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Study on environment-economy-society relationship model of Liaohe River Basin based on multi-agent simulation

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ABSTRACT

Based on sustainable development theory and the method of system dynamics and multi-agent simulation, the environment-economy-society relationship model of Liaohe River Basin is constructed by coupling the system dynamics model with the multi-agent model in the software-NetLogo. This paper selects the Qinghe, Fanhe and Puhe River of Liaohe River Basin which are located in Shenyang and Tieling City as the study boundary, then the overall situation of environment, economy and society development is analyzed. At the same time, in order to simulate and predict the overall operation of the model under different policies, three kinds of development scenarios are established by changing some key variables including pollution abatement investment, fixed assets investment and industrial waste water production of ten thousand yuan industrial output value. The results show that the development under different policies can be simulated and predicted by this model, which will provide support for macroeconomic regulation and control the sustainable development strategy of Liaohe River Basin.

1. Introduction

With the development of society, the relationship between society, economy, water environment and ecology is becoming more and more important, especially the water environment problem. The sustainable utilization of water resources is key constrained factor of socialist economy construction and urban sustainable development (Jia and Hua, 2007). As one of China's seven biggest basins, the water environment situation of Liaohe River Basin is very grim. Because its comprehensive pollution index ranks the forefront of the seven major river basins, it becomes key management basin of the State Council (Xi-Ping et al., 2011; Han, 2010).

Liaoning Province is an important heavy industrial base in our country, the main pollution source points are split into eight industries, namely livestock and poultry breeding industry, comprehensive industrial park, petroleum refining industry, food processing industry, small town sewage treatment plants, metallurgy industry, printing and dyeing industry and papermaking industry. The economy and society of Liaohe River Basin should be fully considered when setting the water pollutants emission limits. International experience in watershed management has shown that the best available technology is identified through the pollutant reduction technology assessment system to determine pollutants emission limits and develop pollutant reduction technology programs that will greatly facilitate technological innovation and promote water quality (Meng and Wang, 2008) Only to make the coordinated development of environment, economy and society systems, the sustainable development can realize in the future of mankind (Chen et al., 2010a).

In recent years, multi-agent systems are more and more widely used in all aspects of the social system research (Avci and Selim, 2016; Sethia and Karlapalem, 2011; Zhang et al., 2013; Hu et al., 2016), its goal is to transform large complex systems into small systems which are mutually communicated, coordinated, and easy to manage. At the same time, the system dynamics (SD for short) is a subject of information feedback science, and it is also a comprehensive subject to understand and solve the problem of the systems (Wang, 1994). Regional sustainable development model which including the water environment, economy, society, energy and other subsystems have been conducted by many scholars at home and abroad using the system dynamics method, which has well studied the strategy of sustainable development. Wei Jin, Linyu Xu attempted to incorporate system dynamics (SD) into EF to develop a dynamic EF forecasting framework, and provide a platform to support policy making for urban sustainability improvement (Jin et al., 2009). Furthermore, several typical coupling development scenarios are simulated in this research, through which we finally

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determine the best development scenario of sustainable development (Song and Liu, 2006; Fatma, 2015; Guan et al., 2011a; Han and Zhu, 2011). Dongjie Guan proposed a dynamic combination method of SD–GIS to model and evaluate the urban development in Chongqing city of China suffering from depletion of resource and degradation of environment (Schieritz and Milling, 2003).

However, SD model cannot reflect the local changes in real time; multi-agent simulation cannot give the overall effect to individual units in a timely manner, so these two models cannot solve the complex system simulation on ones own (Guan et al., 2011b; Kim and Juhn, 1997). Therefore, the environment-economy-society relationship model is constructed in the NetLogo platform coupled the SD and multi-agent method. In more detail, SD model includs environment, economy and society subsystems and multi-agent model includes environment agent, economy agent, society agent and tendency degree agent. Finally, feasibility test and real time control of Liaohe River Basin emission limits are studied based on three aspects of the environmental, economic and social.

2. Methodology

Step 1: Set three subsystems including the environment, economy and society subsystem. Then operation flow diagram (Haghshenas et al., 2015; Vafa-Arani et al., 2014; Shen et al., 2009; Mavrommati et al., 2013) of each subsystem is drawn after exploring the dynamic mechanism of sustainable development model and analyzing the operation rules of the internal system. At last, environment-economy-society SD model of Liaohe River Basin is established.

