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Research Article

Analysis on Scientific and Technological Innovation of Grain Production in Henan Province Based on SD-GM Approach

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A sustainable growth of grain outputs mainly relies on improving output per unit area through scientific and technological innovation. From the perspective of scientific and technological innovation, taking the grain production process as the research object, a systems model of scientific and technological innovation in grain production is constructed based on the relevant data of Henan Province from 2010 to 2019. Firstly, the internal mechanism of grain production scientific and technological innovation is explored, and the feedback loop of grain production scientific and technological innovation is then established. Secondly, system dynamics and grey system theory are combined to construct table functions and logistic functions to establish the grain production scientific and technological innovation system model. Through testing the model, the stability and feasibility of the model are demonstrated, and the simulation and prediction of the innovation system of grain production scientific and technological in Henan Province are carried out. Thirdly, in order to explore the impact of feasible policy schemes on grain production, seven policy plans are designed to simulate grain production policy scenarios from the perspective of scientific and technological innovation. The results show that: (1) The adjustment of individual policies, especially the adjustment of the protection policy of scientific and technological innovation in grain production or the subsidy policy of agricultural materials, has a weak influence on the improvement of grain output. The progress of agricultural technology is the main support for improving the comprehensive grain production capacity. (2) The future grain growth potential of Henan Province should focus on increasing the yield per unit area, and the protection of cultivated land resources should not be ignored. (3) The combination of policies has mutually reinforcing effect, which leads to an ideal system simulation effect. Finally, from the perspective of the composition of scientific and technological innovation system in Henan Province, this study puts forward countermeasures and suggestions for the implementation of the strategy of "storing grain in technology" in Henan Province.

1. Introduction

With the diminishing role of factor input drivers, the increasing resource, and the environmental constraints, how to accelerate the transformation of grain production methods, ensure grain security, and realize agricultural modernization and sustainable resources is a realistic problem that must be solved [1]. Under the growth of the traditional grain production model, which is driven by inputs such as pesticides and fertilizers, being unsustainable, scientific and technological innovation is bound to become the leading force in the modernization of grain production and in ensuring grain security. Since the "Thirteenth Five-Year Plan," the contribution rate of China's agricultural scientific and technological progress has exceeded 60%, and the contribution rate of scientific and technological progress to agricultural growth has exceeded the sum of land, capital, and all other factors. China's grain outputs per unit area have increased from 1,029.33 kg/hm^2 in 1949 to 5,734.00 kg/hm^2 in 2020, which has been greatly improved. Agricultural scientific and technological innovation is becoming the foundation of the core competitiveness of modern agriculture, the source of endogenous backbone, and the basis of transformation and upgrading. According to the survey data of the Ministry of Agriculture and Rural Affairs of the People's Republic of China, in 2019, China vigorously promoted the development of agriculture through science and education and achieved remarkable results. It is estimated that, under the same production conditions and without any increase in investment, the increase in grain outputs can be more than 10% just by increasing the rate of agricultural technology to household [2]. Therefore, relying on the modernization of agricultural production and the progress of agricultural technology to improve the output efficiency of production factors is the main way to achieve grain security and sustained growth of agricultural economy [3]. Henan is the first agricultural province and the first grain-producing province in China, and is the core area of national grain production. With 1/16 of China's cultivated land, Henan has produced 1/10 of the grain, which not only solves the problem of grain ration problem of the people in the whole province but also realizes the sustainable development of grain production and at the same time makes an important contribution to ensuring China's grain production security. The strategic position of agricultural scientific and technological innovation in Henan Province is prominent, however, the development of agricultural scientific and technological innovation in Henan Province still suffers from insufficient synergy of agricultural scientific and technological innovation, and insufficient effective supply of agricultural scientific and technological innovation. Therefore, it is crucial to explore the scientific and technological innovation system of grain production in Henan Province to ensure grain security.

In order to ensure the steady growth of grain output, many agricultural practitioners, managers, and academic researchers have made in-depth research on the driving factors and internal principles of agricultural production technology progress. Scholars have done more research on grain security, grain production, and agricultural scientific and technological innovation by using the system dynamics theory [4]. Kim [5] has constructed a simulation model of the food-energy system based on system dynamics method, which can be used to analyze the global grain market and energy market. He and Liu [6] constructed a grain production system dynamics model by analyzing the relationships of key factors affecting grain production and the interaction between factors and grain production. Based on the theory of system dynamics, Xu et al. [7, 8] simulated and analyzed the grain security situation in Jiangsu Province and concluded that accelerating the popularization of agricultural scientific and technological innovation and improving grain output are the fundamental ways to ensure grain security in Jiangsu Province. Lei and Zhan [9] established a system dynamics model of comprehensive coordination between environmental resources and grain production, and explored the reasonable combination mode of taking grain self-sufficiency rate and grain reserve rate as target adjustment indicators. Many scholars have also built a dynamic simulation model under grain security from the perspective of cultivated land to establish a macro farmland control system in order to achieve the goal of grain security [10–12]. Research results at home and abroad show that the system dynamics is well adapted to the portrayal of WEF Nexus [13]. Based on the system dynamics theory, Li et al. [14], Wang et al. [15], and Wang et al. [16] established Water-Energy-Food Nexus simulation models to explore the rational allocation scheme of WEF synergistic development in various cities. Based on SD model construction and simulation to analyze the structure of China's grain crop mechanized production system, Li et al. [17] found that economic development level, land management scale, and agricultural labor force transfer are the main factors affecting the grain crop mechanized production system. Based on multivariate statistics and system dynamics, Mo et al. [18] constructed the dynamic model of agricultural structure in various cities of Shandong Province, predicted the change trend of its agricultural structure, and proposed that it is urgent to increase agricultural scientific and technological investment in order to further promote the adjustment of agricultural structure in various cities. He et al. [19] designed a grain system model based on system dynamics and constructed an SDSOP model by combining analytic hierarchy process (AHP) and objective programming model, which ultimately determined that the optimization of China's grain system would be realized in 2030. Aboah and Setsoafia [20] explored the synergistic effect of cocoa-plantain intercropping system on farmers' gross margin in Ghana based on SD model and suggested that farmers could shift production inputs from growing high-value crops to staple food crops to increase the synergistic effect of intercropping.

Grey system theory is founded by Chinese scholar Prof. Julong Deng in 1982. Because of its capability in mining new information from grey data, it has quickly attracted the attention of various fields of social economy. There have been a large number of scholars applying grey forecasting series models to forecast and analyze grain production and grain yield [21–23]. Ma et al. [24] used LASSO model to screen out the factors that have a significant impact on grain production, and built China's grain production prediction model GM (1, 6). The research shows that the input structure of agricultural production is not reasonable, and the improvement of grain outputs depends on the progress of scientific and technological and the improvement of planting technology. Taskeen and Yasir [25] used grey level co-occurrence matrix (GLCM), radial basis function (RBF) of support vector machine (SVM), and other data mining technologies to build an automatic weed detection system, thus increasing rice outputs and reducing production costs. Yang and Li [26] screened out the index system of factors influencing grain yield, and constructed a grey interval forecasting model to forecasting the demand of major grain varieties in China. At the same time, many scholars have made use of grey models to analyze the level of agricultural scientific and technological innovation, which provides technical basis for exploring the development of agricultural scientific and technological innovation [27, 28].

Scholars at home and abroad have produced a wealth of research results on grain production, and have made detailed research on grain yield, grain security, and agricultural scientific and technological innovation, which provides a good research idea for this study. Incomplete and uncertain information of scientific and technological innovation in grain production exists widely, which is a complex system process with part of information known and part of information unknown. However, the traditional research methods have fragmented the links between the elements of scientific and technological innovation system in grain production, ignoring the influence of synergy among factors that improve the level of scientific and technological innovation and the dynamic feedback law. Therefore, this study combines system dynamics with grey system theory, drawing on the characteristics of SD as a dynamically processing complex relationships among variables and grey system as uncertain system with "small samples and poor information," to study the impact of scientific and technological innovation on grain production from a system perspective, considering the feedback relationships between the constituent elements and their relationship with the behavior of the system as a whole. To explore the essential characteristics of grain production scientific and technological innovation system structure, construct a model of grain production scientific and technological innovation system, and comprehensively evaluate the scientific and technological innovation system of grain production in Henan Province.

The rest of the study can be divided into the following sections. In Section 2, the research methods of this study are given and the scientific and technological innovation system model of grain production in Henan Province is constructed. In Section 3, the model of Henan Province's grain production scientific and technological innovation system is tested. In Section 4, considering scientific and technological innovation, seven scenarios of different grain production policies are simulated. Conclusions and future work are then discussed in Section 5.

2. Scientific and Technological Innovation Model of Grain Production Based on SD-GM

2.1. Analysis Method

2.1.1. System Dynamics. System Dynamics (SD) is a computer technology that simulates the structure and dynamic behavior of society, economy, and ecosystem. It emphasizes the use of a systemic, holistic as well as developmental and movement perspective, combining qualitative and quantitative analysis, to achieve the study of the internal structure of the system under study and its dynamic behavior relationships with the help of computer simulation techniques, which is suitable for dealing with complex and nonlinear relationships among variables [29].

