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The green development in China through the lens of complex cybernetics: Insight for a new era

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ABSTRACT

Measuring the level of green development is far from being a well-assessed problem, due to both the broad meaning of green development and the presence of randomness in environmental changes. In this paper, we develop the sustainable development evaluation index system from different perspectives, including resource utilization, green development management, green development quality, environmental protection, growth quality and green lifestyle. This evaluation index system is further viewed as a cybernetic system. Following a rough set approach, we properly address the issue of uncertainty and develop a robust estimation methodology. Neighborhood rough set and rough set methods based on genetic algorithms (GAs) have been used to identify the key indicators within the system. First, the results illustrate how a cybernetic approach deals with green policy and economic growth. Second, such a cybernetic approach provides new insights into identifying the main attributes for a sustainable development. Finally, stategies of improving green development in different parts of China are provided, concluding this paper.

1. Introduction

The recognition of the increasing impact of ecological and environmental problems on human beings has brought us to the "ecological era", in which the protection of the ecological environment and the improvement of green development strategies have become priority. Countries worldwide take active measures to deal with the environmental problems and seek green development one after another (Xiao et al., 2022). In this perspective, the United States proposed "Green Economy" and the "Green New Deal" in 2008, while the United Nations launched the Sustainable Development Goals (SDGs) for 2030 in 2015.

In this context and with its huge population, China embraced green development. This was one of the most important development modes of ecological civilization construction since 2012 in the 18th National Congress of the Communist Party of China. Five years later, in the 19th edition of the Congress, China put forward the policy guideline of "promoting green development, focusing on solving prominent environmental problems, strengthening ecosystem protection, and reforming the ecological environment detection system", making green development a national strategy. This is an inevitable requirement to break through the bottleneck constraints of resources and environment, and it is an unavoidable choice to adjust the economic structure, change the development mode and realize sustainable development (Feng et al., 2021).

Traditional economic growth theory believes that factors affecting economic growth are land, workforce, capital affluence, technological progress, and scale of the economy (Wenbiao, 2019). However, studies reveal that there is still a lack of systematic and scientific research on the economic influence of ecological, environmental protection, and green development. Starting from the paper published by Pearce (1992), a study that pioneered the green economy concept, the scientific debate has given to the green development an increasing attention in an attempt to unify the economic development and the carrying capacity of natural resources (Xiao et al., 2022). This means that there is an increasing need to consider the integrated system of humans, economy, and ecology as an important factor in exploring and analyzing development issues (Yiqing et al., 2020). Thus, a modern economy should reconcile high-quality development with economic growth and ecological environment, social welfare, and output efficiency (Aluko and Obalade, 2020). More specifically, high-quality development with a special focus on green development has become the core of the modern economic system (Gh et al., 2012; Ayag, 2021).

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As green development is today a top priority for sustainability, a better understanding of it is needed for ensuring economic development and resources conservation. Yet, the level of green development is difficult to measure (Bai et al., 2022; Yang et al., 2022; Wang and He, 2022). In the current research on the measurement of green development, the main methods can be divided into two categories: comprehensive index system (Xiao et al., 2013) and green development efficiency such as data envelopment analysis (DEA) (Sun et al., 2018; Zhou, 2018), and stochastic frontier analysis (SFA) (Feng et al., 2017; Liu et al., 2018a, 2018b). In practice, there are limitations in the current evaluation methodologies of green development efficiency, for they cannot fully capture the complexity of green development level. Thus, compared to methodologies of green development efficiency, the composite index method is the most widely adopted evaluation method for obtaining more accurate estimation results (Han et al., 2016; Wang et al., 2018; Turturean et al., 2019).

In this paper, we introduce cybernetics to construct a comprehensive index system for the level of green development and view the index system as a cybernetic system. This perspective is a good starting point because cybernetics disseminates the green development into a vast range of natural and social perspectives that can trace green development back to cybernetics. This methodology can incorporate the information from more diverse composite indexes that can enable cybernetics to be used to specify how to maximize and make sequential decisions based on the calculated results.

However, a cybernetic system composed by a composite index system introduces uncertainty (Ghaderi et al., 2019; Zhang et al., 2020). On the one hand, various complex data is needed to properly reflect green development in different regions, and changes and fluctuations of data naturally increase the uncertainty. On the other hand, the interaction of the data with their environment is also unknown within the system. This interaction provides feedback to the system and is the key feature involving the randomness of the modeling process. Fortunately, the rough set methodology is a common feature selection of data dimensionality reduction used in data mining. It has the advantage of identifying more relevant features and reducing the dimension of data even when there exists uncertain and vague information.

