DOI 10.15302/J-SSCAE-2022.01.006

High-Quality Development of Modern Smart Ecological Agriculture

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Abstract: This study analyzes the upcoming trends of China's agricultural product demand, industrial structure, and labor demand for the next 30 years and proposes that China should insist on developing modern smart ecological agriculture in the future to realize rural revitalization. To ensure national food security and achieve sustainable development of high-efficiency, green, and high-value agriculture, China should promote agricultural efficiency improvement, system optimization, and efficient recycling of resources. It is necessary to reconstruct four systems to achieve this: innovative agricultural science and technology, modern agricultural management, socialized agricultural service, and new-era agricultural personnel systems. Biological, ecological, equipment and information technologies should be innovated to improve the agriculture sector. Furthermore, five major projects are recommended, including a pilot demonstration project for modern smart ecological agriculture, modern production and living waste treatment project, high-quality development, monitoring and evaluation project for the whole agricultural industry chain, planting and breeding combined project led by breeding enterprises, and agricultural and rural personnel nurturing project.

Keywords: agricultural development strategy; modern agriculture; smart agriculture; ecological agriculture

1 Introduction

Agriculture is the foundation for a big agricultural country like China. Since the country's reform and opening-up, agricultural development in China has made great achievements [1]. First, the supply of agricultural products and the ability to guarantee food security have been significantly improved, effectively meeting the growing consumption needs of the people. Second, breakthroughs have been made in the construction of agricultural infrastructure, resulting in a significant improvement in the ability to guarantee agricultural supply. Third, the ability to lead and support agricultural science and technology has been further strengthened, and quality and green agriculture have become the central themes of modern agriculture. Fourth, the agricultural industry pattern has shown new changes. Typically, the digital agricultural economy accounts for 7.3% of the industry's added value, and online sales of agricultural products have reached about 400 billion CNY [2].

With a decisive victory in alleviating poverty and building a moderately prosperous society in an all-around way, as China embarks on a new journey to achieve the second centenary goal, agriculture and rural areas have entered a new historical development period [3]. However, China's agricultural development still faces many problems and challenges [4]. The pressure of food security and maintaining an adequate supply and quality of primary agricultural products always exists [5]. In addition, with the expansion of the large-scale breeding industry, the pressure on the environment continues to increase [6]. Further, with the coexistence of small farmers and large-scale production in

Received date: November 20, 2021; **Revised date**: December 30, 2021

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Fund program: CAE Advisory Project "Strategic Research and Development Roadmap of China's Modern Smart Ecological Agriculture" (2020-ZD-07)

Chinese version: Strategic Study of CAE 2022, 24(1): 038–045

Cited item: Liu Xu et al. High-Quality Development of Modern Smart Ecological Agriculture. *Strategic Study of CAE*, https://doi.org/10.15302/J-SSCAE-2022.01.006

the planting industry, it is very difficult to greatly improve labor productivity and farmers' incomes [7,8]. Moreover, the agricultural production and product circulation systems are struggling to meet consumers' growing diversified and individualized demands for food safety, nutrition, and health. [9,10]. The efficient recycling system of agricultural resources [11] and the talent system supporting future agricultural development are still the shortcomings of China's agricultural development [12]. Apart from these, the spread of the pandemic, the severe recession of the world economy, and the challenges of economic globalization are gradually increasing [13].

In recent years, based on the problems faced by agricultural development in China and the trend of world science and technology development, a group of far-sighted scientists in China has proposed modern biological agriculture from the perspective of introducing modern science and technology to improve agricultural production efficiency [7]. They also proposed efficient ecological agriculture from the perspective of coordinating agricultural production and ecological protection [12]. From the perspective of informatization of the entire industrial chain of agricultural production, concepts and practices such as smart agriculture [8] are proposed; these are expected to solve the above-mentioned problems, thereby ensuring sustainable agricultural development and the safe supply of major agricultural products.