Step 2: With the help of NetLogo software, the multi-agent simulation model is established, and the problems of sustainable development are studied qualitatively and quantitatively.

Step 3: Coupled the SD model and multi-agent model, the model is used to verify whether the water pollutants discharged from the eight typical industries in Liaohe River basin can meet the requirements of environmental, economic and social coordinated development.

Step 4: Three types of simulation scenarios are put forward, namely economic priority scenario, environmental protection optimization scenario and neutral scenario. The development trends of environment, economy and society subsystems are analyzed under different development scenarios.

To sum up, the specific technology roadmap is shown in Fig. 1.

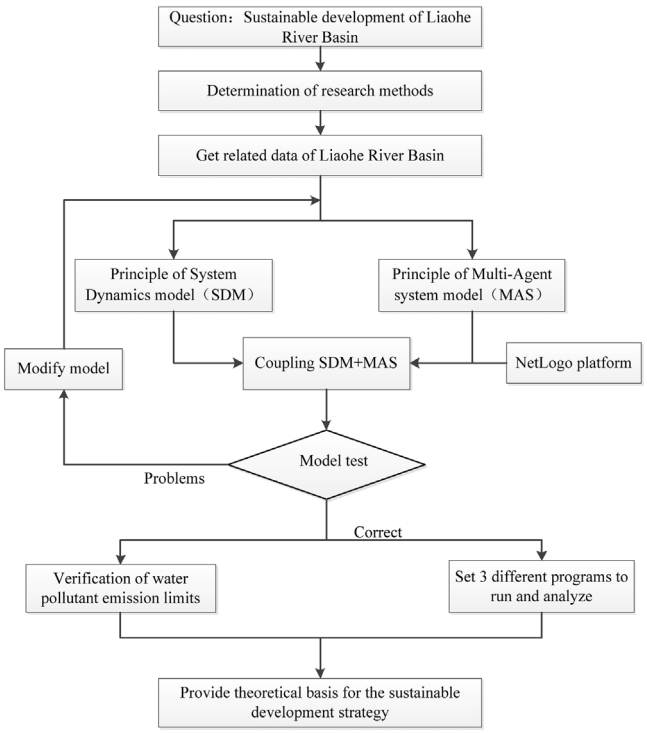

Fig. 1. Technology Roadmap.

3. The system dynamics model development

3.1. Parameter determination method

The basic structure of the system dynamics model is information feedback, the behavior of the model is mainly determined by the structure of the model, so it is not very sensitive to the parameter changes. In this paper, the following parameter estimation methods are used in the process of model construction:

(1) The direct determination method.
(2) The average value method.
(3) The logic inference method.
(4) The linear regression method: Univariate or multivariate linear regression methods are used to fitting analysis based on the relationship between the unknown variables and the partial variables in the model, and the regression analysis is carried out by using the software Eviews8.0.

Using the data in Liaoning Province Statistical Yearbook (Liaoning Bureau of Statistics, 2015), the research report from 2005 to 2015, and some research parameters to simulate the situation of 2005–2025 years. The baseline year is 2005, and the simulation time interval is 1 years.

3.2. Integrated framework and causal feedback diagram

Input/output characteristics and feedback conversion characteristics of material flow and information flow reveal the structure of the system and the driving mechanism of the system. This paper refers to a lot of information about the environment, economy, society, population and other systems, the framework model of environment-economy-society system (Fig. 2) and causality feedback relationship (Fig. 3) between parameters of Liaohe River Basin was constructed with the development law of Qinghe River, Fanhe River and Puhe River of Liaohe River Basin which are located in Shenyang city and Tieling city.

3.3. Subsystem

Environment-economy-society system dynamics model of Liao River Basin is divided into environment, economy and society subsystem. Based on the theory of sustainable development, combined with the actual situation of Liaohe River Basin and the development of water pollutant emission limits, the above three systems are selected.

3.3.1. Environment subsystem

Environment is the place where human beings live, and it is the foundation and guarantee of the sustainable development system. Environmental pollution will directly affect the population mortality, thus changing the social operating mechanism. In addition, environmental pollution will restrict the development of the economy on a certain degree. After the depletion of environmental resources, it will limit the further development of the economy.

Environment subsystem is divided into three parts, water environment, atmospheric environment and solid waste. The main pollutants including “Discharged Volume of NH3-N (DVNH3-N)”,