A Study on Carbon Emission from Plantation Industry in Jiangsu Province Based on Using System Dynamics

He Yuan*[a], Yang Xuan[b]

School of Management, Chengdu University of Information Technology, Chengdu, China

Abstract: Research objective: to analyse the role of land, population, society and economy in influencing carbon emissions from a systemic perspective, and to simulate the carbon emissions from plantation industry under different policy scenarios in Jiangsu Province from 2016 to 2030, so as to provide a decision-making basis for its low-carbon development strategy and low-carbon plantation industry. Research method: System Dynamics. Findings: (1) Rapid economic development has a significant effect on the increase of carbon emissions from plantation industry in Jiangsu Province; (2) Improving the efficiency of agricultural materials utilisation can all effectively reduce carbon emissions from plantation industry in Jiangsu Province. Conclusions: The important ways for low-carbon development of plantation industry in Jiangsu Province is to transform the mode of economic growth, adjust the structure of land using and improve the efficiency of the use of agricultural materials, and promote the use of organic fertilisers, organic agricultural films, et.

1. Introduction

Carbon emissions from agriculture are often influenced by the state of economic development. To increase sustainable economic growth through agriculture sector, there is a need to introduce green technologies that produce less carbon emissions[1].Piwowar, A[2] thought agriculture in Poland is one of the major sources of emissions of gaseous pollutants. Reducing emissions of, among others, gas from agriculture requires the introduction of innovative techniques and tools to increase the efficiency of agricultural production.

Cultivation is a major source of agricultural carbon emissions in the southeastern region of China. It was found that the cultivation industry there contributes more than 50% to non-CO_2 greenhouse gases from agricultural sources, of which the average contribution rate of cultivation in Jiangsu Province is located in the first place in China, which is 70.85% [3]. In this study, we refer to the method of Wu Meng [4] and others to calculate the carbon emission of plantation industry in Jiangsu Province, based on the theory of systematics and the theory of sustainable development, establishing a simulation model of carbon emission from agricultural plantation, simulating and analysing the changes and possible regulation of plantation system, and taking Jiangsu Province as the study area, and its plantation carbon emission status is simulated to provide a basis for decision-making of its low-carbon development strategy and low-carbon development of the plantation industry.

2. Study Area and Data

2.1. Study Area

The terrain of Jiangsu is dominated by plains, which cover an area of more than 70,000 square kilometres, accounting for more than 70% of the area in Jiangsu, the proportion of which is the first among all provinces in China. It is necessary to simulate the carbon emission system of the plantation industry in Jiangsu Province and simulate the policy, so as to provide certain basic information for further research.

2.2. Data Sources

The data used in this paper are all obtained from the 2016-2023 China Rural Statistical Yearbook [5] and Jiangsu Statistical Yearbook [6].

3. Research Methodology

Plantation industry, as a major source of carbon emission in agriculture, has an important impact on the social economy as well as carbon emission. System dynamics which was proposed by Professor J. W. Forrester in 1958 is a system simulation method for this study. [7-8]

3.1. Boundary of Modelling

The model takes Jiangsu Province as the spatial boundary, and the time boundary is 2016-2030. Among them, the simulation base year is 2016, the main historical data period is 2016-2023, and 2024-2030 is the forecast period,

*[a]heyuan@cuit.edu.cn; [b]1733978892@qq.com

and the time step is set at 1 year to reduce the error caused by the change of time period in the forecast.

3.2. Composition of the Carbon Emission System of the Plantation Industry

The four subsystems of economy, population, environment and land are mutual environment and constitute the carbon emission system of plantation industry. The causal relationship of the modelling system is shown in Figure 1.

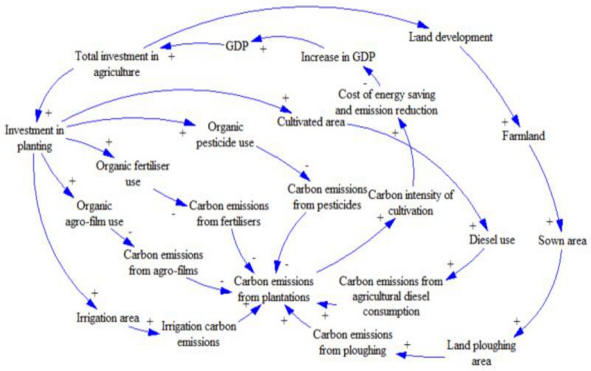

Figure 1 Cause and Effect Diagram of Carbon Emission System in Plantation Industry

The stock flow diagram of the plantation carbon emission system is shown in Figure 2.