In this paper, we introduce cybernetics to construct a comprehensive index system for green development level. Specifically, we view the index system as a cybernetic system to involve the randomness in the modeling process. For this reason, we view the complex index system as cybernetics and use a rough set approach to study the uncertainty of the cybernetics. This is a suitable approach for the considered problem.

The structure of this work is as follows. In Section 2, we provide a discussion and review of green development and the methods on evaluating green development level and provide some background on related topics helps us identify what gaps occur in the literature. In Section 3, we illustrate the data that is adopted in this study. In Section 4 we construct a cybernetic system and use the rough set approach for its estimation. We also do a robustness test of the estimation results. In Section 5, we discuss the indexes produced by our analysis in Section 4. Conclusions are given in Section 6. Although this paper mainly focuses on green development in China, the framework proposed in this study can be applied to other countries and regions.

2. Literature background

2.1. Review of green development

To improve the living conditions of mankind, an economy can adopt green development policies that improve economic growth and promote human well-being while limiting the risks of environmental impact (Ikram, 2022). Indeed, such policies are being pursued across the globe. Early in the 1980s, the United Nations put forward the concept of "green" to the international public for the first time with the worsening global climate change and energy depletion. Pearce (1990) then proposed the "green economy" concept. From then on, how to solve economic growth and ecological sustainability has become one of the focus issues of economic research, which has attracted many experts and scholars, who developed new concepts such as green growth, green transformation, and green development.

Originating from the connotation of sustainable development, green development is a new pattern to integrate environmental protection with economic profits, emphasizing both "green" and "development". The existing research on green development can be categorized into three paradigms (See Table 1):

1) *Ecological economics* focused on the new situation of green empowerment of economic growth, including circular economy, low carbon economy, and ecological economy (Weber and Cabras, 2017; Liu et al., 2018a, 2018b; Shi et al., 2022). Within this paradigm, scholars believed that the level of green development is positively related to the efficiency of energy utilization (Liu et al., 2018a, 2018b; Jin and Han, 2018; Cheng et al., 2023), to emission of CO2 (Weber and Cabras, 2017; Shen et al., 2021; Shi et al., 2022) and SO2 (Fu and Geng, 2019), and can be improved as a result of green technological development (Su et al., 2022).

2) *Public management* attached importance to how institutions and governance can help to form a new green lifestyle. Most scholars analyzed the green economy's operating mechanism and internal requirements (Duthie, 2001; Ikram, 2022; Yang et al., 2023) and tried to find out the essential characteristics and institutional point of view on the topic (Shi et al., 2022; Ikram, 2022). Plans for green development depend on green development governance (Wan et al., 2022) and green lifestyle (Ali et al., 2023; Zhao et al., 2023).

3) *Ecology* paid attention to how the natural capital can promote a new and beautiful living environment. Green development has composed of natural capital including blue sky, green land and energy resources, ecological conditions of forest and air quality (Cheng et al., 2023), and also water resources (Islam et al., 2022; Yang et al., 2023). It has been confirmed that there exists strong correlation between natural capital and green development (Austin, 2017; Su et al., 2022; Cheng et al., 2023), and natural capital emphasizes more on the green living environment (Bai et al., 2022).

These three research areas reveal that many perspectives need to be considered in the process of evaluating green development. Yet, most studies only focused on one or two of them. In this paper, we try to probe green development with a more comprehensive causality analysis that

Table 1
The three paradigms of green development.

Green development	Main theme	Index	Publications
Ecological economics perspective	circular economy; low carbon economy; ecological economy	energy utilization; emission of CO2; emission of SO2; green technological development	Weber and Cabras (2017); Liu et al., 2018a, 2018b); Jin and Han (2018); Fu and Geng (2019); Shen et al. (2021); Su et al. (2022);Shi et al. (2022); Cheng et al. (2023)
Public management perspective	institutions; green governance	green development governance; green lifestyle	Ikram (2022); Shi et al. (2022); Wan et al. (2022); Yang et al. (2023); Ali et al. (2023); Zhao et al. (2023)
Ecology perspective	natural capital; a new and beautiful living environment	blue sky; green land; energy resources; ecological conditions of forest; air quality; water resources	Austin (2017); Su et al. (2022); Bai et al. (2022); Islam et al. (2022); Cheng et al. (2023); Yang et al. (2023)

accounts for all of these perspectives. We comprehensively use 20,400 observed data points to construct an index system suitable to measure the level of green development in a nation. Since not all indicators have the same importance in different regions moving towards green development, here the green development is analyzed as a cybernetic system.

