniques, plant protection technology, agricultural resource recycling technology, agricultural product processing and storage technology, rural clean energy development and utilization technology and others, the state and relevant government departments must formulate corresponding policies and measures to promote their research, development, promotion and application. Especially, the state should preferentially support the research and development of basic, key and general technology [20].

Of course, both agricultural system innovation and technology innovation need to give full play to the innovation-driving role of market mechanisms. As low carbon agriculture is still market-oriented agriculture, only to full play to the role of market, can the initiative and creativity of various innovative agents really be launched to provide enough power for low carbon agriculture development [55].

3.3. Market Mechanism and Low Carbon Agriculture Development

Generally, because natural environment has the property of public goods, there is a problem of market failure in natural eco-environment protection. However, powerful market forces in the distribution of competitive socio-economic resources are really inaction in eco-environment protection? Answer is certainly no, as eco-environment protection may properly be integrated with real economy development. Especially on low carbon agriculture development, because agriculture is the most closely related industry to nature, there is an intrinsic relationship of unity between it and eco-environment protection. From the perspective of practice at home and abroad, market mechanism has a very important role in low-carbon agriculture development. Therefore, through economic benefits to encourage agricultural producers and operators actively to engage low carbon activities are not only necessary, but also have practical socio-economic base [22].

In fact, the signing and implementation of the "Kyoto Protocol" marking the formal establishment of global environment cooperation mechanism has proven the viability of market on promoting low carbon socio-economic development and natural eco-environment protection. The core of the Kyoto Protocol's GHG reduction mechanism is through carbon-quota allocation and GHG emissions right trading to achieve the goals of global GHG emissions reduction, which not only plays the role of market mechanisms to reduce GHG emissions, but also makes worldwide joint GHG control better achieved [56] [57]. Based on such mechanisms, agricultural GHG emissions may also be incorporated into GHG emissions right trading system to allow agriculture's GHG emissions reduction quota traded on market to stimulate the enthusiasm of farmers to reduce GHG emissions.

The development of low carbon agriculture and the change of farmers' existing production mode will usually increase farmers' production and management costs. If only through mandatory policies and measures to force farmers to change the existing production and management mode of agriculture will increase production and operation costs and farming burden. This will not only discourage their enthusiasm, but also even lead to more farmers to leave agriculture, which will fail to achieve the desired effects of policies as well as lead to undesirable social problems. Therefore, it is necessary to make use of market mechanisms and other policy instruments simultaneously to promote low carbon agriculture development [58].

One of the most basic and effective measures for market-oriented low carbon agriculture development is to practice farmers' GHG emissions right trading. After the state and relevant departments set a reasonable limit of GHG emissions based on the uniform standards of land units for farmers, distribution and trading through markets may not only get satisfactory effects, but also provide more ways for farmers' income growth. In addition, through quota trading to encourage farmers to reduce GHG emissions may promote the improvement and popularization of low carbon agriculture technologies and production mode [59].

3.4. The Path of Low Carbon Agriculture Action

The effectiveness of low carbon agriculture development depends on the transaction of GHG emissions right quotas and their creation. Without doubt, if there is no the creation of GHG emissions right quotas, GHG emissions right trading cannot be practiced. Therefore, paper analyzes agricultural GHG emissions reduction and low carbon agriculture development mode from the perspective of the creation and trading of GHG emissions reduction quotas. It is possible to seek fair countermeasures to solve it, for example, improving the ways of agricultural inputs, land use and farming, protecting wetlands, developing efficient carbon sink agriculture, and so forth.

3.4.1. Change in Agricultural Input Mode

The improvement of agricultural productivity is closely related to industrial development. Inputs such as fertilizers, pesticides and machinery in agriculture have occupied an important position with faster industrialization process. However, they raise agricultural energy demand and GHG emissions, while they greatly enhance agricultural productivity. Therefore, it is necessary to change the way of agricultural production to practice traditional and organic farming.