These concepts can all solve the problems faced by China's agricultural development in the future. However, to achieve high-quality agriculture development, a comprehensive development path needs to be explored. Analyzing the achievements and problems of China's agricultural development, drawing on the trend and experience of international agricultural development, and combining the current historic opportunities faced by China's agricultural development, this paper proposes that the basic strategy of developing modern smart ecological agriculture should be adhered to over the next 30 years, to lay a solid foundation for the modernization of the country.

2 Challenges of China's agricultural development in the next 30 years

2.1 Changing trends and challenges of the demand for agricultural products

Agricultural product consumption depends on population size and structure, income level, and consumption habits, among other factors. Based on the relevant literature and currently available data on China's future macroeconomic growth, population size, structure changes, and urbanization and industrialization development levels, it is possible to infer the future trend of China's demand for agricultural products (Fig. 1). As shown in Fig. 1, in terms of demand for planting products, the consumption of grain rations has decreased significantly, and household consumption has gradually shifted to high-value agricultural products. In terms of aquaculture and aquatic products, with the rapid growth of per capita income and the improvement of urbanization, the demand of Chinese residents for high-protein products will continue to grow in the future, and the total and per capita consumption will further increase.

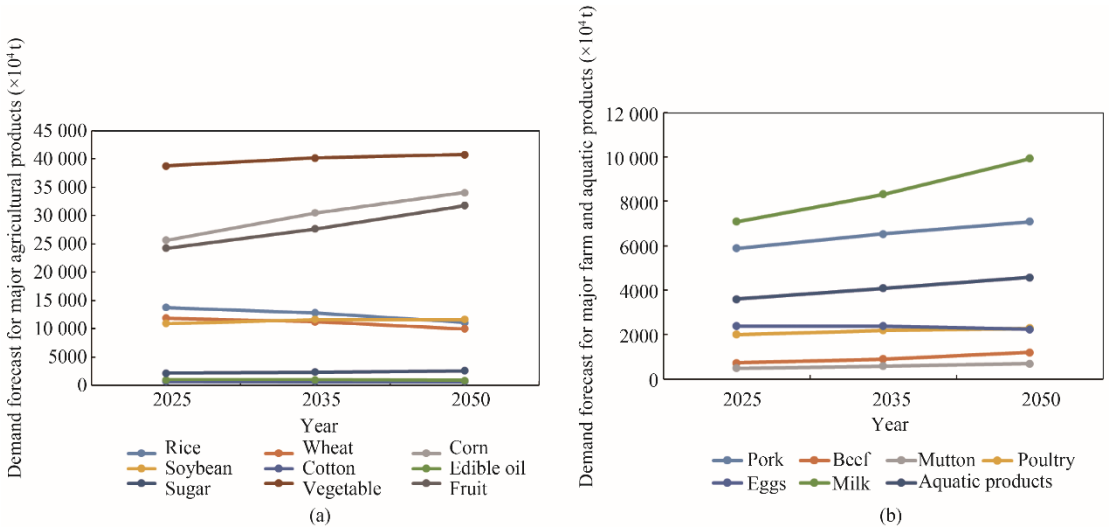

Fig. 1. Demand forecast of main agricultural products in China in the next 30 years.

From the projected changes in food demand in China over the next 30 years, it can be deduced that there will be higher requirements for the total amount, structure, and quality of food, making it difficult to balance the overall food supply and demand. Meanwhile, although population growth has declined significantly, income growth and

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aging will significantly impact agricultural product consumption and agricultural production. Finally, in addition to changes in quantity, the demand for green agriculture and multi-functional agriculture by Chinese urban and rural residents will also continue to increase. The versatility of agricultural production and ecological agriculture will become a demand beyond the agricultural product itself and become a new growth point for agricultural development.