The basic methods of system dynamics include feedback loop, stock-flow diagram, equations, and simulation platform. Among them, the feedback loop uses feedback chain to represent the logical relationship among system elements, and more than two feedback chains are connected end to end to form a feedback loop. The positive and negative polarities in the feedback chain represent positive and negative effects, respectively, which are positive and negative feedback loops. The relationship diagram composed of several positive and negative causal circuits is called causal circuit diagram. Flow diagram, also known as stock-flow diagram, quantifies the drawn model based on feedback loop graph, which mainly includes state variables, rate variables, auxiliary variables, and constants. Based on analyzing the properties of various elements of the system and their mutual relations, a simulation model which can describe the system structure or behavior process and has certain logical relations or mathematical equations is established, and then experiments or quantitative analysis are carried out.

2.1.2. Grey System Model. Grey system theory is a new method to mining "partial" known information in a "small samples and poor information" uncertainty system with "partial information known, partial information unknown" as the research object.

Grey incidence analysis is one of the two cornerstones of grey system theory. Its essence is to model the time series or cross section data of the system on the basis of distance space and topological space. This method is equally applicable to the number of samples and whether there are obvious rules in the samples. Moreover, the calculation is simple and convenient, and there is usually no discrepancy between quantitative results and qualitative analysis results. At present, the commonly used grey incidence models are mainly Deng's incidence degree [30], grey incidence of B-mode [31], grey incidence of C-mode [32], generalized incidence degree [33], grey slope incidence degree [34], and three-dimensional dynamic grey incidence model [35]. GM series prediction model is the basic model of grey prediction theory, especially the grey GM (1, 1) model put forward by Prof. Deng, which is widely used because of its features of small data, easy operation, and high accuracy in the short-term prediction. Its main principle is to accumulate the original series, so that the generated data series has a certain quasi-exponential law, and the new series generated by accumulation eliminates the randomness and instability of the original series to a great extent. The trend line corresponding to the new series can be approximated by exponential function curve, and then the system can be predicted by using the approximated curve as a model. According to the data characteristics of the scientific and technological innovation system of grain production, this study chooses the classical EGM (1, 1) model to combine with SD for prediction.

Specific calculation steps of classical EGM (1, 1) model are as follows:

(1) In this paper, the observed value of the system behavior sequence, i.e., the original data sequence is

$$X^{(0)} = \left\{x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)\right\}. \quad (1)$$

(2) Accumulate the original data once to obtain the 1-AGO sequence as follows:

$$X^{(1)} = \left\{x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(n)\right\}. \quad (2)$$

where, $x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), k = 1, 2, \ldots, n.$

(3) Let its mean generation sequence be

$$Z^{(1)} = \left\{z^{(1)}(1), z^{(1)}(2), \ldots, z^{(1)}(n)\right\}. \quad (3)$$

where, $z^{(1)}(k) = 1/2\,(x^{(1)}(k) + x^{(1)}(k-1))$, $k = 2, 3, \ldots, n$.

(4) The EGM (1, 1) model is

$$x^{(0)}(k) + az^{(1)}(k) = b. \quad (4)$$

where $-a$ is the development coefficient and b is the grey action.

(5) The first-order linear differential equation of $X^{(1)}$ is

$$\frac{\mathrm{d}x^{(1)}(t)}{\mathrm{d}t} + ax^{(1)}(t) = b. \quad (5)$$

(6) The parameter vector $\hat{a} = [a, b]^T$ is obtained by the least square method:

$$\hat{a} = \left(B^T B\right)^{-1} B^T Y. \quad (6)$$

where $Y = \begin{bmatrix} y^{(0)}(2) \\ y^{(0)}(3) \\ \vdots \\ y^{(0)}(n) \end{bmatrix}, B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n) & 1 \end{bmatrix}$.

(7) The time response of the EGM (1, 1) model is

$$\hat{x}^{(1)}(k) = \left(x^{(0)}(1) - \frac{b}{a}\right)e^{-a(k-1)} + \frac{b}{a}, \quad k = 1, 2, \ldots, n. \quad (7)$$

(8) Regressive reduction:

$$\hat{x}^{(0)}(k) = \hat{x}^{(1)}(k) - \hat{x}^{(1)}(k-1), \quad k = 2, 3, \ldots, n. \quad (8)$$

(9) The grey prediction model of the original sequence is

$$\hat{x}^{(0)}(k) = \left(1 - e^{a}\right)\left(x^{(0)}(1) - \frac{b}{a}\right)e^{-a(k-1)}, \quad k = 1, 2, \ldots, n. \quad (9)$$

Cobb–Douglas production function [36] was first proposed by mathematician C. W. Cobb and economist Paul H. Douglas, and later refined by economists such as Robert Merton Solow to be widely used in the empirical study of inputs and outputs of production activities. In this study, based on the C-D production function, the combination obtained by integrating the grey system model into the C-D production function is used to study the scientific and technological innovation system of grain production. By taking the simulated value of GM (1, 1) as the original data of least square regression, the parameter estimation error caused by data fluctuation is eliminated to a certain extent, so the grey production function is more satisfactory in practice.

However, the grey system studies non-dynamic and discrete problems, while the scientific and technological innovation of grain production is a dynamic and rising process. Therefore, this study regards the behavior pattern of grain production scientific and technological innovation system as determined by the information feedback mechanism within the system. Grey system theory is combined with system dynamics, to establish a dynamics system model of the scientific and technological innovation of grain production. A simulation system is implemented using DYNAMO simulation language and Vensim software. The dynamic relationship among the system organization, function, and behavior is studied for a better system structure.

To sum up, the construction steps of grain production scientific and technological innovation model based on SD-GM are as follows:

Step 1. System analysis. Exploring the relationship between variables of scientific and technological innovation system in grain production.

Step 2. Structural analysis. Constructing feedback loops diagram of scientific and technological innovation system in grain production.

Step 3. Model construction. Draw the stock-flow diagram of scientific and technological innovation system in grain production, and construct system equations and table functions.

According to the data characteristics and its growth rate, the corresponding table function is constructed. Referring to equations (1)–(9), the EGM model and system auxiliary variables are used to construct the equation of amount of change in expenditures and amount of change of personnel. The output ability index model is then constructed based on grey system theory and C-D production function:

$$\hat{Y} = Ae^{\delta}\hat{F}^{\alpha}\hat{P}^{\beta}\hat{M}^{\gamma}\hat{E}^{\mu}, \quad (10)$$

where $\hat{Y}$ is the GM (1, 1) simulation value of grain output per hectare, $\hat{F}$ is the GM (1, 1) simulation value of fertilizer input per hectare, $\hat{P}$ is the GM (1, 1) simulation value of pesticide input per hectare, $\hat{M}$ is the GM (1, 1) simulation value of man-machine dynamic index, and $\hat{E}$ is the GM (1, 1) simulation value of expenditures input per hectare.

Step 4. Model accuracy test. Through simulation, the model is constantly debugged, checked, modified, and improved.

Step 5. Outputs the simulation and prediction results.

Step 6. Policy analysis. According to the characteristics of the model and the problems to be solved, by setting different scenarios, and comparing the simulation results with the results, to find a more reasonable solution to the problems and provide decision-making reference for policy makers.

2.2. Causal Circuit Diagram. In this study, the whole scientific and technological innovation of grain production is regarded as a system, and the boundary of the system is the entire scope of Henan Province, and the variables closely

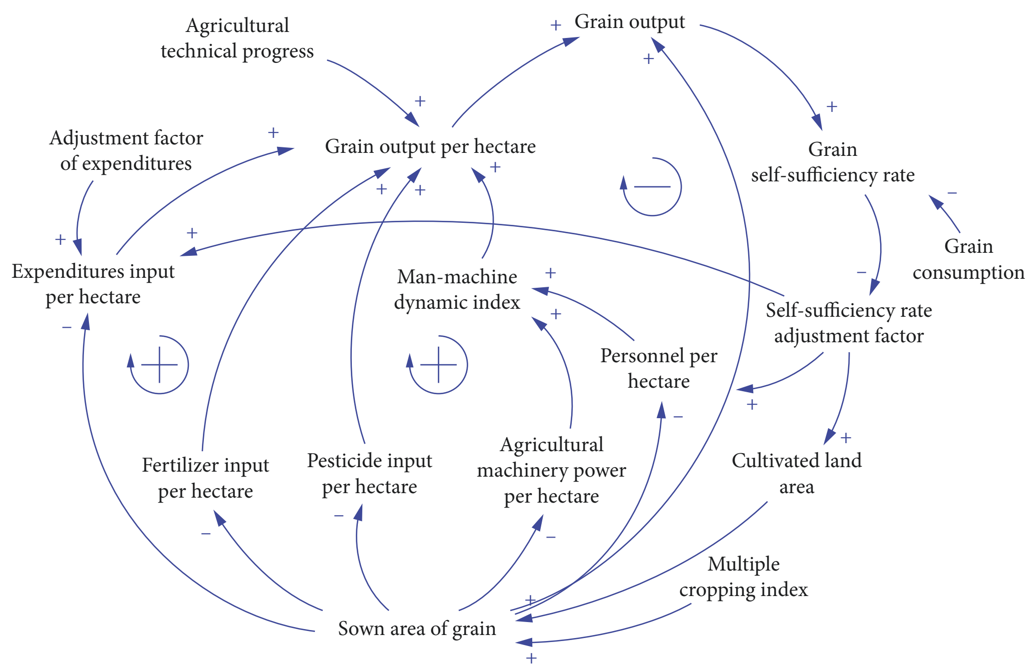

Figure 1: Feedback loop diagram between main variables of the system.

related to scientific and technological innovation in grain production are all included in the boundary to ensure the closedness of the system boundary. This study assumes that the natural production conditions are stable, and based on the research of relevant research documents, identify the influencing factors such as scientific and technological innovation expenditures, personnel, and agricultural technology factors, i.e., the three main factors of “human, financial, and material,” and the feedback loop diagram of the main variables of the scientific and technological innovation system of grain production are constructed as shown in Figure 1.