3.4.2. Agricultural Machinery and Arable Land Reduction

CO_2 is an important part of GHGs, while the combustion of diesel and gasoline consumed by agricultural machinery and equipment is one of the main sources of agricultural carbon dioxide gas. In addition, increase in arable land leads to the reduction of wetlands and forests and the release of organic carbon in soil further to exacerbate agricultural carbon dioxide emissions. Therefore, in theory, change in agricultural machinery and equipment inputs and arable land has a greater impact on agricultural carbon dioxide emissions.

According to the regression results of China's data from 1991 to 2014, 1% increase in agricultural machinery and equipment inputs will result in 1.74% increase in carbon dioxide emissions from agriculture given other conditions, while 1% increase in arable land will result in 0.29% increase in carbon dioxide emissions from agriculture given agricultural machinery and equipment inputs. Apparently, empirical results confirm that change in the agricultural machinery and equipment inputs and the arable land has a greater impact on agricultural carbon dioxide emissions.

Agricultural production and business activities are inseparable from machinery and associated power and energy use. Therefore, it is necessary to promote energy-saving and efficient agricultural machinery and equipment to improve the efficiency of agricultural machinery use, and at the same time to minimize agricultural machinery use, thereby reducing carbon dioxide emissions caused.

In addition, to increase arable land through the reduction of wetlands and forests has not only a significant impact on agricultural GHG emissions, but also the reclamation of natural wasteland will still result in a decrease in soil organic carbon. According to statistics, land reclamation and continuous planting will make organic carbon contents in shallow soil reduced 13% - 40% [60]. Therefore, properly to control deforestation and wetland reduction will have a significant role in curbing GHG emissions.

3.4.3. Reduction of Inorganic Chemicals in Agricultural Production

Nitrogen oxides are an important part of greenhouse gases, while nitrogen oxide emissions from agriculture mainly come from soil nitrification and denitrification process, which is closely related to the use of fertilizers and pesticides. After fertilizers are made into soil, a considerable part of fertilizers is in the form of organic or inorganic nitrogen. Insoluble, adsorbed and water soluble nitrogen compounds will be reduced to nitrites and at the same time converted to N_2O and NO_X into atmosphere in the role of soil microbial denitrification [61].

Moreover, the increasing usage of chemical fertilizers will cause soil compaction, the deterioration of land's physical and chemical properties and the decrease of soil organic matters, and result in soil fertility decline, too [62]. Although the "chemical agriculture" may raise the productivity and yields of land in a short time, it will bring about a great damage on environment and soil quality. Therefore, it is necessary widely to promote organic fertilizers and efficient agricultural machinery in agriculture.

Straw is an important raw material of organic fertilizers and biomass energy, but most of straws in China are burned as burning materials or even discarded. Compared with the recycled use of straws' organic elements made into organic fertilizers, the opportunity costs of straw burning are larger, and at the same time it releases a lot of greenhouse gases. According to the average 25 kg of daily manure of per beef or dairy cattle, if the 50% of total country's straws are used, they may feed 86 - 100 millions of cattle, increasing the dung of 780 - 910 million tons. Moreover, these fertilizers are all organic fertilizers containing approximately 134.8 - 157.3 ten thousand tons of nitrogen being equivalent to 404.4 - 471.9 ten thousand tons of ammonium nitrate [63]. Therefore, agriculture development and animal husbandry may be combined, which may not only fully use the by-products of agriculture to get income, but also may get organic fertilizers and curb soil compaction and deterioration.

Of course, the development of low carbon agriculture is not only to reduce or prevent the use of chemical fertilizers and agricultural machinery, but also to rationally use resources to achieve maximum benefits. However, agricultural GHG emissions right trading mechanisms can help to reduce fertilizer inputs and to improve the efficiency of agricultural machinery to seek the win-win pattern of farmers' income growth and environmental improvement.

3.4.4. Agriculture's Carbon Sequestration Potentials and Its GHG Emissions Reduction

One of the most effective ways of low carbon agriculture development is to fully use market mechanism. In addition, to reduce the release of organic carbon oxides and others is also an important way, as it may not only reduce GHG emissions, but also prevent soil organic carbon loss and improve soil fertility. Again, innovative no-till methods and the protection and reconstruction of agricultural wetland system are effective ways to play the role of agricultural carbon sequestration, too.