2.2 Changing trends and challenges of the agricultural industry structure

Based on the long-term trend of international agricultural development and China's development experience over the past 40 years, the proportion of China's agricultural output value and employment in the overall economy will further decline in the next 30 years and develop toward convergence (Fig. 2). First, with the further growth of China's economy and the continuous improvement of agricultural production efficiency, the structural transformation of China's macroeconomy toward non-agricultural activities will continue to accelerate. It is observed that the economic growth of the agricultural sector is accompanied by a continuous decline in its share. Second, from the perspective of the long-term trend of international agricultural development, with improvement in agricultural production efficiency, China's agricultural GDP and labor force will continue to decline with the transformation of the economic structure and gradually develop toward convergence.

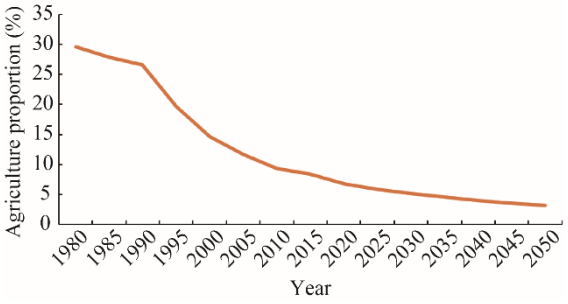

Fig. 2. Predicted proportion of agricultural GDP in China in the next 30 years.

Improving long-term total factor productivity in agriculture is always a meaningful way to solve the contradiction between the limited supply of resources and growing food demand. It is also an important means to realize "grain storage in the land and in technology." In addition to technical, institutional, and policy factors, the slowdown in agricultural total factor productivity growth is also constrained by existing agricultural production methods, business models, and factor market distortions. Our analysis shows that existing production methods limit the realization of economies of scale in agricultural production and mechanization promotion. The extension of the agricultural industry chain is insufficient and the cross-link distribution of value-added agricultural products is unreasonable. Factor market distortions lead to a mismatch between land and labor resources.

2.3 Changing trends and challenges of agricultural labor demand

From the perspective of the law of world economic development, with the economy's growth, the total agricultural labor force in a country and its proportion to social employment will continue to decline. Due to the differences in income between different industries, the proportion of agriculture in the total national economy will gradually shrink with economic development, and employees in the agricultural sector will gradually shift to industry and service sectors. Since the reform and opening up, the total agricultural labor force and its proportion in China have shown a downward trend; however, unlike in developed countries, the decline is much slower than the proportion of agriculture in the economy (Figs. 2 and 3). In the new era, further improving agricultural labor productivity and reducing the number of employed people in the agricultural sector are the inevitable choices for China to successfully realize the transformation and modernization of agriculture and rural areas. Agricultural GDP and the proportion of labor employment will continue to decline with the transformation of the economic structure and will gradually develop toward the direction of convergence.

Although China's agricultural employment in the total number of social employment has dropped significantly in the past 40 years, the proportion of agricultural employees will still face enormous challenges from the current 25% to 4% in the next 30 years. In addition, institutional mechanisms for the cultivation and use of high-quality labor in the agricultural sector have not been established. At present, the system and mechanism for cultivating a high-quality

agricultural labor force in China have not yet been established. As a result, even after receiving agricultural education, most students do not secure employment in the agricultural sector after graduation.

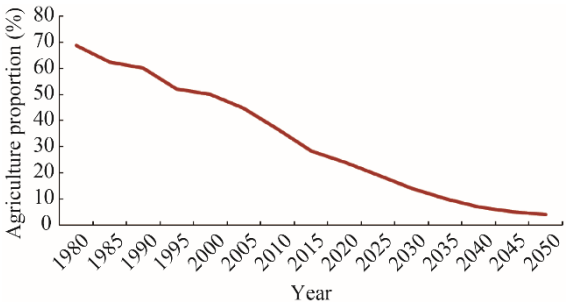

Fig. 3. Predicted proportion of agricultural labor in China in the next 30 years.