2.2. Review of cybernetics and rough set

The cybernetics approach has always been an intriguing field. Norbert Wiener (1948) first defined cybernetics as the scientific study of control and communication in the animal and the machine. Later, he extended this definition to the field of communication within social systems, and he advised that communication is based upon the spoken word being transmitted from a sender and decoded by a receiver. He noted that this decoding step can potentially be affected by the mental state of the receiver (Wiener, 1950). Shannon (1948) and Marko (1967) further developed the connotation of cybernetics as the science of message transmission, processing, and the regulation and control of complex systems (Scott, 2011). Cybernetics is applicable when a system contains a causal relationship, with dynamics or behaviors developed from the system that can affect the wider environment and thus conversely affects the system. As such, the purpose of cybernetics is to unravel unifying theories on how complex systems function and can be controlled (Scott, 2011).

With the continuous development of cybernetics, its applications are becoming more and more extensive (Kline, 2020; Petrick, 2020). Yet, how to properly deal with the uncertainty of cybernetics is becoming a difficult problem. For example, the environment of a cybernetics model is always unknown, and interaction relationships and changes within the cybernetics are also unknown. These uncertainty problems increase the difficulty in the process of dynamic programming the information set. Fortunately, rough set theory is quite suitable for dealing with uncertainty problems in an information system. Rough set theory has an advantage in dealing with more complex information, as it can better process, filter, classify, and find helpful information. The relevance of rough set method to cybernetics thinking can be effectively used for analyzing the dynamics of the involvement processes. Within this work, we apply the rough set method to explore how complex systems function and interact.

Pawlak (2004) proposed a rough set in the early 1980s. Rough sets have been found out to possess the peculiar advantage of truly reflecting the information and revealing the potential rule of the data in a very flexible way. They are particular adapted to social data (Pawlak and Skowron, 2007; Seiki Ubukata et al., 2018; Xia et al., 2022). Thus, they can be applied to data analysis and data mining of cybernetics in decision making and feature selection, and even in finding out the rule for uncertain data based on belief functions. The rough set is a powerful mathematical tool handling uncertainty, vagueness, and inconsistent data, and as methods of a rough collection developed, now rough set is extended to neighborhood rough set, and rough set based on genetic algorithms (GAs) (Lotf et al., 2022; Xia et al., 2022; Yin et al., 2023).

We show that the combination of rough set methods with GAs and neighborhood rough sets improves understanding green development for two reasons. First, such combined methodology does not require any prior knowledge of the cybernetic system. Second, neighborhood rough set and rough set methods based on GAs can deal with mixed data without breaking the order structure of the data. Thus, this method can handle more information and properly deal with more uncertainty and randomness.

This work aims at providing a framework to assess the level of green development as a cybernetic system by integrating the rough set method to determine the crucial indicators in such cybernetic system. Neighborhood rough set and rough set methods based on GAs can improve learning performance. Although they suffer from a common limitation that they need a complete set of information to perform properly, the construction of a cybernetic system in our methodology can overcome this limitation. The advantages of our approach is based on providing general relationships and identifying the most important factors that could contribute to the green development. Researchers and practitioners may also find this methodology valuable to help narrow down the set of factors without providing any prior knowledge of the feature space.

3. Materials and data collection

To comprehensively reflect the insights from different kinds of indicators for green development, this paper constructs an index system based on the "green development index system" published by China National Development and Reform Commission (2016) and Lin and Lezzi (2020). This novel index system is comprised of six different perspectives, including resource utilization (C_1), green development governance (C_2), green development quality (C_3), environmental protection (C_4), growth quality (C_5) and green lifestyle (C_6). To better understand the indicators of green development, resource utilization (C_1) is further categorized into energy consumption (C_{11}), reduction of energy consumption per-unit GDP (C_{12}), and so on, reflecting other indicators that are further categorized into second-level indicators (such as C_{21}, C_{22}, C_{63}) that appear in Fig. 1.