Land is largest carbon stock pool on earth and land's carbon stock is three times more than the carbon stock of plants [64]. This shows that agriculture has enormous potentials for carbon storage. However, because soil organic carbons are mostly concentrated on soil surface and have an index decreasing with the depth growth [65], they are easily oxidized into carbon dioxide released into atmosphere. Therefore, the rational tillage and management of land is very helpful for the development of low carbon agriculture. Among them, no tillage system may play a very significant inhibition on soil organic carbon leakage. Moreover, no tillage system may take full advantage of stubble matter to form a protective film on the surface, effectively preventing soil degradation and providing nutrients and organic matters for soil supplement.

Moreover, because no tillage system reduces inputs in agricultural machinery and other equipment, it reduces GHG emissions from the widespread use of agricultural machinery and other equipment as well as guarantees soil fertility and promotes farmers' income growth under the premise of farmers' cost savings. Of course, although no tillage system is a "win-win" approach on ensuring the interests of farmers and the control of GHGs, it has its own drawbacks, too. The reason is that, perennial no-tillage may cause the harmful bacteria and pests of previous crop, and thus no tillage system must be carried out in conjunction with crop rotation and pest prevention to avoid unnecessary losses.

Wetlands have strong carbon absorption function, which may effectively prevent the overflows of soil organic carbon and reduce GHG emissions. Some studies have shown that carbon sequestration in wetlands per unit area is nine times more than that in forests and oceans [66]. Although wetlands have such a strong carbon sequestration capacity, China's wetland system has not been well protected. The survey results of national wetlands show that, existing wetlands in China have more than 38 million hectares (excluding rice fields), but only 40% have been better protected [67]. The transformation of a large of wetlands into arable farmland increased agricultural GHG emissions. Therefore, to protect existing wetlands, to increase and rebuild wetland system, to change old land use way such as reclaiming the parts of lakes for farmland, the woodland and wasteland reclamation and so forth, and to play the carbon sequestration potentials of woodlands and wastelands are other key ways for low carbon agriculture development and the control of agricultural GHG emissions.

4. Conclusions

The development of low carbon agriculture occupies a very important position in whole low carbon economy, as agriculture is most closely related to nature in all industries and agriculture itself is one of the major sources of GHG emissions, too. To develop low carbon agriculture, it is necessary firstly to find the possibility of GHG emissions reduction from agricultural production process. Only through changing the way of agricultural inputs, improving the use efficiency of agricultural machinery, fertilizer and other inputs, strengthening rational farming and land use management and developing efficient carbon sink agriculture, can GHG emissions in agricultural production and economic activities be effectively controlled.

Especially, the key to low carbon agriculture development is to use market-oriented mechanisms to give farmers more options depended on their own costs and benefits to make the most effective allocation of resources. Through economic means to inspire the peasants' enthusiasm of agricultural GHG emissions reduction and through interest mechanisms to stimulate and promote the progress and innovation of agricultural GHG emissions reduction technologies, all these can accelerate the development of low carbon agriculture.

Considering the comprehensive development of low carbon agriculture, the core of low carbon agriculture development is to promote low carbon agriculture scheme and technology innovation. However, this paper only discusses the scheme, mechanism and road of low carbon agriculture development in China from macro level. Therefore, the specific mode of low carbon agriculture development and technology innovation need to be further discussed and researched in the future.

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References

[1] Uwe, A.S., Bruce, A.M. and Erwin, S. (2007) Agricultural Sector Analysis on Greenhouse Gas Mitigation in US Agriculture and Forestry. *Agricultural Systems*, **94**, 128-140. https://doi.org/10.1016/j.agsy.2006.08.001

[2] Vermont, B. and Cara, S.D. (2010) How Costly Is Mitigation of Non-CO_2 Greenhouse Gas Emissions from Agriculture? A Meta-Analysis. *Ecological Economics*, **69**, 1373-1386. https://doi.org/10.1016/j.ecolecon.2010.02.020

[3] David, N. (2012) Low-Carbon Agriculture: Objectives and Policy Pathways. *Environmental Development*, **1**, 25-39. https://doi.org/10.1016/j.envdev.2011.12.004

[4] IPCC (2007) Fourth Assessment Report of the Intergovernmental Panelon Climate Change. In: Metz, B., Davidson, O.R., Bosch, P.R., Dave, R. and Meyer, L.A., Eds., Cambridge University Press, Cambridge.