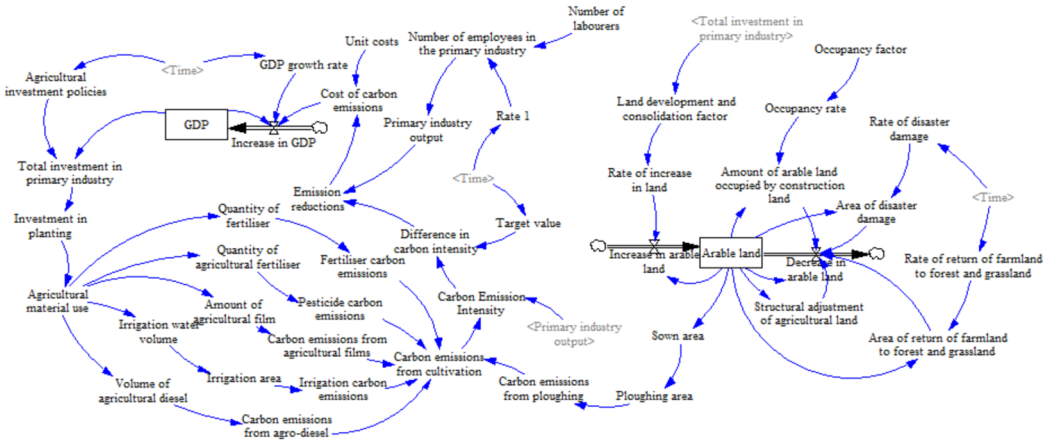

Figure 2 Stock Flow Diagram of the Carbon Emission System for the Plantation Industry

4. Model Testing and Simulation Analysis

4.1. Analysis of Model Test Results

After a system dynamics model has been established, it is necessary to test the model to determine the degree of compatibility between the model and the real situation, in order to ensure the authenticity and validity of the model. Commonly used system dynamics model testing methods include intuitive and operational testing, and historical testing.

4.1.1. Intuitive and operational testing

The reasonableness of the model was tested by the equation test and the magnitude test functions that come with the Vensim software. The test results show that: the equation on both sides of the scale is consistent, the model trial run did not produce pathological results. Therefore, theH model constructed in this paper is reasonable.

4.1.2. Historical testing

The historical data from 2016-2023 are substituted into the model for simulation verification, and this paper selects GDP, population, agricultural material usage, ploughing area and carbon emission as test variables from the system. And compares the simulated values measured by the model with the historical data to carry out the model historical simulation test, i.e. the consistency test.

The simulation results show that the relative error rate of the system model does not exceed 10% (Table 1), which is within the error tolerance. This indicates that the simulation results of the plantation carbon emission model are reliable.

Table 1 Relative Error of Simulation

Unit: %

Year	GDP	Demog raphic	Agricultural material use	Ploughing area	Carbon emission
2016	3.12	1.05	6.25	1.33	2.66
2017	5.63	-3.27	7.11	4.61	3.79
2018	2.08	-5.01	4.78	-3.22	7.41
2019	-5.32	2.38	7.29	-1.68	3.82
2020	4.82	1.32	2.19	2.75	6.93
2021	-3.79	4.81	5.62	3.70	7.91
2022	6.58	-3.09	5.08	2.15	2.04
2023	6.19	5.70	6.15	4.58	6.69

4.2. Simulation and Prediction of Carbon Emissions from Plantation in Jiangsu Province

Through the simulation of the carbon emission system of plantation industry in Jiangsu Province, the simulation data of carbon emission from plantation industry in Jiangsu Province from 2016 to 2030 are obtained (Table 2). The simulation results show that, with the further development of social economy and population, the total carbon emissions from plantation industry in Jiangsu Province will keep the trend of climbing year by year.

Table 2 Carbon emissions from plantation in Jiangsu Province, 2016-2030

Unit: 10 t^4

Year	Carbon emission	Year	Carbon emission
2016	363.80	2024	377.34
2017	342.51	2025	382.51
2018	338.23	2026	387.42
2019	325.76	2027	397.21
2020	319.96	2028	410.77
2021	320.55	2029	423.84
2022	336.87	2030	429.91
2023	352.21		

4.3. Policy Simulation and Analysis

Policy simulation refers to changing some policy variables in the model to study the impact of the policy change on the final result of the whole system, which is both the necessary function of the system dynamics analysis and the method of this paper to seek a low-carbon regulatory path.

Carbon emissions from the plantation industry are related to the land use structure, economic level, material use efficiency, and so on. Therefore, this study mainly carried out scenario simulation for three policies of high economic growth, technological progress and land use structure adjustment.

Option 1: Regulate the pace of economic development to achieve rapid GDP growth.

Option 2: Adjust inputs and use of individual farm inputs.

Option 3: Reduce the area of arable land occupied by construction land.

Table 3 Carbon Emission Simulation Results for Each Programme

Unit: 10^4t

Year	Option 1	Option 2	Option 3	Year	Option 1	Option 2	Option 3
2016	372.36	356.23	358.44	2024	382.60	371.59	375.41
2017	353.76	338.23	341.37	2025	387.45	374.61	379.78
2018	343.68	332.39	335.78	2026	393.29	382.59	384.91
2019	329.85	320.48	323.11	2027	403.54	389.98	394.27
2020	325.39	311.34	318.56	2028	419.31	403.67	408.19
2021	326.97	315.53	319.87	2029	427.18	416.32	419.74
2022	345.34	329.82	332.70	2030	437.19	421.91	424.37
2023	359.87	346.21	350.94				