Data for the indicators in Fig. 1 cover a period from 2003 to 2022, and come from the China Statistical Yearbook, the bulletin of China's environmental situation, the statistical yearbook of China's mainland resources, and the publication of ecological quality of China's coastal waters. Data for indicators are related to 30 regions in China: Beijing, Guangdong, Yunnan, Shanxi, Tianjin, Shandong, Hebei, Henan, Guangxi, Inner Mongolia, Hubei, Liaoning, Jiangsu, Chongqing, Heilongjiang, Shanghai, Jilin, Zhejiang, Anhui, Fujian, Jiangxi, Hunan, Hainan, Guizhou, Shaanxi, Gansu, Qinghai, Ningxia, Sichuan and Xinjiang. There are altogether 20,400 data collected and the calculation results are shown in Appendix 1.

4. Modeling and robustness test

4.1. Modeling

We adopt a case study in China to analyze the situation of green development by drawing upon cybernetic theory, aligning the use of rough set and cybernetics. Here, the level of green growth is viewed as a cybernetic system, and the data collection activity focused on collecting the specific indicators listed in Fig. 1. Cybernetics allows us to view green development as a complex system. A rough set is used to deduct the redundant indicators of green development and identify what is essential for measuring green development. The integration of cybernetics and a rough set provides a possibility to estimate the system's feedback.

A cybernetic system is defined as a quadruple $S = (U, A, V, f)$. In such system, $U = \{u_1, u_2, \ldots, u_n\}$ is a finite, non-empty universe set or dataset at a particular moment. A is the set of attributes, which can be decomposed as $C \cup D = A$, where C is the set of conditional attributes and D is the set of decision attributes. V is a set of attribute values, while $f : U \times A \rightarrow V$ is a mapping function that indicates the value $v \in V$ of each attribute $a \in A$ for any observation $u_i \in U$, for $i = 1, \ldots, n$.

In the rough set framework, S can be viewed as a decision table. According to the index system, C can be divided into 33 indicators. The value of D is based on real data, available on the bulletin of China's environmental situation. When in the report we clearly assess that the "green development is better than last year", D is equal to 1. Otherwise, the value is 0.

In Fig. 2, regions and attributes are firstly input in the cybernetic system. There exists a black box because the iteration process in this system is unknown. To overcome the uncertainty in this system and obtain the optimal characteristics within the system, a neighborhood rough set method has been used.