3 Trends and opportunities for future agricultural development

3.1 International trends

Contemporarily, a new round of technological revolution is in the ascendant, and new technologies such as gene editing, artificial intelligence, 5G, and blockchain are integrating and leading agricultural reform. International agriculture has gone through the serial development process of mechanization, chemistry, and informatization, and now it has entered a new stage of intelligent and sustainable agriculture.

The Food and Agriculture Organization of the United Nations has successively promoted the Globally Important Agricultural Heritage Systems, Agroecology, and Climate Smart Agriculture programs to increase productivity, enhance adaptability, and use agricultural multifunctionality. The core purpose of these plans is reflected in three aspects: the first is to increase productivity, that is, to introduce new technologies and methods to improve productivity per unit area without destroying the sustainable production capacity of the land. The second is to enhance adaptability, that is, to strengthen the protective role of natural ecosystems in agriculture and building capacity of farmers. The third is to play multiple functions of agriculture, that is, to emphasize the overall improvement of economic, ecological, and social benefits.

At the same time, major developed countries are also accelerating the deployment of smart agriculture, ecological agriculture, and biological agriculture, among others, to seize the commanding heights of agricultural technology innovation and industrial development.

The United States continues to lead in smart field agriculture. Most farmlands in the United States realize intelligent decision-making in the whole lifecycle and production process of agricultural products with the help of the agricultural Internet of Things and big data analysis. Moreover, the United States has defined sensors, gene editing, and precision breeding as key research directions in the *2030 U.S. Food and Agricultural Science and Technology Development Strategy* [14].

The EU countries are gradually “eco-ordering” their agriculture, controlling the production of agricultural products with strict standards and introducing a *Strategic Research Agenda for Agricultural Informatization.* Germany, for example, has fully automated its harvesting process with the help of Industry 4.0 technology, while the Netherlands has made great progress in specialization, automation, and mechanization by developing factory farming in greenhouses, mainly in the flower and vegetable industries, to manage land constraints.

Japan has dramatically increased the commercialization rate of agricultural products through professional division of labor, intelligent management, and brand marketing in the context of a big population and land scarcity, and in 2015 launched the Next Generation Technology for the Creation of Agriculture, Forestry, and Water Industries based on intelligent machinery combined with IT.

3.2 Historical opportunities

Under the current international situation, China’s agricultural development has ushered in a new historic period, which is manifested in the following aspects.

First, the achievement of the task of poverty eradication and building a moderately prosperous society, the prominent contradiction between the people’s growing need for a better life and unbalanced and insufficient development, and the entry of agricultural development into a period of comprehensive implementation of the rural

DOI 10.15302/J-SSCAE-2022.01.006

revitalization strategy.

Second, as the national food security strategy that emphasizes domestic production capacity, moderate imports, and scientific and technological support is implement, basic self-sufficiency in cereals and absolute food security are ensured. As such, agricultural development has entered a period when more attention is paid to the quality of agricultural products and food safety, as well as meeting diversified and personalized demands.

Third, modern biotechnology, information technology, and equipment technology have made breakthroughs; modern seed industry, intelligent agriculture, multi-functional agriculture, and other models are developing rapidly; and agricultural development has entered a period of modernity, with intelligence and socialization as its hallmarks.

Fourth, ecosystem service functions and regional ecological security are of great concern, and the development concept of "lucid waters and lush mountains are invaluable assets" is gradually gaining popularity, with agricultural development entering a period of economic, ecological, and cultural multi-functional coupling, along with green development with recycling, diversity, efficiency, and sustainability as the main features.

In this context, to realize the vision of sustainable and robust agriculture, rich and decent farmers, and a beautiful and ecological countryside, it is necessary to not only increase the output of products but also improve their quality and ensure food safety. It is also necessary to increase the output of land, obtain economic benefits, give full play to the ecosystem's various environmental services, and promote sustainable rural development. Meanwhile, the quality of agricultural products and the competitiveness of domestic and international markets should be promoted to keep abreast of the frontiers of international agricultural technology and management development.