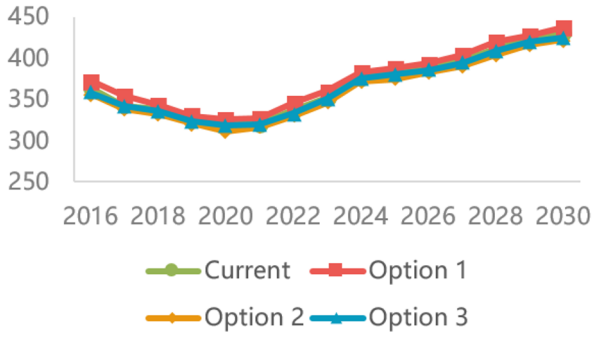

Figure 3 Comparison of carbon emissions by scenario with original projections

According to the three policy scenarios set above, the carbon emissions from the plantation industry in Jiangsu Province from 2016 to 2030 are obtained respectively (Table 3 and Figure 3). It can be found during the measurement results:

(1) Economic growth is an important factor in the growth of total carbon emissions from plantation in Jiangsu Province, and it is difficult to achieve carbon reduction. The data show that socio-economic development is significantly positively correlated with plantation carbon emissions, and economic growth is an important factor contributing to the growth of total carbon emissions.

(2) Adjusting the land use structure and controlling the transformation of arable land to construction land have certain effect on reducing carbon emissions from planting, but the effect is significantly weaker than the improvement of the efficiency of agricultural material use.

(3) The improvement of agricultural material use efficiency is the main way to curb carbon emissions from plantation industry in Jiangsu Province. The data show

that the improvement of agricultural material use efficiency plays an important role in achieving carbon emission reduction in the plantation industry.

5. Conclusions and Recommendations

5.1. Conclusions

Through the simulation of the model SD, the following conclusions are mainly obtained:

(1) The results of the policy simulation show that the high speed of economic development has a significant effect on the increase of carbon emissions from the plantation industry. Therefore, the traditional way of economic development at the cost of high resource consumption and environmental degradation should be changed, and a low-carbon economy should be comprehensively promoted so that economic development remains efficient and sustainable.

(2) Adjusting the land use structure and improving the efficiency of agricultural materials can effectively reduce carbon emissions from plantation industry in Jiangsu Province, among which, the effect of improving the efficiency of agricultural materials is relatively more significant.

(3) In this paper, the carbon emission system of plantation industry in Jiangsu Province has been simulated and the policy simulation has been carried out, which helps to quantitatively explain the problems in the development of Jiangsu Province and explore the direction and mode of low-carbon plantation industry. However, due to the subjectivity of the SD model in the selection of some factors and the description of correlation, how to combine with other methods to objectively optimise the model and better simulate the carbon emission system of the plantation industry needs to further in-depth study.

5.2. Policy Recommendations

(1) Changing the mode of economic development, comprehensively promoting a low-carbon economy and a circular economy. We should change the economic development mode and explore the low-carbon economy and circular economy development mode with low energy consumption, low pollution and high technology.

(2) Adjusting the land-use structure and promoting the intensive use of land to minimize carbon emissions. The Government should strictly control over the scale of construction land and prohibit the uncontrolled sacrifice of agricultural land for the expansion of construction land. At the same time, it should promote afforestation activities to increase forest coverage, expand the area of public green space to improve ecological functions, and reduce carbon emissions by increasing carbon sinks.

(3) Improving the use efficiency of agricultural materials, promoting the use of organic fertiliser and other important means to achieve low-carbon development of the plantation industry. With the continuous development of the economy, while increasing the proportion of investment in the primary industry, some organic materials should be purchased, and some standards should be set for the use of traditional materials, so as to reduce carbon emissions from planting in Jiangsu Province.

References

1. Ali, R., Ishaq, R., Bakhsh, K., & Yasin, M. A. (2022). Do agriculture technologies influence carbon emissions in Pakistan? Evidence based on ARDL technique. Environmental Science and Pollution Research,29(28),43361-43370.10.1007/s11356-021-18264-x.
2. Piwowar, A.(2019).Low-Carbon Agriculture in Poland: Theoretical and Practical Challenges.Polish Journal ofEnvironmentalStudies,28(4),2785-2792.10.15244/pjoes/92211.
3. LI Yang,CHEN Minpeng.(2021) Analysis of factors affecting non-CO2 greenhouse gas emissions from agricultural sources in China[J]. Journal of Environmental Science,41(12):5174-5189.
4. WU Meng,REN Li,CHEN Yinrong.(2017) Simulation study on the dynamics of urban land use carbon emission system--taking Wuhan as an example[J]. China Land Science,31(02):29-39.
5. (2023)Department of Rural Socio-Economic Statistics, National Bureau of Statistics. China Rural Statistics Yearbook [M]. China Statistics Press, Beijing.
6. (2023)Jiangsu Bureau of Statistics. Jiangsu statistical yearbook [M]. China Statistics Press, Beijing.
7. (1969)Jay W.Forrester.Urban Dynamics[M].Mass:The MIT Press,Cambridge.
8. (2009)Wang Qi-Fan. System Dynamics (2009 Revision)[M]. Shanghai University of Finance and Economics Press,Shanghai.