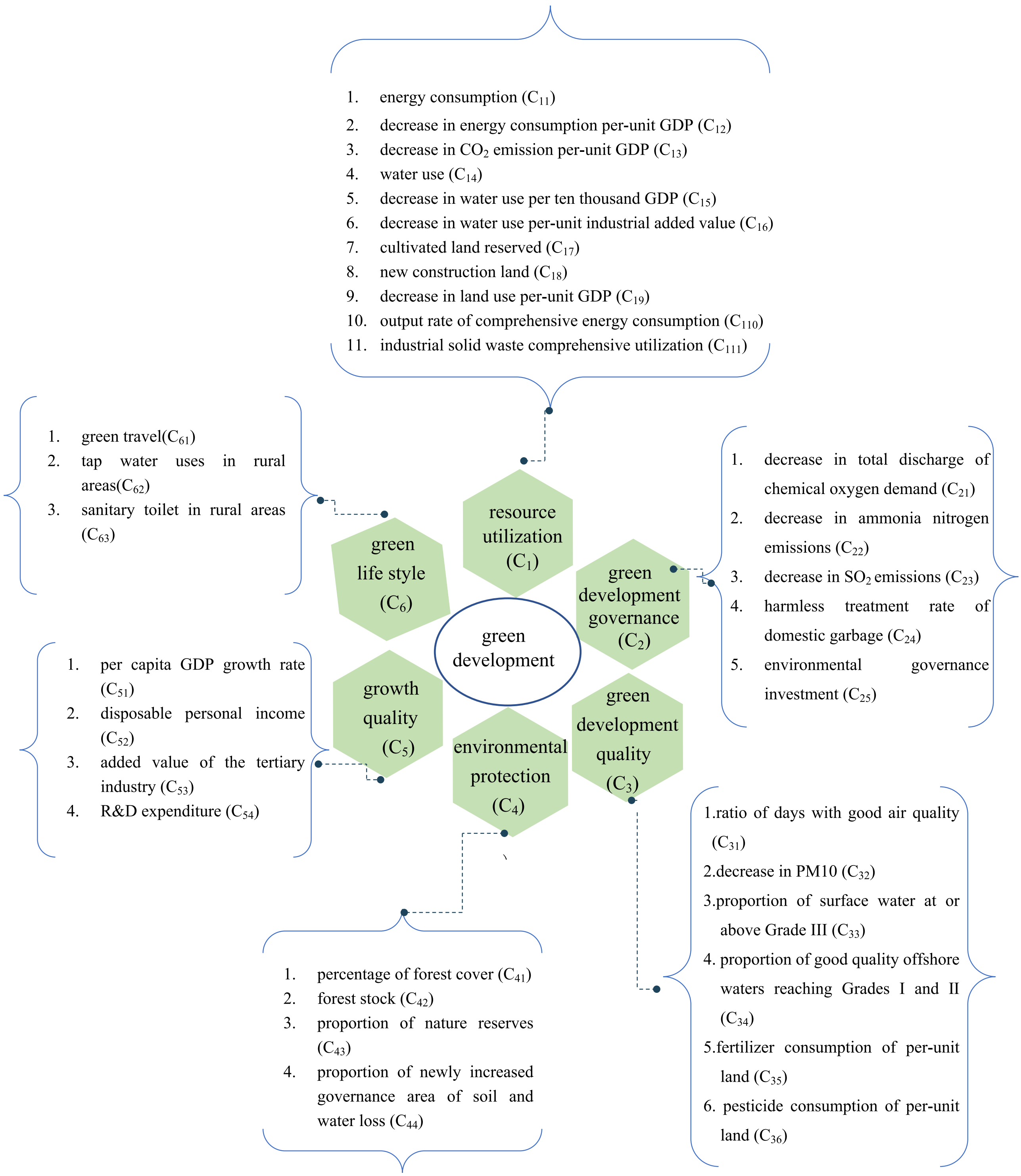

Fig. 1. Index system for green development. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

A rough set is derived based on a similar relation. For a rough set, A is typically the set of attributes that describes all the elements of X_i. Thus, an equivalence relation exists between any two elements x_i and x_j of X, and can be expressed as IND(A) such as $a(x_i) = a(x_j) \forall a \in A$ .This means that for a given set of attributes A, two observations $x_i$and $x_j$are indistinguishable if all their attributes A coincide. Yet, this equivalence relation is a strict equality of numeric values. In a neighborhood rough set, the equivalence relation does not perform in the way of $a(x_i)$ equal to $a(x_j)$, but in the way that $a(x_i)$ belongs to a neighborhood of $a(x_j)$. Given any x_i,x_j,$x_k \in U$and $B \subseteq A$, the neighborhood $\delta_B(x_i)$of x_i in feature space B is defined as:

$$\delta_B(X_i) = \{X_j \in U| \Delta^B(X_i, X_j) \leq \delta\} \tag{1}$$

Where $\Delta : U \times U \rightarrow \mathbb{R}^+$ is a distance function satisfying:

$$\Delta(x_i, x_j) \geq 0, \Delta(x_i, x_j) = 0$$

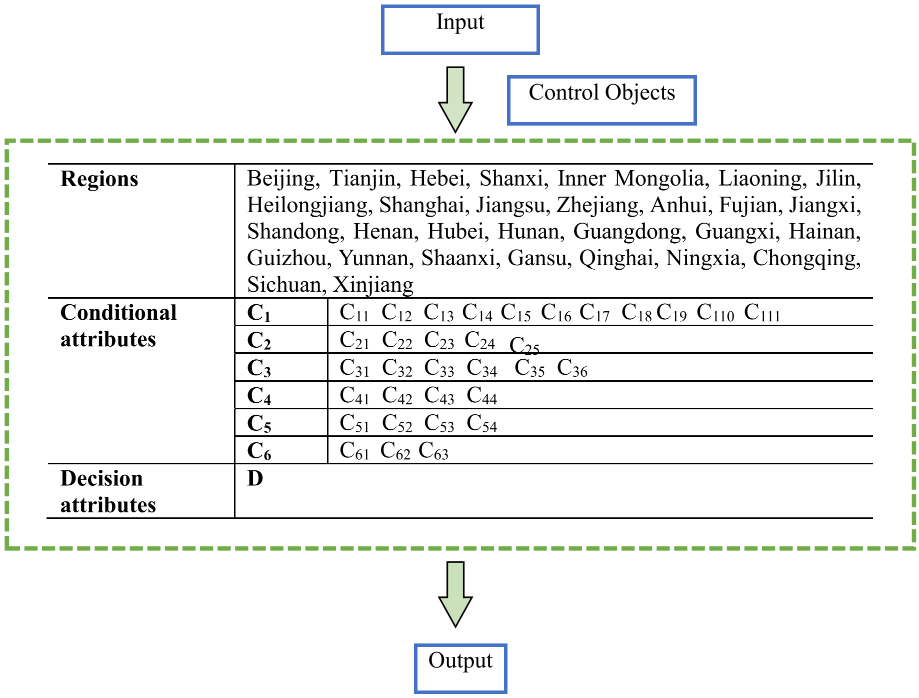

Fig. 2. Cybernetic system for green development
Note: C_1, C_2, C_3,C_4,C_5,C_{11},C_{12},…,C_{63} are the indicators of index system for green development, see Fig. 1. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