Loop 1 Grain output $\longrightarrow^{+}$ Grain self-sufficiency rate $\longrightarrow^{-}$ Self-sufficiency rate adjustment factor $\longrightarrow^{+}$ Cultivated land area $\longrightarrow^{+}$ Sown area of grain $\longrightarrow^{-}$ Personnel input per hectare/Fertilizer input per hectare/Pesticide input per hectare/Man-machine dynamic index $\longrightarrow^{+}$ Grain output per hectare $\longrightarrow^{+}$ Grain output. This feedback loop illustrates the input of agricultural technology factors and grain output. When the grain self-sufficiency rate is insufficient, the government can attract farmers and scientific and technical personnel to engage in scientific research on grain production and “new professional farmers” to engage in modern grain cultivation through increased expenditures and protecting policies for scientific and technical personnel in grain production, adding vitality to the grain production scientific and technological talent market through policy subsidies, and agricultural technology progress is improved. The agricultural technological progress is improved, and the efficiency of the use of ecological fertilizers, pesticides, and machinery is enhanced, thus promoting the increase of output and ensuring the safety of grain production. Therefore, Loop 1 is a positive feedback loop.

Loop 2 Grain output $\longrightarrow^{+}$ Grain self-sufficiency rate $\longrightarrow^{-}$ Self-sufficiency rate adjustment factor $\longrightarrow^{+}$ Cultivated land area $\longrightarrow^{+}$ Sown area of grain $\longrightarrow^{+}$ Grain output. The loop shows that the government protects the grain output and the red line of cultivated land by implementing policies such as “storing grain in the land” and adjusting the sown area of grain. The whole feedback loop is negative, when grain self-sufficiency is insufficient, the policy encourages scientific and technological innovation and the protection of cultivated land. By improving the quality and utilization efficiency of cultivated land, it avoids the decline of grain self-sufficiency, and has the function of self-regulation.

Loop 3 Grain output $\longrightarrow^{+}$ Grain self-sufficiency rate $\longrightarrow^{-}$ Self-sufficiency rate adjustment factor $\longrightarrow^{+}$ Expenditures input per hectare/Personnel input per hectare $\longrightarrow^{+}$ Grain output per hectare $\longrightarrow^{+}$ Grain output. This feedback loop is negative feedback as a whole, which reflects the situation of insufficient grain self-sufficiency rate and the demand for grain increases. The implementation of policies such as input of expenditures in scientific and technological and comprehensive subsidies for agricultural materials is an important aspect to improve the efficiency of grain production. When the grain self-sufficiency rate is insufficient, the subsidy policy can be adjusted. That is, when the level of grain self-sufficiency rate drops, the input in expenditures and related subsidy policies can be strengthened, which will increase the number of scientific and technological innovation personnel per hectare, improve the technical level of grain production, and increase the grain output. When the level of grain self-sufficiency increases, the weakening of subsidy policy leads to the transfer of scientific and technological innovation practitioners to other industries, and so this loop has the function of stabilizing grain self-sufficiency.

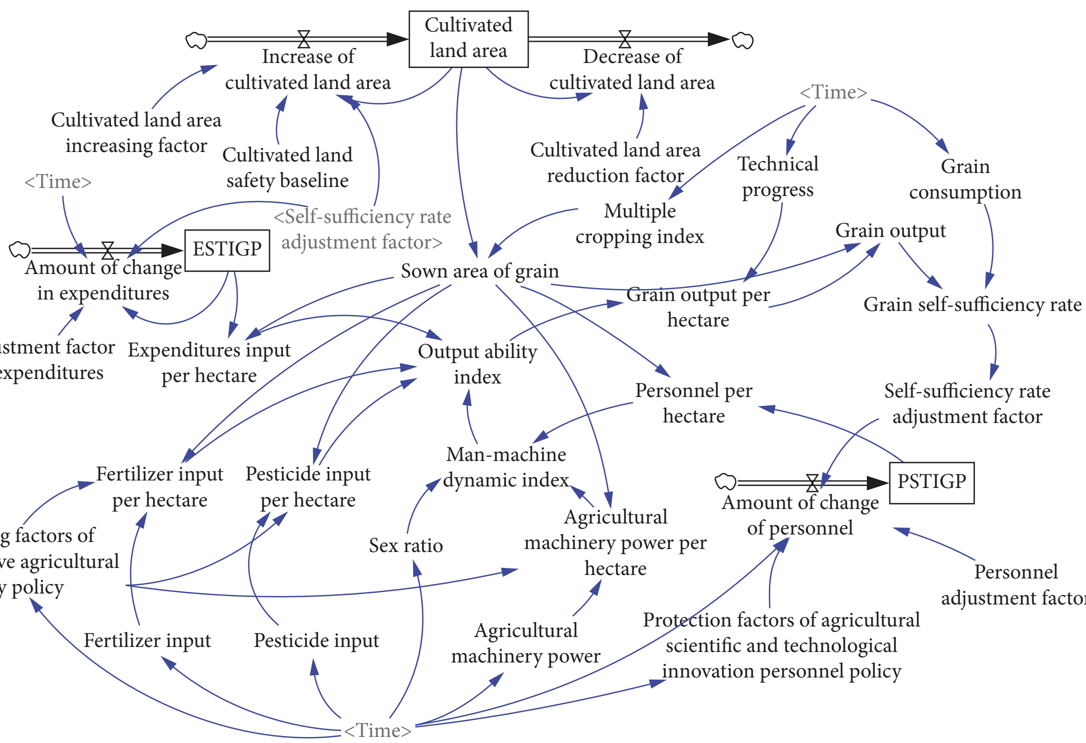

Figure 2: Feedback loop diagram between main variables of the system.

2.3. System Model Construction. Based on the system feedback loop, the system stock-flow diagram is drawn by using the system dynamics software Vensim, as shown in Figure 2. It mainly includes three main factors of the expenditures in scientific and technological innovation of grain production (ESTIGP), agricultural technology factors, and the personnel of scientific and technological innovation of grain production (PSTIGP). Among them, in order to analyze the impact of the corresponding policies on grain production, this study refers to the literature [7, 37] and current policies, and adds corresponding policy factors as auxiliary variables for improving grain output per hectare, scientific and technological innovation, and agricultural technological progress, thus providing ideas for ensuring grain production and realizing grain self-sufficiency.

2.4. Determination of Parameters and Equations. System dynamics mainly emphasizes the structure of the system. The phenomenon of incomplete data exists in the scientific and technological system of grain production, which can be compensated by the characteristics of grey system theory. At the same time, based on the characteristics that grey system theory has no special requirements for data types, it can find the relationship between system elements and construct table functions. The methods to determine the relevant parameters in the system model are mainly as follows: Henan Statistical Yearbook, Henan Scientific and Technological Statistical Yearbook, and China Statistical Yearbook official website data, drawing on the existing relevant literature [18, 38, 39] and estimation method. For variables and equations with nonlinear characteristics, using the advantages of grey production function, grey prediction model, and SD theory, the grey system theory and SD theory are fused to construct table function and logic function [40]. We try to build a grain production system model from the perspective of scientific and technological innovation, and get the main parameters and equations of the system model, as shown in Table 1.

3. Model Test

Any model is a simplification and abstraction of the real world, which has certain errors and cannot fully reflect the reality. Model testing is the main implementation means to ensure the reality and accuracy of the constructed model, and it is also a crucial link in constructing the model. It is a necessary condition to prove the feasibility of a model by testing the model structure, model parameters, and model running results [41].

3.1. Model Structure Test. The behavior of the system is determined by the system model structure. Whether the system is established based on the basic principles and practical experience of the scientific and technological innovation system of grain production is the core of the model structure test [42]. In the scientific and technological innovation system of grain production constructed in this study, the grain self-sufficiency rate affects the personnel, the amount of change of expenditures input and the cultivated land area, which adjusts the sown area and thus affects the grain output. The grain output is also affected by agricultural technical factors, which determines whether the grain

Table 1: Main equations and parameters of system model.