4 Development path of modern smart ecological agriculture

Standing at the historic intersection of the two centenary goals, based on both the experiences and problems of agricultural development as well the expected future development trend, this study concluded that the development of modern smart ecological agriculture is an inevitable choice for China over the next 30 years. It is an essential foundation for building a socialist modern state that is rich, strong, democratic, civilized, harmonious and beautiful. To consolidate agricultural and rural development, China should promote three strategies—efficiency enhancement, system optimization, and efficient resource circulation—and restructure the innovative agricultural science and technology system, modern agricultural management system, socialized agricultural service system, and agricultural talent system in the new era, thereby ensuring that the two goals of guaranteeing national food security and sustainably developing efficient, green and high-value agriculture are achieved.

4.1 The concept

The path of modern smart ecological agriculture significantly improves agricultural productivity and efficiency through advanced technology and production methods; realizes the scientific linkage of production materials before production, precise allocation of production factors during production, and perfect matching of supply and demand for products after production through artificial intelligence, big data, and cloud computing; and realizes efficient use of resources and sustainable improvement of ecological functions through the circulation of material systems in production systems.

Development of modern wisdom and ecological agriculture considers ecology as the key factor and wisdom as the means, and uses high-tech support to achieve: (a) synergy and co-prosperity of production, ecology, and life; (b) coupled development of biology, information technology, and equipment technology; (c) integration of modernization, intelligence, and ecology; and (d) co-improvement in efficiency, effectiveness, and effect.

Modern smart ecological agriculture advocates a "new concept" of efficiency improvement and the sustainable use of resources; promotes a "new way" of closely coupling production, technology, ecology, and information elements; builds a "new model" of regional intelligent ecological agricultural development suitable for different ecological zones; cultivates "new farmers" who can produce, operate, and manage agriculture; and develops a "new business model" of agricultural and rural digital economy development that integrates the three agricultural industries and urban and rural areas.

4.2 Development goals

The core idea behind developing modern smart ecological agriculture is the achievement of two fundamental goals.

The first goal is to ensure national food security, that is, to establish the bottom line of basic self-sufficiency in cereals and absolute food security, achieve food security autonomy and control, and ensure food safety and

nutritional health. By 2050, the self-sufficiency rate of cereals should exceed 85%, of which the self-sufficiency rate of rations should be more than 95%. The scale and modernization of food production will be realized based on innovations and breakthroughs in information technology, biotechnology, and equipment technology.

The second goal is to simultaneously realize high-efficiency, green, and high-value agriculture, and achieve sustainable development with optimized configuration of the agricultural industry system, efficient use of resource recycling, and continuous improvement of ecological functions. By 2050, the production of green, safe, and nutritious vegetables and fruits will increase significantly. The efficiency of agricultural water use will also increase significantly. The soil quality will improve once soil quality degradation is fundamentally curbed. Cost-effectiveness and efficiency of agricultural production will increase significantly. Waste will be recycled harmlessly, and agricultural surface pollution and greenhouse gas emissions will decrease steadily. Agricultural production will be carbon neutral, and the ecological environment will be fundamentally improved. Finally, a sustainable development pattern of agriculture will be formed with efficient resource utilization, a good production environment, and beautiful scenery.

4.3 Development strategies

The key to developing modern smart ecological agriculture is to continuously promote three major strategies.

The first is the efficiency improvement strategy. China needs to guarantee its red line of farmland area, constantly make breakthroughs in food technology, and effectively innovate food policies. The innovation and application of the biological seed industry, biological products, and biological waste disposal (biological treatment of waste) should be strengthened. Apart from this, a modern, scientific, and technological innovation system of intelligent ecological agriculture should be established. The complete mechanization of agricultural production, equipment intelligence, service socialization, and prudent management needs to be promoted vigorously to realize the modernization of agricultural production and processing. Further, China should develop new technologies and models of agricultural resource utilization, ecological restoration, and environmental protection, and enhance the productivity of agricultural resources and the ecological value of agricultural systems.