if and only if

$$x_i = x_j \tag{2}$$

$$\Delta(x_i, x_j) = \Delta(x_j, x_i) \tag{3}$$

$$\Delta(x_i, x_j) + \Delta(x_j, x_k) \geq \Delta(x_i, x_k) \tag{4}$$

In the neighborhood rough set framework, categorical attributes reflect equivalence relation and numerical features reflect neighborhood relation. They are then both used to approximate the decision (Qinghua Hu et al., 2008; Xibei Yang et al., 2011). Compared to a rough set, a neighborhood rough set is more flexible, because it can deal with mixed numerical and categorical variables within a unique framework.

The specific algorithm steps are reported in Table 2:

Upon the relationship of neighborhood rough set, we define $\boldsymbol{S} = (\boldsymbol{U}, \boldsymbol{A}, \boldsymbol{V}, \boldsymbol{f})$ and set $\lambda = \mathbf{2}$ (λ is the parameter in the calculation of the neighborhood radius) and $\boldsymbol{sig_{ctrl}} = \mathbf{0.001}$ ($\boldsymbol{sig_{ctrl}}$ is the control parameter of the lower limit of importance, which is taken small and positive). Then in our case, we use the relationship of neighborhood rough set to find out the positive set, and if there is more than one positive set, we select the one which can be merged with most of the attributes. From the positive set, we now unfold the weight of each indicator for Level 1, and the second level index can also be obtained by removing them in turn and calculating the difference between the weight of the indicator in Level 1 and the weight of removing the second-level index. As a result, $\boldsymbol{SGF}(\{\boldsymbol{c_{XH}}\}) = \boldsymbol{U}(\boldsymbol{c_x}) - \boldsymbol{U}(\boldsymbol{c_x} - \mathbf{c}_{\boldsymbol{xh}})$.

Table 2
The specific algorithm steps for neighborhood rough set.

Algorithm 1: neighborhood rough set

Input: decision table $S = (U, A, V, f)$
Output: the relative importance of secondary indicators in the sense of rough sets
Begin:
Decision table ← $S = (U, A, V, f)$
$I\lambda$←2 parameters in calculating neighborhood radius
sig_{ctrl}←0.001 control parameter of the lower limit of importance
Repeat
for $POS_c(D) = \bigcup_{i=1}^{n} C_{-}(X_i) = \bigcup_{i=1}^{n} \bigcup_j \{A_{ij} | A_{ij} \subseteq C_{-}(X_i)\}$
$\delta_B(x_i) = \{x_j | x_j \in U, \Delta^B(x_i, x_j) \leq \delta\}$
$U(C_x)$ weight ofC_x, $C_x \subseteq POS_c(D)$
$U(C_x - C_{xh})$ weight of $C_x - C_{xh}$ c_{xh} is under the selected positive set and is removed in turn
$SGF(\{c_{XH}\})$ $SGF(\{c_{XH}\}) = U(c_x) - U(c_x - c_{xh})$
Until $POS_c(D) = \varnothing$
End
Return $POS_c(D)$, $SGF(\{c_{XH}\})$

4.2. Results

The output of the calculation results is represented in Table 3.

Table 3 reports the output of the cybernetic system using a neighborhood rough set. Leading indicators affecting green development in a specific region in China are selected. From Table 3, we can see that energy consumption and waste gas emission, industrial solid waste comprehensive utilization, rate of high air quality days, and economic and technology development are the common indicators for the east, middle and west regions. That means reducing energy consumption, reducing waste emission (waste gas, solid waste, household waste), and improving economic and air quality are the common measurements for China to enhance green development.