Variable	Equation and logical relation
Grain output	Grain output = grain output per hectare ∗ Sown area of grain/10,000
Cultivated land area	Cultivated land area = INTEG (Increase of cultivated land area – Decrease of cultivated land area, 8177.45)
Increase of cultivated land area	Increase of cultivated land area = max ((Cultivated land safety baseline – Cultivated land area) ∗ Cultivated land area increasing factor ∗ Self – sufficiency rate adjustment factor, 0)
Decrease of cultivated land area	Decrease of cultivated land area = Cultivated land area ∗ Cultivated land area reduction factor
Sown area of grain	Sown area of grain = Cultivated land area ∗ Multiple cropping index
Output ability index	Output ability index = EXP(7.08254) ∗ Man-machine dynamic index^(0.117228) ∗ Fertilizer input per hectare^(1.12496) ∗ Pesticide input per hectare^(−1.2333) ∗ Expenditures input per hectare^(−0.179951)
Man-machine dynamic index	Man-machine dynamic index = Personnel per hectare ∗ Agricultural machinery power per hectare ∗ Sex ratio
Personnel per hectare	Personnel per hectare = PSTIGP/(Sown area of grain ∗ 1000)
Amount of change of personnel	Amount of change of personnel = IF THEN ELSE(Time = 2010, 2309, (1 – EXP (0.124)) ∗ (2309 – 1023.53/0.124) ∗ Personnel adjustment factor ∗ Self-sufficiency rate adjustment factor ∗ EXP (−0.124 ∗ (Time-2010)) ∗ Protection factors of agricultural scientific and technological innovation personnel policy)
Agricultural machinery power per hectare	Agricultural machinery power per hectare = Agricultural machinery power ∗ 10/Sown area of grain ∗ Influencing factors of comprehensive agricultural subsidy policy
Fertilizer input per hectare	Fertilizer input per hectare = Fertilizer input/Sown area of grain ∗ 100 ∗ Influencing factors of comprehensive agricultural subsidy policy
Pesticide input per hectare	Pesticide input per hectare = Pesticide input/Sown area of grain ∗ 1000 ∗ Influencing factors of comprehensive agricultural subsidy policy
Expenditures input per hectare	Expenditures input per hectare = ESTIGP/(sown area of grain ∗ 100)
Amount of change in expenditures	Amount of change in expenditures = IF THEN ELSE(Time = 2010, 54691.6, ESTIGP ∗ (1 + 0.0344972 ∗ Self-sufficiency rate adjustment factor) ∗ Adjustment factor of expenditures)
Grain self-sufficiency rate	Grain self-sufficiency rate = Grain output/Grain consumption

Table 2: Simulation value of grain production scientific and technological innovation system.

Year	ESTIGP (10^4 yuan)	PSTIGP (person)	Sown area of grain (10^3 hm^2)	Grain output per hectare (kg/hm^2)	Grain output (10^7 kg)
2010	228,913.00	15,639.00	9,740.16	5,719.23	5,570.62
2011	283,605.00	17,948.00	9,856.30	5,490.67	5,411.77
2012	305,843.00	18,764.00	10,413.60	5,614.02	5,846.24
2013	329,826.00	19,485.00	10,672.90	5,698.12	6,081.52
2014	355,689.00	20,121.00	10,959.10	5,804.15	6,360.81
2015	383,581.00	20,684.00	11,143.00	5,900.11	6,574.51
2016	412,957.00	20,833.00	11,221.20	5,951.30	6,678.09
2017	444,571.00	20,960.00	10,911.70	6,009.03	6,556.89
2018	478,667.00	21,092.00	10,844.40	6,099.16	6,614.16
2019	515,524.00	21,249.00	10,740.00	6,177.79	6,634.92

Note. The actual values of variables involved in this study are shown in Henan Statistical Yearbook. Among them, the actual value of Grain output per hectare = (Grain output ∗ 10,000)/Sown area of grain, ESTIGP = Internal expenditures on R&D ∗ Gross output value of agriculture/Gross domestic product ∗ Sown area of grain/Total sown area of farm crops, PSTIGP = R&D personnel ∗ Gross output value of agriculture/Gross domestic product ∗ Sown area of grain/Total sown area of farm crops.

production can be self-sufficient. At the same time, in the process of modeling, by looking for relevant literature, based on the internal operation principle of system dynamics and actual data, the grey prediction model and grey production function are used to construct the relationship equation between variables. Finally, the system feedback loop diagram, stock-flow diagram, and nested formula of the model all meet the basic principles and laws related to grain production. Therefore, the model structure constructed in this study is scientific and feasible, and can pass the structural test.

3.2. Test of Model Running Results. The test of model operation results is also called historical value test, that is, the historical moment of model is selected as the initial point for simulation, and the accuracy between simulation results and historical data (actual values) is tested to verify the validity of

TABLE 3: Reference table for accuracy test grade.

Accuracy grade	Grade I	Grade II	Grade III	Grade IV
Relative error α	0.01	0.05	0.10	0.20
Degree of grey incidence ε_0	0.90	0.80	0.70	0.60

TABLE 4: System accuracy calculation table.

Category	ESTIGP	PSTIGP	Sown area of grain	Grain output per hectare	Grain output
Average relative error	0.0253	0.0451	0.0014	0.0170	0.0177
Absolute degree of incidence	0.9955	0.8798	0.9788	0.9999	0.9759
Relative degree of incidence	0.9971	0.9677	0.9848	0.9999	0.9778
Synthetic degree of incidence	0.9963	0.9237	0.9818	0.9999	0.9769

the system model [43]. Based on the grain production scientific and technological innovation model established above, the simulation values of main variables can be obtained by running the system, as shown in Table 2.

Taking the grain production of Henan Province as an example, this study carries out the average relative error test and incidence test, respectively.

(1) Record the original sequence as $X^{(0)}$, the simulated value sequence and residual sequence are recorded as $\overline{x}^{(0)}$ and $\varepsilon^{(0)}$, respectively. $\Delta_k = |\varepsilon(k)/x^{(0)}(k)|$ is called the relative error of k-point simulation, and $\overline{\Delta} = 1/n\sum_{k=1}^{n}\Delta_k$ is called average relative error. Given α, when $\overline{\Delta} < \alpha$ and $\Delta_n < \alpha$ is valid, the model is called a residual qualified model. Generally speaking, if the relative error is less than 0.1, the model can be considered to have better effectiveness [40]. Please refer to Table 1 for the specific accuracy level.

(2) Let $X^{(0)}$ be the original sequence, $\widehat{X}^{(0)}$ be the corresponding simulation sequence, the sequences $X^{(0)}$ and $\widehat{X}^{(0)}$ have the same length and the same time interval, all of which are equal time interval sequences, and ε is the degree of grey incidence of $X^{(0)}$ and $\widehat{X}^{(0)}$. If $\varepsilon_0 > 0$, there is $\varepsilon > \varepsilon_0$ for a given, the model is called the qualified model of degree of incidence, where

$$\varepsilon = \left[1 + \left|\sum_{k=2}^{n-1} x(k) + \frac{1}{2}x(n)\right| + \left|\sum_{k=2}^{n-1} \widehat{x}(k) + \frac{1}{2}\widehat{x}(n)\right|\right] \times \left[1 + \left|\sum_{k=2}^{n-1} x(k) + \frac{1}{2}x(k)\right| + \left|\sum_{k=2}^{n-1} \widehat{x}(k) + \frac{1}{2}\widehat{x}(n)\right| + \left|\sum_{k=2}^{n-1} (\widehat{x}(k) - x(k)) + \frac{1}{2}(\widehat{x}(n) - x(n))\right|\right]^{-1}. \quad (11)$$

According to Tables 3 and 4, the average relative errors of the system models constructed in this study are all less than 0.05, as for the Grade I accuracy and the Grade II accuracy. They all passed the incidence test, and the absolute degree of incidence, relative degree of incidence, and synthetic degree of incidence are all above 0.87, which shows that there is a good incidence between the simulated values and the actual values obtained. On the whole, the accuracy of the model constructed in this study has reached the second level or above.

3.3. Model Parameter Test. The parameters in the system dynamics model reflect the relationships between variables. The accuracy and rationality of setting the model parameters determine the accuracy of the running results of the system model. Parameter estimation test can compare the sensitivity of model parameters and the stability of operation results by adjusting model parameters. In this study, by adjusting the cultivated land area variable, the expenditures variable of science and technology innovation, and the personnel of scientific and technological innovation variable in the simulation equation, after adjusting the parameters of each variable by −10% and +10%, respectively, the degree of influence on the model and the stability of the model are analyzed.

Adjust the coefficient of amount of change in expenditures input in the simulation equation of ESTIGP variables by −10% and +10%, respectively, run the system model, and compare the running results with the actual data to calculate the error rate (in Table 5).

As can be seen from Table 3, when the adjustment coefficient in the simulation equation of the amount of change in expenditures is adjusted by +10% and −10%, respectively, the error between the simulation value and the actual value generally increases in different ranges, but the increase is not large. The accuracy of some indexes increases very slightly, but the overall accuracy of the simulation model has decreased due to the correlation characteristics of the simulation model, which shows that the model parameters set in this study are reasonable, and the simulation equations are stable and effective. Similarly, the coefficients of other simulation equations in the system stock-flow diagram are adjusted by +10% and −10%, respectively. To avoid redundancy, the error trends of the simulated and actual values of the system operation with +10% and −10% changes in the coefficient of output ability index simulation equation and the amount of change of personnel variation equation are shown in Figures 3 and 4, in which the simulation results of the system with unadjusted coefficients are

Table 5: Comparison of coefficient test results.