[5] Linda, J. (2001) Climate Change and Agricultural Sustainable Development. Beijing Press, Beijing. (In Chinese)

[6] Liu, Y. (2010) Broadening Agricultural Development Pathways. *Environmental Protection*, **6**, 29-31. (In Chinese)

[7] FAO (2009) Low Greenhouse Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming Systems. FAO, Rome.

[8] Kyle, M., Constantine, S. and Vanessa, S. (2009) Decisions to Reduce Greenhouse Gases from Agriculture and Product Transport: LCA Case Study of Organic and Conventional Wheat. *Journal of Cleaner Production*, **17**, 222-230. https://doi.org/10.1016/j.jclepro.2008.04.009

[9] Usuga, J.C.L., *et al.* (2010) Estimation of Biomass and Carbon Stocks in Plants, Soil and Forest Floor in Different Tropical Forests. *Forest Ecology and Management*, **260**, 1906-1913. https://doi.org/10.1016/j.foreco.2010.08.040

[10] Alluvione, F., Moretti, B., Sacco, D. and Grignani, C. (2011) EUE (Energy Use Efficiency) of Cropping Systems for a Sustainable Agriculture. *Energy*, **36**, 4468-4481. https://doi.org/10.1016/j.energy.2011.03.075

[11] Petra, T. (2004) Carbon for Farmers: Assessing the Potential for Soil Carbon Sequestration in the Old Peanut Basin of Senegal. *Climatic Change*, **67**, 273-290. https://doi.org/10.1007/s10584-004-1821-2

[12] Liang, Y., Gollany, T., Rickman, R.W. and Albrecht, S.L. (2008) CQESTR Simulation of Management Practice Effects on Long-Term Soil Organic Carbon. *Soil Science Society of America Journal*, **72**, 1486-1493. https://doi.org/10.2136/sssaj2007.0154

[13] Yuri, L.Z., Rattan, L. and Dimas, V.S.R. (2005) Changes in Soil Organic Carbon Stocks under Agriculture in Brazil. *Soil & Tillage Research*, **84**, 28-40. https://doi.org/10.1016/j.still.2004.08.007

[14] Gan, Y.T., Liang, C., Wamg, X.Y. and McConkey, B. (2011) Lowering Carbon Footprint of Durum Wheat by Diversifying Cropping Systems. *Field Crops Research*, **122**, 199-206. https://doi.org/10.1016/j.fcr.2011.03.020

[15] Mariela, F., *et al.* (2010) Organic Carbon and Stable 13C Isotope in Conservation Agriculture and Conventional Systems. *Soil Biology & Biochemistry*, **42**, 551-557. https://doi.org/10.1016/j.soilbio.2009.11.020

[16] Mark, P., Robert, H., Jan, L. and Howard, M. (2001) Economic Impacts of Carbon Charges on U.S. Agriculture. *Climatic Change*, **50**, 445-473. https://doi.org/10.1023/A:1010684106573

[17] Hediger, W. (2006) Modeling GHG Emissions and Carbon Sequestration in Swiss

Agriculture: An Integrated Economic Approach. *International Congress Series*, **1293**, 86-95. https://doi.org/10.1016/j.ics.2006.02.001

[18] Pete, S., *et al.* (2007) Policy and Technological Constraints to Implementation of Greenhouse Gas Mitigation Options in Agriculture. *Agriculture, Ecosystems and Environment*, **118**, 6-28. https://doi.org/10.1016/j.agee.2006.06.006