The Chinese economy has entered a stage of high-quality development and is currently in a critical period of transforming its development mode, optimizing its economic structure and transforming its growth momentum. In this process, optimizing the industrial structure will inevitably have an impact on the green development. On the one hand, industrial structure optimization promotes the reduction of labor from pollution by adjusting the proportional relationship between industries and within industries. The shift from intensive industries to clean production industries can improve economic development, reduce environmental pollutant emissions, and ultimately enhance green production. At the same time, industrial structure optimization also improves resources by adjusting resource allocation structure, reducing

Table 3
Output of neighborhood rough set.

Regions	Reduction set	Sigset	Weight
Mainland	C_{12} *(decrease in energy consumption per-unit GDP)*	*6.67*	13.12
	C_{13}*(decrease in CO_2 emission per-unit GDP)*	*0.17*	0.33
	C_{18} *(new construction land)*	*1.33*	2.62
	C_{19} *(decrease in land use per-unit GDP)*	*0.33*	0.65
	C_{110}*(output rate of comprehensive energy*	*1.17*	2.30
	consumption)	*13.00*	25.57
	C_{24}*(harmless treatment rate of domestic garbage)*	*0.67*	1.32
	C_{25}*(environmental governance investment)*	*4.00*	7.87
	C_{31}*(rate of days with good air quality)*	*5.17*	10.17
	C_{32}*(decrease in PM10)*	*1.50*	2.95
	C_{33}*(proportion of surface water at or above Grade III)*	*2.00*	3.93
	C_{34}*(proportion of good quality offshore waters*	*0.83*	1.63
	reaching Grades I and II)	*0.67*	1.32
	C_{36}*(pesticide consumption of per-unit land)*	*1.00*	1.97
	C_{41}*(percentage of forest cover)*	*1.00*	1.97
	C_{42}*(forest stock)*	*3.00*	5.90
	C_{43}*(proportion of nature reserves)*	*2.67*	5.25
	C_{44}*(proportion of newly increased governance area of*	*2.00*	3.93
	soil and water loss)	*0.17*	0.33
	C_{51}(per capita *GDP growth rate)*	*1.83*	3.60
	C_{53}*(added value of the tertiary industry)*	*0.17*	0.33
	C_{54}*(R&D expenditure)*	*1.50*	2.95
	C_{61}*(green travel)*		
	C_{62}*(tap water uses in rural areas)*		
	C_{63}*(sanitary toilet in rural areas)*		
East	C_{12}*(decrease in energy consumption per-unit GDP)*	3.50	13.73
	C_{16}*(decrease in water use per-unit industrial added*	1.00	3.92
	value)	3.00	11.76
	C_{24}*(harmless treatment rate of domestic garbage)*	2.00	7.84
	C_{31}*(ratio of days with good air quality)*	3.00	11.76
	C_{32}*(decrease in PM10)*	0.50	1.96
	C_{33}*(proportion of surface water at or above Grade III)*	0.50	1.96
	C_{35}*(fertilizer consumption of per-unit land)*	0.50	1.96
	C_{43}*(proportion of nature reserves)*	5.00	19.61
	C_{51}(per capita *GDP growth rate)*	0.50	1.96
	C_{54}*(R&D expenditure)*	6.00	23.53
	C_{63}*(sanitary toilet in rural areas)*		
Middle	C_{12}*(decrease in energy consumption per-unit GDP)*	2.50	10.00
	C_{19}*(decrease in land use per-unit GDP)*	3.33	13.33
	C_{110}*(output rate of comprehensive energy*	2.50	10.00
	consumption)	2.50	10.00
	C_{111}*(industrial solid waste comprehensive utilization)*	5.83	23.33
	C_{31}*(ratio of days with good quality)*	2.50	10.00
	C_{33}*(proportion of surface water at or above Grade III)*	1.67	6.68
	C_{41}*(percentage of forest cover)*	1.67	6.68
	C_{43}*(proportion of nature reserves)*	0.83	3.32
	C_{44}*(proportion of newly increased governance area of*	0.83	3.32
	soil and water loss)	0.83	3.32
	C_{52}*(disposable personal income)*		
	C_{61}*(green travel)*		
West	C_{12}*(decrease in energy consumption per-unit GDP)*	1.82	7.56
	C_{16}*(decrease in water use per-unit industrial added*	0.45	1.87
	value)	0.45	1.87
	C_{110}*(output rate of comprehensive energy*	1.36	5.65
	consumption)	1.82	7.56
	C_{24}*(harmless treatment rate of domestic garbage)*	2.27	9.43
	C_{25}*(environmental governance investment)*	1.36	5.65
	C_{31}*(ratio of days with good air quality)*	1.82	7.56
	C_{33}*(proportion of surface water at or above Grade III)*	0.45	1.87
	C_{34}*(proportion of good quality offshore waters*	0.45	1.87
	reaching Grades I and II)	3.18	13.21
	C_{43}*(proportion of nature reserves)*	1.82	7.56
	C_{44}*(proportion of newly increased governance area of*	0.45	1.87
	soil and water loss)	1.82	7.56
	C_{52}*(disposable personal income)*	4.55	18.90
	C_{53}*(added value of the tertiary industry)*		
	C_{54}*(R&D expenditure)*		
	C_{62}*(tap water uses in rural areas)*		
	C_{63}*(sanitary toilet in rural areas)*		