The second is the system optimization strategy. This refers to the use of multi-omics integrated technology to analyze the formation mechanism of biological substances and precisely regulate the production and development of plants and animals and their metabolic pathways, establish a modern intelligent ecological agricultural production system, realize precise planting and breeding, improve the efficiency of agricultural resources utilization and agricultural production, and gradually promote the application of intelligent agricultural technology in the whole process of agricultural production. It is also necessary to build a smart supply chain for agricultural products, improve the efficiency of agricultural products circulation, meet the personalized and diversified consumption needs of urban and rural residents, build a smart integrated agricultural and rural information service network, and promote the scientific allocation of science and technology, talent, land, capital, and other factors.

The third is the resource-efficient recycling strategy. We should explore agro-ecosystems such as diversified planting, combined farming and breeding, agroforestry compounding, and landscape optimization to achieve an effective circulation of materials in agricultural production systems. Alongside, we should promote the application of technologies such as biological disposal of waste and precise control of water and fertilizer to achieve waste treatment in the entire process, thereby reducing the environmental impact of agricultural production. Meanwhile, this strategy can also improve the function of agricultural ecosystems and the ecology of agricultural production through the optimal allocation of regional resources, ecology and industrial layout, and the expansion of agricultural functions.

4.4 Policy approaches

In the development of modern smart ecological agriculture, the main goal is to reconstruct the four agricultural development systems.

The first is the innovative agricultural science and technology system. A science and technology innovation system adapted to the development of modern smart ecological agriculture as well as an interdisciplinary technology innovation mechanism should be constructed. Following this, investment in research and development of core technologies and key bottleneck technologies to develop modern smart ecological agriculture should be increased. The research and development and innovation capabilities in the fields of biological breeding and key gene discovery, intelligent agricultural machinery and equipment, green input creation, food nutrition and health improvement, intelligent agricultural product supply chain, agricultural ecological function enhancement, and agricultural

DOI 10.15302/J-SSCAE-2022.01.006

environmental protection should be significantly enhanced to grasp the initiative of international competition and achieve comprehensive independent innovation of modern agricultural technology.

The second is the modernized agricultural business system. China should adhere to and improve the basic rural management system, guide the standardized and orderly transfer of land management rights, and reduce the transaction costs of agricultural land transfer through modern information technology and management techniques. Supporting the development of large farmers, family farms, farmers' cooperatives, agriculture-related enterprises, and other new business entities can also promote various forms of moderate-scale operations and specialized production. In addition, we should also develop a new industry, that is, the digital economy of agriculture and rural areas with the integration of three industries and urban–rural integration.

The third is the socialized agricultural service system. It is necessary to develop new specialized and socialized service systems with full coverage, regional integration, and complete support by way of intelligent agricultural machinery and equipment services, precise agricultural production technology services, and financial services for agricultural production and marketing systems. We should also establish and improve the integration mechanism between modern agricultural production and cross-border technological innovation and extension services, and collaborate to promote the modernization of small and big farmers simultaneously. It is also important to promote the synergistic development of agricultural industry chain services and agricultural production through supply chain innovation, and create a favorable development environment for modern high-value agriculture.

The fourth is the new era of the agricultural talent system. It is necessary to strengthen the revitalization of rural talents and cultivate a group of agricultural management talents who know about agriculture and like working in rural areas, further promote higher education for agricultural reform, strive to break down the barriers between various disciplines, and cultivate a group of interdisciplinary and complex agricultural science and technology talents. We should also gradually implement a vocational qualification certification system for farmers and implement a lifelong education project to create a group of new professional farmers who can participate in agricultural production, are good at management, and know business.

4.5 Technical approaches

The focus of developing modern smart ecological agriculture is to innovate four technical systems.

First, innovating biotechnology to transform agriculture. Modern agricultural biotechnology, closely related to industrialization, mainly includes transgenic technology, gene-editing technology and gene sequencing and analysis, molecular design of breeding biochip technology, and molecular marker technology for the selection and breeding of new varieties of animals and plants. It also includes atomic transfer radical polymerization technology for biological waste treatment, enzyme engineering technology for biological manufacturing, fermentation engineering technology, and biosynthesis technology.