[19] Jeremy, R.F. and Ben, H. (2012) Reducing Greenhouse Gas Emissions from Agriculture: Avoiding Trivial Solutions to a Global Problem. *Land Use Policy*, **29**, 727-736. https://doi.org/10.1016/j.landusepol.2011.11.009

[20] Dou, X.S. (2013) Low-Carbon Economy Development: China's Pattern and Policy Selection. *Energy Policy*, **63**, 1013-1020. https://doi.org/10.1016/j.enpol.2013.08.089

[21] Dou, X.S. (2009) Strategic Thinking on the Issue of Agriculture, Rural and Farmers. *Scientific Decision-Making*, **10**, 1-15. (In Chinese)

[22] Dou, X.S. and Cui, H.Y. (2017) Low Carbon Society Creation and Socio-Economic Structural Transition in China. *Environment, Development and Sustainability*, **19**, 1577-1599. https://doi.org/10.1007/s10668-016-9834-3

[23] Zhang, B. and Chen, G.Q. (2014) Methane Emissions in China 2007. *Renewable and Sustainable Energy Reviews*, **30**, 886-902. https://doi.org/10.1016/j.rser.2013.11.033

[24] Odlare, M., Abubaker, J., Lindmark, J., Pell, M., Thorin, E. and Nehrenheim, E. (2012) Emissions of N_2O and CH_4 from Agricultural Soils Amended with Two Types of Biogas Residues. *Biomass and Bioenergy*, **44**, 112-116. https://doi.org/10.1016/j.biombioe.2012.05.006

[25] Phan, N.T., *et al.* (2012) Effect of Beef Cattle Manure Application Rate on CH_4 and CO_2 Emissions. *Atmospheric Environment*, **63**, 327-336. https://doi.org/10.1016/j.atmosenv.2012.09.028

[26] Williams, J. and Crutzen, P.J. (2010) Nitrous Oxide from Aquaculture. *Nature Geoscience*, **3**, 143. https://doi.org/10.1038/ngeo804

[27] Velthof, G.L., *et al.* (2014) The Impact of the Nitrates Directive on Nitrogen Emissions from Agriculture in the EU-27 during 2000-2008. *Science of the Total Environment*, **468-469**, 1225-1233. https://doi.org/10.1016/j.scitotenv.2013.04.058

[28] Ferreira, A. de O., *et al.* (2013) Soil Carbon Stratification Affected by Long-Term Tillage and Cropping Systems in Southern Brazil. *Soil & Tillage Research*, **133**, 65-74. https://doi.org/10.1016/j.still.2013.05.011

[29] Noel, D.U. (2000) Conservation Practices in US Agriculture and Their Implication for Global Climate Change. *The Science of the Total Environment*, **256**, 23-38. https://doi.org/10.1016/S0048-9697(00)00462-9

[30] Linda, N., Peter, H.V. and Eddy, J.M. (2012) Trends in Future N_2O Emissions due to Land Use Change. *Journal of Environmental Management*, **94**, 78-90.

[31] Alla, G., Thomas, H., Lee, H.L., Steven, R. and Brent, S. (2009) The Opportunity Cost of Land Use and the Global Potential for Greenhouse Gas Mitigation in Agriculture and Forestry. *Resource and Energy Economics*, **31**, 299-319. https://doi.org/10.1016/j.reseneeco.2009.04.007

[32] David, P., *et al.* (1973) Food Production and the Energy Crisis. *Science*, **182**, 443-449. https://doi.org/10.1126/science.182.4111.443

[33] Heichel, G.H. (1976) Agricultural Production and Energy Resources. *American Scientist*, **64**, 64-72.