Variable	Sown area of grain (10^3 hm^2)			Grain output per hectare (kg/hm^2)			Grain output (10^7 kg)		
Year	Simulation value	Actual value	Relative error (%)	Simulation value	Actual value	Relative error (%)	Simulation value	Actual value	Relative error (%)
+10%									
2010	9,740.16	9,740.17	0.0001	5,719.23	5,730.72	0.2005	5,570.62	5,581.82	0.2007
2011	9,856.30	9,859.87	0.0362	5,490.67	5,815.41	5.5842	5,411.77	5,733.92	5.6183
2012	10,413.60	10,434.56	0.2009	5,606.70	5,652.73	0.8144	5,838.62	5,898.38	1.0132
2013	10,672.90	10,697.43	0.2293	5,683.28	5,631.07	0.9271	6,065.69	6,023.80	0.6954
2014	10,959.10	10,944.97	0.1291	5,781.49	5,604.04	3.1665	6,335.98	6,133.60	3.2995
2015	11,143.00	11,126.30	0.1501	5,869.42	5,815.25	0.9315	6,540.32	6,470.22	1.0834
2016	11,222.60	11,219.55	0.0272	5,913.16	5,791.69	2.0974	6,636.09	6,498.01	2.1250
2017	10,914.20	10,915.13	0.0085	5,963.28	5,977.25	0.2338	6,508.45	6,524.25	0.2422
2018	10,847.40	10,906.08	0.5380	6,045.35	6,096.52	0.8393	6,557.65	6,648.91	1.3726
2019	10,742.30	10,734.54	0.0723	6,115.73	6,237.21	1.9477	6,569.70	6,695.36	1.8768
Average relative error			0.1392			1.6742			1.7527
−10%									
2010	9,740.16	9,740.17	0.0001	5,719.23	5,730.72	0.2005	5,570.62	5,581.82	0.2007
2011	9,856.30	9,859.87	0.0362	5,490.67	5,815.41	5.5842	5,411.77	5,733.92	5.6183
2012	10,413.60	10,434.56	0.2009	5,621.40	5,652.73	0.5543	5,853.92	5,898.38	0.7538
2013	10,672.90	10,697.43	0.2293	5,713.11	5,631.07	1.4569	6,097.52	6,023.80	1.2238
2014	10,959.10	10,944.97	0.1291	5,827.06	5,604.04	3.9797	6,385.92	6,133.60	4.1137
2015	11,143.00	11,126.30	0.1501	5,931.19	5,815.25	1.9937	6,609.14	6,470.22	2.1471
2016	11,219.90	11,219.55	0.0031	5,989.96	5,791.69	3.4234	6,720.64	6,498.01	3.4261
2017	10,909.00	10,915.13	0.0562	6,055.44	5,977.25	1.3081	6,605.89	6,524.25	1.2513
2018	10,840.90	10,906.08	0.5976	6,153.79	6,096.52	0.9394	6,671.24	6,648.91	0.3358
2019	10,737.00	10,734.54	0.0229	6,240.85	6,237.21	0.0583	6,700.82	6,695.36	0.0815
Average relative error			0.1426			1.9499			1.9152

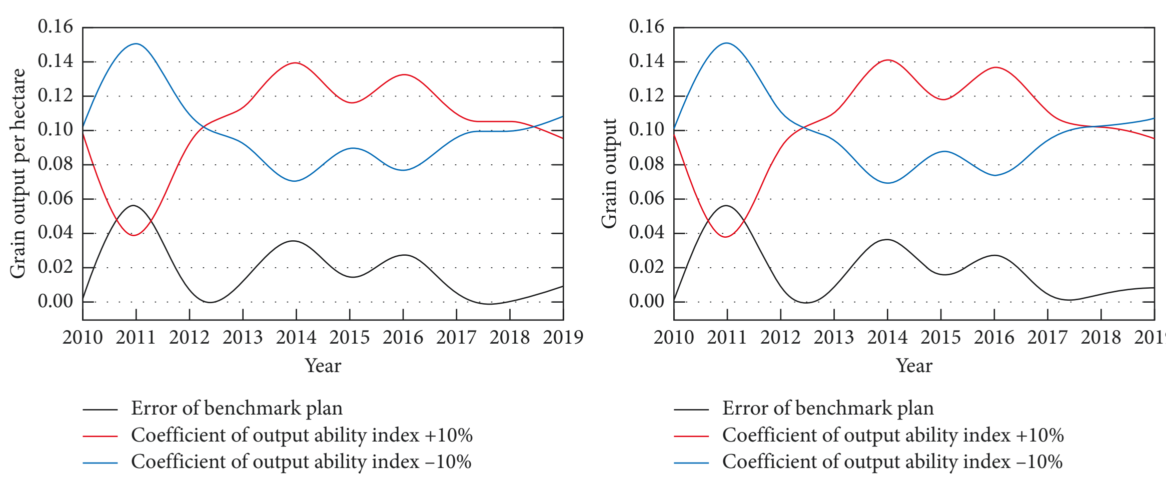

Figure 3: Error trend diagram of adjustment of output ability index coefficient.

used as the benchmark plan for comparison with the simulation results of coefficient adjustment. The analysis shows that the average relative errors of grain output per hectare and grain output are 10.3883% and 10.4007%, respectively, when the output ability index coefficient is increased by 10%. When the agricultural production index coefficient is decreased by 10%, the average relative errors are 9.9274% and 9.9304%, respectively. The error between the simulated value and the actual value obtained by adjusting the coefficient of output ability index simulation equation has greatly increased, and the error accuracy is Grade IV. When the adjustment coefficient of amount of change of personnel variation is raised by 10% and lowered by 10%, respectively, the average relative errors of the PSTIGP, grain output per hectare, and grain output are 4.5550%, 1.7628%, 1.7993% (+10%) and 4.7375%, 1.6569%, 1.7354% (–10%), respectively, and the error accuracy has decreased. It can be found that the change of simulation equation coefficient all causes the increase of the relative error rate between the system simulation value and the actual data, and the effect is consistent with the change of simulation equation coefficient of the amount of change in expenditures, which shows that the simulation equation and parameter setting constructed in this study are reasonable and effective.

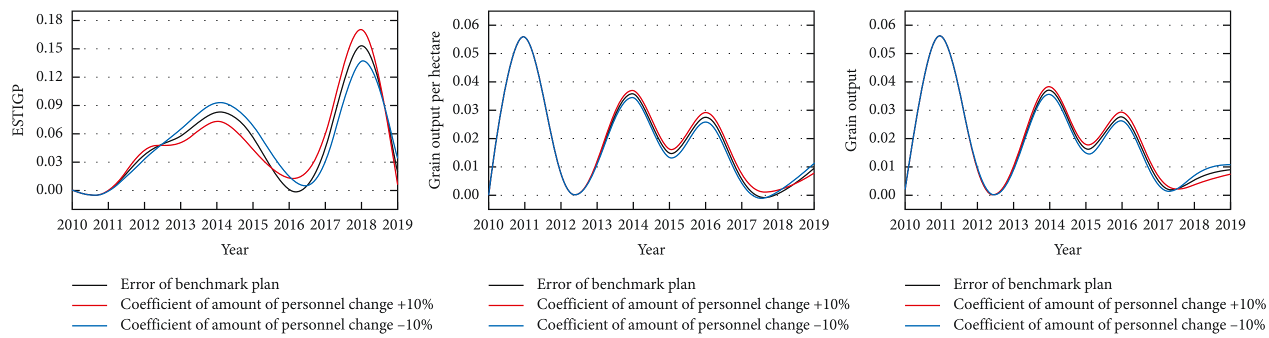

Figure 4: Error trend diagram of adjustment of amount of change of personnel.

4. Scenario Simulation of Grain Production Policy Based on Scientific and Technological Innovation

Scenario analysis refers to setting a certain development trend of policies over time under the uncertainty of future policy environment and implementation mode, simulating the dynamic changes of the system model caused by this scenario assumption. And based on the comparison of simulation results with actual results to explore the path and reasons for the dynamic changes to occur, as the aim is to explore possible measures and directions. In the scenario analysis, the variables directly affected by policies in the system model are selected as policy parameters, and the values of the policy parameters are changed by adjusting the policies. Then, the system dynamics model is used to simulate the effects of different policy and the dynamic change results of the model. Combining the previously constructed system model of grain production scientific and technological innovation and the research of relevant scholars, this paper selects the aspects of protection factors of agricultural scientific and technological innovation personnel policy, the influencing factors of comprehensive agricultural subsidy policy, and the improvement of agricultural technological progress to carry out scenario simulation experiments and further analyzes the experimental results.

4.1. System Simulation Results and Analysis under the Current Policy Context. Assuming that the future grain production policy is consistent with the current policy, namely, the level of grain production subsidies and agricultural technology progress refer to the current standard and growth level, and the exogenous variables in the model are unchanged. Using the existing system operation inertia simulation of the system model to predict the future system trend, and the simulation prediction results of the main variables are obtained as follows (see Figure 5). From the simulation results, it can be seen that the ESTIGP has been in a steady growth trend, while the growth of the PSTIGP is slow. After fluctuating in 2011, the grain output per hectare gradually shows a steady upward trend. The grain output is consistent with the trend of sown area of grain, showing a fluctuating upward trend. However, due to the limitation of cultivated land area and the influence of scientific and technological progress, the sown area of grain tends to level off. The report "Outline of the 14th Five-Year Plan for National Economic and Social Development of Henan Province and the Long-term Goals in 2035" (hereinafter referred to as the Outline) issued by the People's Government of Henan Province points out that at the critical moment of the 14th Five-Year Plan starts and the focus of the "three agricultural" (Agriculture, Rural and Farmers) work to achieve is historically shifted, as a large agricultural province and a large rural population province of Henan, how to plan the layout is crucial. The Outline proposes that the comprehensive grain production capacity will be more than 65,000 million kg in 2025, and adhere to the goal of the red line of the cultivated land. It also emphasizes resolutely shouldering the important task of grain security, deeply implementing the strategy of "storing grain in land and technology." Promote the construction of high-standard farmland construction and independent innovation in the seed industry, seek breakthroughs in biological breeding and modern agricultural technology. Accelerate the introduction of talents, and build an agricultural equipment manufacturing center and an agricultural scientific and technological research and development center facing the world. Therefore, although the grain output of Henan Province in 2019 has reached 66,953.6 million kg > 65,000 million kg, under the sudden impacts of natural disasters, economic shocks and COVID-19, the grain security is facing unprecedented challenges. Henan Province still needs to take up the national and even world grain security, and needs to constantly carry out scientific and technological innovation to ensure not only the grain output but also the grain quality.