Second, innovating equipment technology to strengthen agriculture. In the future, China's agricultural equipment technology should be oriented to the main food and cash crops, facility agriculture, animal husbandry, agricultural waste processing and utilization, and other production links of intelligent and precise production needs. According to the characteristics of agricultural production in different regions and agronomic requirements, we must research intelligent equipment technology for precision operations, and build information, Internet of things, satellite positioning, and other equipment technologies as the core of intelligent technology and equipment system of agricultural machinery.

Third, innovating ecological technology to support agriculture. Our agricultural ecological technology system should be based on the principle of ecological suitability, starting from the rationalization of the structure of the ecological and economic system. It is necessary to (1) innovate precise technical systems for resource inputs such as water and land resources, chemical fertilizers, and pesticides; (2) innovate the material recycling technology system, represented by forest economy and agroforestry compound management, inter-planting, and other compound planting technologies; (3) innovate species symbiosis technology system, represented by ecological cultivation in rice fields and fish-vegetable symbiosis; and (4) innovate the technology system of sustainable utilization and protection of biodiversity.

Fourth, innovating information technology to enhance agriculture. Currently, a new generation of information technology represented by the Internet, Internet of Things, big data, cloud computing, artificial intelligence, and blockchain is flourishing and interpenetrating with modern agriculture. This has given birth to a new industry and model of smart agriculture, which continues to establish more advanced productivity, production methods, and economic forms for modern agriculture. From the perspective of application areas, it can be summarized as crop

information acquisition technology, intelligent agricultural production management, intelligent circulation of agricultural products, monitoring and evaluation of agricultural decarburization, agricultural consultation and decision making, and intelligent agricultural knowledge services.

4.6 Engineering approaches

The development of modern smart ecological agriculture requires the construction of five major projects.

First, a pilot demonstration project of modern smart ecological agriculture. Based on the characteristics of agricultural production in each province, we will explore the roadmap for the county-wise deployment of the "three strategies," the institutional innovation for the construction of the "four systems," and the specific programs and safeguards for the implementation of the "five projects," as discussed above. The implementation plan will be completed in 2022, and a replicable model will be built and widely promoted in the 14th Five-Year Plan.

Second, the creation of an enterprises-led planting–breeding combination mode. It is necessary to establish a large-scale ecological agriculture model with farming enterprises as the main body, material recycling as the core, and integrated farming and local waste consumption, and explore the market operation mechanism of government guidance, enterprise, and farmer cooperation with 10%, 30%, and 80% coverage in 2025, 2035, and 2050, respectively.

Third, the modern production and domestic waste treatment project. It is necessary to implement standardized management of production and harmless treatment of domestic waste based on biological and other technologies, implement the soil ecological health cultivation project, establish a major national research and development project on biological waste disposal, and cultivate and grow the waste treatment industry. The standardized management and waste treatment industry will be created and improved in 2025, and waste treatment should be at 80% and 100% capacity in 2035 and 2050, respectively.

Fourth, the project of monitoring and evaluating high-quality development of the whole agricultural industry chain. It is necessary to first research on key technologies of agriculture-related data collection and integration analysis; accordingly, we must build a large data monitoring platform and create evaluation standards for high-quality development of the whole agricultural industry chain. In 2025, it will cover the main agriculture-related departments and more than 50% of production and operation subjects; this will then increase to 80% in 2035.

Lastly, the agricultural and rural talent cultivation project. It is necessary to start upgrading agricultural education in higher education institutions to train students for innovation in agricultural research, thereby encouraging the cultivation of high-quality farmers, as well as of high-quality rural management and management talents. The aim is to create a replicable model by 2025 and build a talent cultivation and management system that can effectively support the modernization of agriculture and rural areas by 2035.

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