[34] Piero, C. and Mario, G. (1997) Fossil Energy Use in Agriculture: An International Comparison. *Agriculture, Ecosystems and Environment*, **65**, 231-243. https://doi.org/10.1016/S0167-8809(97)00048-0

[35] Miko, U.F.K., *et al.* (2012) Comprehensive Evaluation of the Climate-Change Implications of Shifting Land Use between Forest and Grassland: New Zealand as a Case Study. *Agriculture*, *Ecosystems and Environment*, **150**, 123-138. https://doi.org/10.1016/j.agee.2012.01.004

[36] Matthias, S. and Nicolas, L. (2009) Policy for Organic Farming: Rationale and Concepts. *Food Policy*, **34**, 237-244. https://doi.org/10.1016/j.foodpol.2009.03.005

[37] Yang, H., Li, C.X., Chen, Y. and Fu, R. (2012) Developing Potential of Low-Carbon Agriculture in Heilongjiang Province. *Journal of Northeast Agricultural University* (*English Edition*), **19**, 91-96. https://doi.org/10.1016/S1006-8104(12)60045-2

[38] Zhao, S.S. (2011) Cost and Benefit Analysis of International Carbon Emissions Trading. *Scientific Decision-Making*, **5**, 36-59. (In Chinese)

[39] Lester, R.B. (2009) Plan B 4.0: Mobilizing to Save Civilization. Earth Policy Institute Press, Washington DC.

[40] Flugge, F. and Schilizzi, S. (2005) Greenhouse Gas Abatement Policies and the Value of Carbon Sinks: Do Grazing and Cropping Systems Have Different Destinies? *Ecological Economics*, **55**, 584-598. https://doi.org/10.1016/j.ecolecon.2004.12.033

[41] Zhang, L., *et al.* (2014) Net Ecosystem Productivity of Temperate Grasslands in Northern China: An Upscaling Study. *Agricultural and Forest Meteorology*, **184**, 71-81. https://doi.org/10.1016/j.agrformet.2013.09.004

[42] Mccarl, B.A. and Schneider, U.A. (2001) Greenhouse Gas Mitigation in U.S. Agriculture and Forestry. *Science*, **294**, 2481-2482. https://doi.org/10.1126/science.1064193

[43] Stockdale, E.A., *et al.* (2001) Agronomic and Environmental Implications of Organic Farming Systems. *Advances in Agronomy*, **70**, 263-327. https://doi.org/10.1016/S0065-2113(01)70007-7

[44] Li, C.B., *et al.* (2014) Carbon Emission Reduction Potential of Rural Energy in China. *Renewable and Sustainable Energy Reviews*, **29**, 254-262. https://doi.org/10.1016/j.rser.2013.08.073

[45] Zhang, Z.Y., Shi, Z.X. and Zhou, Q. (2003) Impacts of Agrochemical on Entironment & Human Health and Relevant Strategies. *Journal of China Agricultural University*, **8**, 73-77. (In Chinese)

[46] Metay, A., Oliver, R., Scopel, E., Douzet, J.M., Moreira, J.A.A., Maraux, F., Feigl, B.J. and Feller, C. (2007) N_2O and CH_4 Emissions from Soils under Conventional and No-Till Management Practices in Goiânia (Cerrados, Brazil). *Geoderma*, **141**, 78-88. https://doi.org/10.1016/j.geoderma.2007.05.010

[47] Geng, Y., Fu, J., Joseph, S. and Xue, B. (2012) Towards a National Circular Economy Indicator System in China: An Evaluation and Critical Analysis. *Journal of Cleaner Production*, **23**, 216-224. https://doi.org/10.1016/j.jclepro.2011.07.005

[48] Wu, K.Y. (2008) Comprehensive Evaluation on Development of Agricultural Recycling Economy in Chaohu Basin. *China Population*, *Resources and Environment*, **18**, 94-98. (In Chinese)

[49] Jose, M.V. and Ye, Q. (2012) Framing Energy Efficiency and Renewable Energy Policies: An International Comparison between Mexico and China. *Energy Policy*, **51**, 128-137. https://doi.org/10.1016/j.enpol.2012.03.083

[50] Boyd, E., Gutierrez, M. and Chang, M.Y. (2007) Small-Scale Forest Carbon Projects: Adapting CDM to Low-Income Communities. *Global Environmental Change*, **17**, 250-259. https://doi.org/10.1016/j.gloenvcha.2006.10.001

[51] Dogliotti, S., *et al.* (2013) Co-Innovation of Family Farm Systems: A Systems Approach to Sustainable Agriculture. *Agricultural Systems*, **6**, 1-11.