4.2. Scenario Simulation Results and Analysis of Policy Adjustment Plan. In this study, from the perspective of increasing grain production, the protection policy of agricultural scientific and technological innovation personnel, the comprehensive agricultural subsidy policy and the increase of agricultural technological progress are selected as the main adjustment plans. In order to further analyze the simulation results of adjusting different policies, this study takes the simulation results of the current policy background as the benchmark plan, in which the protection policy of agricultural scientific and technological innovation personnel, the comprehensive agricultural subsidy policy

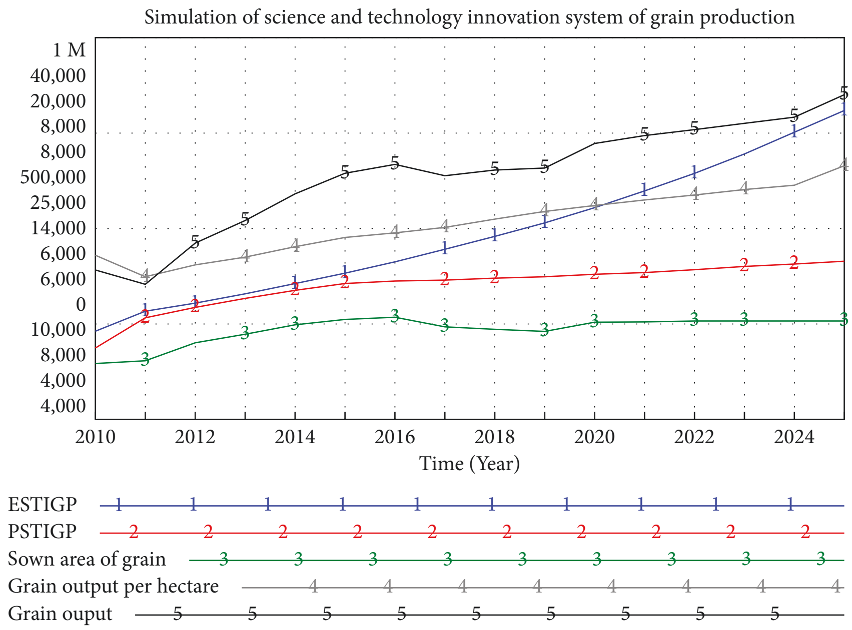

Figure 5: Trend chart of system simulation results from 2010 to 2025.

and the agricultural technological progress are all treated as exogenous variables of the system. The protection policy of agricultural scientific and technological innovation personnel and the comprehensive agricultural subsidy policy are all taken as 1 in the model simulation. As agricultural technological progress has a certain impact rate on grain yield, this study constructs that the improvement of agricultural technological progress has an impact on grain outputs, so set the exogenous variable to take the value of 0. Referring to the relevant literature and the results of the system model test, this study sets the exogenous variable that each policy impact factor that has a facilitating effect on the system to increase the impact size by 1%, in order to evaluate grain production by analyzing and comparing the simulation results after each policy adjustment with the change trend of the benchmark plan. In this study, we will simulate the adjustment of single policy, two policy combinations and three policies combinations, respectively, i.e., a total of seven policy plans will be designed.

4.2.1. Simulation Results and Analysis of Single Policy Plans. The adjustment plans of single policies include three adjustment plans: the protection policy of agricultural scientific and technological innovation personnel (Plan 1), the comprehensive agricultural subsidy policy (Plan 2), and the agricultural technological progress (Plan 3).

Plan 1. The impact of the protection policy of agricultural scientific and technological innovation personnel increased by 1%.

The protection policy of agricultural scientific and technological innovation personnel directly affects the grain output per hectare. In order to understand the influence of this policy change on the system simulation trend, Plan 1 is set under the current policy background, and only adjusts the protection policy of agricultural scientific and technological innovation personnel to increase the impact by 1%. Namely, the value of the protection factors of agricultural scientific and technological innovation personnel policy is 1.01, and the simulation results are shown in Table 6.

When the impact of the protection policy for agricultural scientific and technological innovation personnel is increased, as the total number of scientific and technological practitioners engaged in grain production in Henan Province is low, and the increase of PSTIGP is small, resulting in a lower change in grain output per hectare and grain output, which are both increased by 0.0056% compared with the benchmark plan in 2025, while the sown area of grain does not change. It an be seen that, although the increase in the impact of scientific and technological innovation personnel protection policy has a tendency to increase the grain output, this plan will not achieve the effect of higher increase in grain production if the increase is small and is not effective when implemented alone. On the whole, the protection policy of agricultural scientific and technological innovation personnel has a small positive effect on grain security, and the grain output and sown area of grain have reached the goal of the Outline.

Plan 2. The impact of the comprehensive agricultural subsidy policy increased by 1%.

Comprehensive agricultural subsidy policy is to give direct subsidies to farmers who purchase agricultural machinery, green agricultural materials, and implement standard farmland according to certain standards. This policy can directly improve the grain production efficiency and directly affect the sown area of grain and grain output per hectare. To understand the impact of this policy change on the system simulation trend, Plan 2 is set to increase the impact of adjusting only comprehensive agricultural subsidy

Table 6: Comparison of simulation results between Benchmark plan and Plan 1.

Year	Benchmark plan				Plan 1			
	PSTIGP (person)	Sown area of grain (10^3 hm^2)	Grain output per hectare (kg/hm^2)	Grain output (10^7 kg)	PSTIGP (person)	Sown area of grain (10^3 hm^2)	Grain output per hectare (kg/hm^2)	Grain output (10^7 kg)
2020	21,382.00	11,042.90	6,212.12	6,859.98	21,382.00	11,042.90	6,212.12	6,859.98
2021	21,580.00	11,074.10	6,271.91	6,945.59	21,582.00	11,074.10	6,271.97	6,945.67
2022	21,794.00	11,074.90	6,328.70	7,008.95	21,799.00	11,074.90	6,328.84	7,009.11
2023	22,019.00	11,098.20	6,381.44	7,085.56	22,025.00	11,098.20	6,384.66	7,085.79
2024	22,246.00	11,080.40	6,437.42	7,132.91	22,254.00	11,080.40	6,437.72	7,133.24
2025	22,473.00	11,133.70	6,631.43	7,383.23	22,484.00	11,133.70	6,631.80	7,383.64

policy by 1% in the current policy context, i.e., the comprehensive agricultural subsidy policy takes the value of 1.01, and the simulation results are obtained as shown in Table 7.

When the impact of the comprehensive agricultural subsidy policy increases by 1%, similar to Plan 1, both grain output per hectare and the grain output have a smaller increase, 0.0086% and 0.0073%, respectively, compared with the Benchmark plan, while the sown area of grain decreases by 0.2 thousand hectares. Overall, the increase in the comprehensive agricultural subsidy policy has a catalytic effect on grain production, and the increase of this plan is slightly larger than that of Plan 1. The grain output and sown area of grain have reached the objectives of the Outline, but the incentive effect of comprehensive agricultural subsidy policy on grain production is weak, and it is difficult to implement this plan alone to meet the strategic requirements of continuously improving the comprehensive grain production capacity.

Plan 3. Agricultural technological progress is increased by 1%.

Relying on scientific and technological progress to improve the grain output per hectare is the main way to achieve sustained growth of grain output. By increasing agricultural technological progress by 1%, it is possible to simulate and predict the level of sown area of grain and grain production, as well as the level that each influencing variable needs to reach, which is of guiding significance for agricultural technological progress and grain production. In order to understand the influence of the change of this variable on the system simulation trend, Plan 3 is set under the current policy background, which only improves the agricultural technological progress by 1%, i.e., the technological progress is taken as 0.01, and the simulation results are obtained as shown in Table 8.

Compared with the Benchmark plan, when the agricultural technological progress is increased by 1%, the sown area of grain is reduced by 5.8 thousand hectares. The grain output per hectare and grain output are increased by 23.17 kg/hm^2 and 219.40 million kg, respectively, with the growth rate reaching 0.3494% and 0.2972%, respectively, which is a large increase range. The improvement of this variable has a more obvious promotion effect on grain production, and both the grain output and sown area of grain have reached the target of the Outline. Under the conditions of poor agricultural resource endowment and land resource constraints, with the vigorous promotion of research on key agricultural technologies, the implementation of the strategy of "storing grain in the land and technology," and the gradual improvement of modern agricultural equipment and the promotion of precise crop field management technology, the grain output can still grow when the sown area decreases. This is consistent with the current situation of grain production in China and conforms to the situation of Henan Province. Among the single policy adjustments, the improvement of agricultural technology has the most significant impact on grain output.

4.2.2. Simulation Results and Analysis of Two Policy Combinations. In order to explore whether the combination of different plans play a superposition effect on the system simulation, this study combines the three policies in two combinations to regulate the system together.

Plan 4. The impact of the protection policy of agricultural scientific and technological innovation personnel and the comprehensive agricultural subsidy policy are all increased by 1%.

The effect of the simultaneous action of the two policies is reflected in Figure 6. When the two policies of the protection policy of agricultural scientific and technological innovation personnel and the comprehensive agricultural subsidy policy are adjusted separately, the grain output per hectare has increased by 0.0056% and 0.0086%, respectively. When the two policies acted simultaneously, the grain output per hectare increased by 0.9 kg/hm^2, with an increase of 0.0153%, which is greater than the improvement effect of single policy and slightly greater than the sum of single improvement of the two policies. The sown area of grain decreased by 0.0018%, which is larger than the single policy and equal to the sum of the single increase of the two policies. It reflected that with the increase of the scope of the scientific and technological innovation policy, the "extensive and inefficient" production mode of increasing the sown area of grain gradually changes to a precise and efficient modern grain production driven by scientific and technological innovation. At the same time, the red line of cultivated land is guaranteed and "storing grain in the land and technology" is implemented. As a result, compared with the Benchmark plan, the grain output increased from 73,832.30 million kg to 73,841.80 million kg, with an increase of 0.0138%. On the whole, the influence of the protection

Table 7: Comparison of simulation results between Benchmark plan and Plan 2.

Year	Benchmark plan			Plan 2		
	Sown area of grain (10^3 hm^2)	Grain output per hectare (kg/hm^2)	Grain output (10^7 kg)	Sown area of grain (10^3 hm^2)	Grain output per hectare (kg/hm^2)	Grain output (10^7 kg)
2020	11,042.90	6,212.12	6,859.98	11,042.90	6,212.67	6,860.59
2021	11,074.10	6,271.91	6,945.59	11,074.10	6,272.46	6,946.19
2022	11,074.90	6,328.70	7,008.95	11,074.90	6,329.26	7,009.58
2023	11,098.20	6,381.44	7,085.56	11,098.10	6,385.00	7,086.15
2024	11,080.40	6,437.42	7,132.91	11,080.40	6,437.99	7,133.58
2025	11,133.70	6,631.43	7,383.23	11,133.50	6,632.00	7,383.77

Table 8: Comparison of simulation results between Benchmark plan and Plan 3.

Year	Benchmark plan			Plan 3		
	Sown area of grain (10^3 hm^2)	Grain output per hectare (kg/hm^2)	Grain output (10^7 kg)	Sown area of grain (10^3 hm^2)	Grain output per hectare (kg/hm^2)	Grain output (10^7 kg)
2020	11,042.90	6,212.12	6,859.98	11,042.90	6,234.29	6,884.46
2021	11,074.10	6,271.91	6,945.59	11,073.30	6,294.17	6,969.72
2022	11,074.90	6,328.70	7,008.95	11,075.50	6,351.14	7,034.18
2023	11,098.20	6,381.44	7,085.56	11,096.80	6,406.96	7,109.66
2024	11,080.40	6,437.42	7,132.91	11,082.80	6,460.20	7,159.70
2025	11,133.70	6,631.43	7,383.23	11,127.90	6,654.60	7,405.17

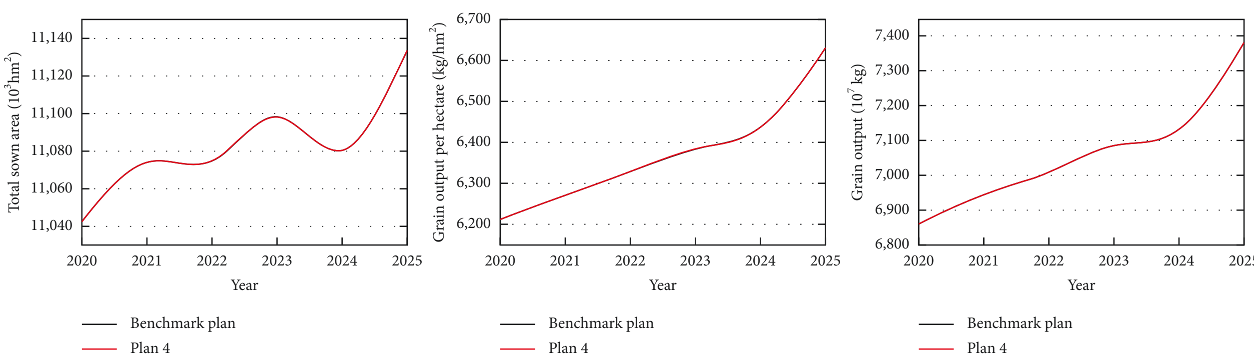

Figure 6: Comparison of simulation results between Benchmark plan and Plan 4.

policy of agricultural scientific and technological innovation personnel and the comprehensive agricultural subsidy policy are simultaneously improved, and the grain output per hectare and grain output are increased significantly. The sown area of grain is also within the target of the Outline, and the comprehensive capacity of grain production is a tendency to increase.

Plan 5. The impact of the protection policy of agricultural scientific and technological innovation personnel and the agricultural technology progress are all increased by 1%.

Under the current policy background, this plan increases the impact of the protection policy of agricultural scientific and technological innovation personnel and the agricultural technology progress by 1%, respectively, to obtain the system model simulation results trend as shown in Figure 7. It can be seen from figure that both the grain output per hectare and the grain output have increased, while the sown area of grain still showed a downward trend, with the increase or decrease ranges of +0.3789%, +0.3258% and −0.0525%, respectively. Grain output reached 74,055.8 million kg, which is greater than the sum of the improvement effect of single policy and the single improvement of these two policies, and is significantly higher than that of Plan 4. Therefore, the protection policy of agricultural scientific and technological innovation personnel and the improvement of agricultural technological progress have a significant positive effect on grain production.

Plan 6. The impact of the comprehensive agricultural subsidy policy and the agricultural technological progress are all increased by 1%.

The comparison between the system simulation results of this plan and the Benchmark plan is shown in Figure 8. Under the joint action of these two policies, the grain output per hectare has increased from 6,631.43 kg/hm^2 in the Benchmark plan to 6,655.18 kg/hm^2, with an increase of 0.3823%. The sown area of grain has decreased to 11,127.80 thousand hectares, a decrease of 0.0534%. The grain output

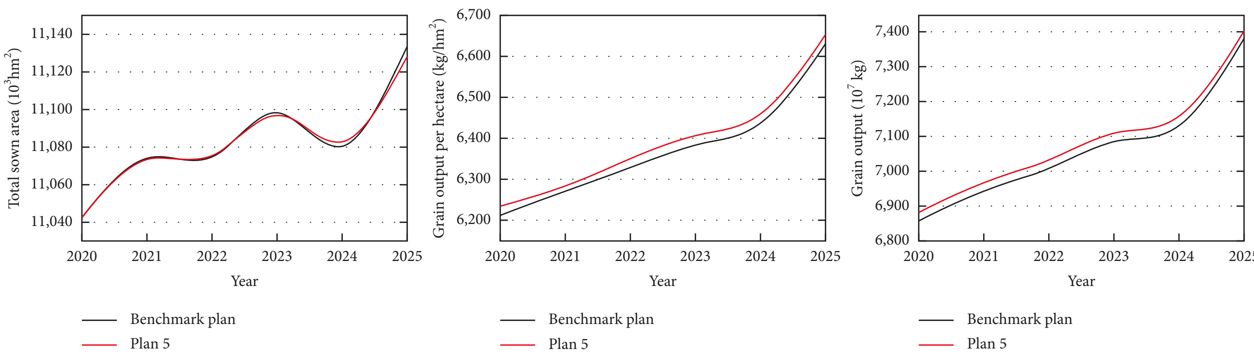

Figure 7: Comparison of simulation results between Benchmark plan and Plan 5.

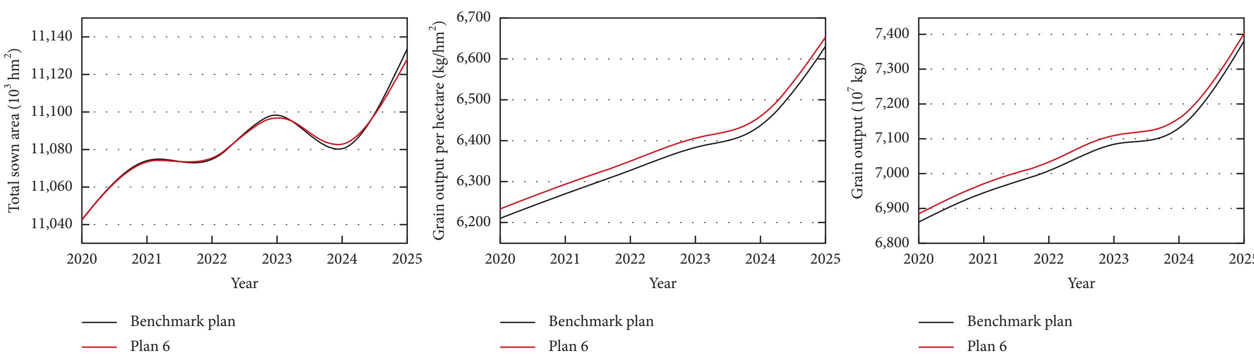

Figure 8: Comparison of simulation results between Benchmark plan and Plan 6.

Table 9: Comparison of simulation results between Benchmark plan and Plan 7.

Year	Benchmark plan			Plan 7		
	Sown area of grain (10^3 hm^2)	Grain output per hectare (kg/hm^2)	Grain output (10^7 kg)	Sown area of grain (10^3 hm^2)	Grain output per hectare (kg/hm^2)	Grain output (10^7 kg)
2020	11,042.90	6,212.12	6,859.98	11,042.90	6,234.84	6,885.07
2021	11,074.10	6,271.91	6,945.59	11,073.30	6,294.79	6,970.39
2022	11,074.90	6,328.70	7,008.95	11,075.50	6,351.84	7,034.97
2023	11,098.20	6,381.44	7,085.56	11,096.70	6,407.73	7,110.50
2024	11,080.40	6,437.42	7,132.91	11,082.80	6,461.06	7,160.59
2025	11,133.70	6,631.43	7,383.23	11,127.80	6,655.55	7,406.13

has increased 224.90 million kg, under the joint action of grain output per hectare and sown area of grain. Compared with Plan 4, 5, and 6, the adjustment of Plan 6 makes the grain output to increase the most, and the smallest increase is Plan 4. It can be seen that in the combination of the two policy combinations, the combination of comprehensive agricultural subsidy policy and agricultural technological progress has a more significant impact on grain production capacity.