[52] Van, M.H., Van, T.T., Tabeau, A. and Eickhout, B. (2006) The Impact of Different Policy Environments on Agricultural Land Use in Europe. *Agriculture, Ecosystems and Environment*, **114**, 21-38. https://doi.org/10.1016/j.agee.2005.11.006

[53] Rega, C. and Spaziante, A. (2013) Linking Ecosystem Services to Agri-Environmental Schemes through SEA: A Case Study from Northern Italy. *Environmental Impact Assessment Review*, **40**, 47-53. https://doi.org/10.1016/j.eiar.2012.09.002

[54] Khalid, Z., *et al*. (2012) The Relationship between Agricultural Technologies and Carbon Emissions in Pakistan: Peril and Promise. *Economic Modelling*, **29**, 1632-1639. https://doi.org/10.1016/j.econmod.2012.05.024

[55] Dou, X.S. (2015) Essence, Feature and Role of Low-Carbon Economy. *Environment, Development and Sustainability*, **17**, 123-136. https://doi.org/10.1007/s10668-014-9542-9

[56] Zheng, Z.N. and Liu, D.S. (2003) Clean Development Mechanism: A New Kind of International Environmental Cooperation Mechanism (Ⅰ). *Energy-Saving and Environmental Protection*, **4**, 10-13. (In Chinese)

[57] Zheng, Z.N. and Liu, D.S. (2003) Clean Development Mechanism: A New Kind of International Environmental Cooperation Mechanism (Ⅰ). *Energy-Saving and Environmental Protection*, **5**, 8-11. (In Chinese)

[58] Chen, Y. (2012) Approaches to Promote China's Low-Carbon Agricultural Development. *Journal of Northeast Agricultural University* (*English* Edition), **19**, 89-92. https://doi.org/10.1016/S1006-8104(13)60058-6

[59] Dou, X.S., Xie, J.J. and Ye, Z.L. (2013) Policy Design and Implementation Issues of Regulating Greenhouse Gas Emissions in China. *International Journal of Environmental Science and Development*, **4**, 321-326. https://doi.org/10.7763/IJESD.2013.V4.363

[60] Thilde, B.B., *et al*. (2009) Environmental Consequences of the Demise in Suidden Cultivation in Southeast Asia: Carbon Storage and Soil Quality. *Human Ecology*, **37**, 388-395.

[61] Huang, G.Q., Wang, X.X. and Qian, H.Y. (2004) The Negative Impact of Fertilizers on Agricultural Ecological Environment and Its Countermeasures. *Ecological Environment*, **13**, 656-660. (In Chinese)

[62] Wang, W.M. (2003) Land Resource Management. Higher Education Press, Beijing. (In Chinese)

[63] Zhang, K.M., Pan, J.H. and Cui, D.P. (2005) On the Low-Carbon Economy. China Environmental Science Press, Beijing. (In Chinese)

[64] Post, W.M., Pastor, J., King, A.W. and Emanuel, W.R. (1990) Aspects of the Interaction between Vegetation and Soil under Global Change. In: Wisniewski, J. and Lugo, A.E., Eds., *Natural Sinks of* CO_2, Kluwer Academic Press, Palmas de Mar, 345-363.

[65] Garcia-Oliva, F. (2004) Assessment and Measurement Issues Related to Soil Carbon Sequestration in Land-Use, Land-Use Change and Forestry Projects under the Kyoto Protocol. *Climatic Change*, **65**, 347-364. https://doi.org/10.1023/B:CLIM.0000038211.84327.d9

[66] Li, X.Y. and Wang, B.B. (2010) Low-Carbon Agriculture: Agricultural Development Road under Dealing with Climate Change. *Rural Economy*, **3**, 10-12. (In Chinese)

[67] Wang, C.F. (2005) Choice of Forestry under Low-Carbon Economy. In: Zhang, K.M., Pan, J.H. and Cui, D.P. Eds., *On the Low-Carbon Economy*, China Environmental Science Press, Beijing, 411-417. (In Chinese)