4.2.3. Simulation Results and Analysis of Three Policy Combinations

Plan 7. The impact of the protection policy of agricultural scientific and technological innovation personnel, the comprehensive agricultural subsidy policy, and agricultural technological progress are all increased by 1%.

In the system model, because the impact and role of policies on the system model are different, the simultaneous changes of multiple policies may also have mutually reinforcing or mutually weakening effects after system simulation. Therefore, in order to analyze the impact effect between different policies, this study designs the simulation trend of the scientific and technological innovation system of grain production under the condition that the protection policy of agricultural scientific and technological innovation personnel, the comprehensive agricultural subsidy policy, and the agricultural technology progress are simultaneously improved, and the results are shown in Table 9. Specifically, from the results in the table, the sown area of grain, grain output per hectare, and grain output are the biggest changes among all plans. The sown area of grain has decreased from 11,133.70 thousand hectares in the Benchmark plan to 11,127.80 thousand hectares, with a decrease of 0.0534%, which meets the red line of cultivated land in Henan

Province. The grain output per hectare and grain output have increased by 24.12 kg/hm^2 and 229.00 million kg, respectively, reaching the Outline of Henan Province. The growth rate reached 0.3883% and 0.3338%, respectively, both of which are greater than the improvement effect of single policy. The growth rate of grain output per hectare and grain output are greater than the sum of single improvement of these three policies at the same time.

Overall, from the simulation results of these seven policy adjustment options, the trend of improving the overall grain production capacity when single policy is applied and when two policies are adjusted at the same time, but it is difficult to achieve a higher goal of sustainable and stable grain production. The simultaneous increase of three policies has a mutually reinforcing effect on the improvement of grain production capacity, and the system simulation effect is the most ideal. However, due to the large population base of farmers in Henan Province, the simultaneous improvement of multiple policies is bound to bring considerable policy costs and financial pressure to the government, and there is also a certain degree of uncertainty in the final implementation of the policies. Therefore, more consideration is needed in the implementation of multiple policy combinations.

5. Conclusions and Policy Recommendations

Grain production scientific and technological innovation system is a complex system with multiple feedbacks. Based on the three main factors of ESTIGP, PSTIGP, and agricultural technology factors, this study constructs the feedback loop of grain production scientific and technological innovation system and explores the dynamic feedback relationship among the main influencing factors of the system. By constructing the system stock-flow diagram, grey production function, grey prediction model, SD theory to construct table function and logic function, and the grain production, the scientific and technological innovation system model is established. In order to explore the impact of feasible policy plans on grain production, seven policy plans are designed in this paper, and the following conclusions can be obtained. Firstly, the adjustment of a single policy, especially only the adjustment of the protection policy of agricultural scientific and technological innovation personnel or the comprehensive agricultural subsidy, has a weak impact on the improvement of grain production. The progress of agricultural technology is the main support to improve the comprehensive grain production capacity. Secondly, the future grain growth potential of Henan Province should focus on increasing the grain output per hectare, while the protection of cultivated land resources should not be ignored. Finally, it is found that the system simulation effect is the most ideal when the combined policies acts on the system, and the combination of policies has a mutually reinforcing effect in the system model established in this study, and the effect of grain production increase is greater than that of single or a combination of two policies. However, considering that simultaneous adjustment of multiple policies will bring about considerable policy costs and financial pressure as well as various uncertainties, more discretion is still needed when implementing multiple policy combinations. Through the above analysis, according to the research results, this study puts forward some policy suggestions to further improve the scientific and technological innovation of grain production.

(1) All-round integration of internal and external resources for collaborative innovation, optimization of diversified talent mechanism, and establishment of grass-roots agricultural technology extension professional team. The scientific and technological innovation of grain production in Henan Province is still facing the shortage of personnel in practical and professional technicians. The positive effect of resource accumulation can be promoted by promoting cooperation between universities and agricultural research institutes in personnel training, scientific research, and resource sharing. By establishing various forms of academic exchange mechanisms such as project cooperation, symposiums, academic conferences, and joint training between universities and agricultural research institutes, a scientific and technological innovation platform with shared resources and complementary advantages will be established. Then, strengthen the strategic cooperation between universities and research institutes, and build a multichannel system mechanism for nurturing, employing, and retaining people. The effective use of scientific and technological innovation in grain production, the transformation and popularization of scientific and technological achievements is the key. Henan Province should innovate the management system of scientific and technological innovation, train and establish a professional grain transforming scientific and technological innovation achievements, deeply implement the grass-roots technology extension service, and open up the "last mile" of transforming scientific and technological achievements into agricultural productivity. Henan Province can use modern information technology and Internet of Things technology to provide technical guidance for grain production and digital management, establish an intelligent, precise, and shared management system for scientific and technological innovation. Speed up the cultivation and introduction of high-quality professional talents for transforming scientific and technological achievements, and build a communication platform for the responsibility of scientific researchers and technical extension personnel, so as to achieve technological adaptation and local adaptation. At the same time, it is necessary to improve and perfect the incentive mechanism for diversified cultivation of agricultural talents. Promote professional grass-roots agricultural technology popularization, train a group of farmers with rich experience in agricultural production, strive to improve farmers' scientific and cultural literacy and productive labor skills, and strengthen the team of innovative "new farmers" in rural scientific and technological. These

actions will help to achieve the effective combination of scientific research, achievement transformation and demonstration and popularization, to ensure the systematic implementation of the strategy of storing grain in technology.

(2) Improve the system of scientific and technological innovation and the dynamic coordination mechanism of operation, establish the mechanism of multi-source input and policy assistance, and improve the policy of scientific and technological innovation in grain production as well as the reward system in such aspects as patents and effective transformation of achievements. Firstly, improve the directivity and precision of funding and policy subsidies, aim at improving the quality and efficiency of agriculture, rationally optimize the resources input channels, and policy guide social forces to join the agricultural scientific and technological innovation market. Secondly, Henan Province should increase subsidies for key technologies, clarify the core objectives and key subsidy targets of agricultural subsidies, focus on operating farmers on a moderate scale, improve the subsidy policies linked to agricultural sustainable production inputs such as high-efficiency slow-release fertilizers and green pesticides, and subsidize the losses caused by engaging in green agricultural production methods. Furthermore, Henan Province should strengthen the intellectual property rights and market supervision, as well as reward measures such as patents and major technological breakthroughs, so as to provide a good innovation institutional environment and policy guarantee for scientific and technological innovation of grain production. At the same time, establish a collaborative relationship among government, market, enterprises, universities, and research institutes in technology research and development, promotion and achievement transformation to form a cooperation and mutually beneficial chain, so as to reduce the innovation risk of innovative subjects and enhance the synergy of grain production and development services. Henan Province should improve the grain production increase capacity through multiple input measures and strive to shorten the transformation cycle of agricultural scientific and technological innovation achievements.

(3) Accelerate the development of biotechnology and information technology and other high-tech production technologies, improve the mechanism for the transformation of innovative scientific and technological achievements, and improve the level of basic grain production. Henan Province should dig deeper into agricultural genetic resources, accelerate the selection and breeding of grain crop varieties, and research light and simplified field management techniques matching with good seeds according to the characteristics of natural resources and geographical basis in various regions. Focusing on the research of major technical problems in production, Henan Province should accelerate the construction of high-standard farmland, improve the level of agricultural machinery and equipment, and promote applicable agricultural machinery. The government should guide scientific research projects to carry out experiments and demonstrations in functional grain production areas, entrepreneurial parks, scientific and technological parks, and modern agricultural industrial parks to promote the research and development of projects and the integration of scientific and technological achievements with industries [3]. At the same time, Henan Province should establish an exchange and sharing platform for agricultural technological innovation, set up a regional testing platform and laboratory that is “professional management and testing.” Thereby realizing the optimization of resources, avoiding the problems of scattered resources and idle equipment, improving the allocation efficiency and utilization rate of scientific and technological resources, and efficiently transform scientific and technological achievements.

Under the dual influence of natural and social factors on grain production, the scientific and technological innovation system of grain production is complex and changeable. How to improve the implementation of national macro-policies to further ensure grain security needs further in-depth study. This paper constructs a grain production scientific and technological innovation system based on system dynamics and grey system theory, which provides a new idea for dynamic research on scientific and technological innovation system of grain production. But there are still some shortcomings in this research, for example, whether policy implementation costs and uncertainty related to policy effects can be added to the system, and whether the research object can be further refined, which will be the direction of further research in the future.

Data Availability

The relevant index data of Scientific and Technological Innovation of Grain Production in Henan Province from 2010 to 2019 from “Henan Statistical Yearbook, Henan Scientific and Technological Statistical Yearbook, and China Statistical Yearbook official website data” presented in this article are open and available. Data can be accessed from https://tjj.henan.gov.cn/tjfw/tjcbw/tjnj/and https://data.stats.gov.cn/english/easyquery.htm?cn=E0103.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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