Note: Eastern mainland China is including Beijing, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan; Middle mainland China is including Shanxi, Henan, Anhui, Hubei, Jiangxi and Hunan; Western mainland China is including Sichuan, Yunnan, Guizhou, Chongqing, Shaanxi, Gansu, Qinghai, Xinjiang, Ningxia, Inner Mongolia and Guangxi.

environmental pollutant emissions, and promoting green development efficiency. On the other hand, the rapid development of the secondary industry has led to an increase in pollutant emissions, which is not conducive to green development.

Urbanization in China is still in the mid-term development stage. With a relatively fast pace of urbanization, industrial transformation and upgrading lead to an increase in household income and a change in lifestyle. Human energy consumption gradually transitions from low-quality biomass and coal to clean energy sources, such as oil, gas and electricity. This transition promotes both economic development and population concentration, as well as the development of renewable energy production supply chains. To meet the demand of urbanization, there will be obvious change in wastewater, exhaust gasses, and waste discharge. As important parts of the green development, energy consumption and waste emissions indicate (both theoretically and practically) whether green development has achieved the desired results or not.

Air quality shows a high correlation with waste gas emission. Due to the continuous changes in atmospheric pollution sources caused by human activities over time and space, air quality can vary significantly. The spatial agglomeration of labor and capital, which leads to the expansion of economic scale and the increase in the product demand, may lead to more atmospheric pollutants. The expansion of economic scale has led to a deepening division of labor and specialization between and within industries, which can motivate new endogenous technological innovation, thereby eliminating a group of backward production capacity enterprises, promoting the industry to evolve towards higher technological levels and thus make air less polluted.

Other indicators also exist that reflect green development. A set of supporting management mechanisms, namely environmental regulation, is also needed. Governments can adopt regulation such as property rights, Pigou taxes and subsidies to implement environmental protection goals. Besides, the sustainability of the ecological environment is a necessary condition for achieving sustainable green development. A series of ecological compensation policies, such as returning farmland to forests and natural forest protection, are also necessary for green development.

4.3. Robustness test

To check the robustness of the estimation results of the rough neighborhood set for the cybernetics, we use Genetic algorithms (GAs) to estimate the cybernetic system again. Drawing from the principles of Darwinian natural selection and genetics theory, genetic algorithms (GAs) have the potential to produce optimal outcomes through a process of generating successive genetic variations of potential solutions and iterative computations (Liang and Huang, 2009; Aihua and Lezzi, 2020). By integrating GAs with rough set theory, a successful result can be efficiently obtained without the need to examine all possible solutions. This approach offers the advantage of identifying key attributes and swiftly deriving the result by reducing the fundamental units of the database. The specific steps of the algorithm are outlined below (See Table 4):

The algorithm begins by converting the original data into a binary form {0,1}. If a data point in a specific region is greater than the average value, it is assigned a value of 1; otherwise, it is assigned a value of 0 (Lin and Lezzi, 2020). This process results in obtaining binary strings of length n, where n represents the number of conditional attributes. For each conditional attribute (c_1, c_2, …, c_n), if an individual includes the first i attributes (i = 1,…,n), then c_i is set to 1; otherwise, it is set to 0.

Next, indicators are selected using the roulette strategy, and a new generation is generated based on the crossover probability and mutation probability, which are critical genetic operators for a new generation to be explored and are always pre-specified. Based on the characteristics of the optimized problem and the principle of maintaining the diversity of the population, we suppose crossover probability is p_c (p_c = 0.7) and

Table 4
The specific algorithm steps for rough set based on GAs.

	Algorithm 2: rough set based on GAs
1	Input: decision table $S = (U, A, V, f)$
2	Output: the relative importance of secondary indicators in the sense of rough sets
3	Begin:
4	Decision table $S = (U, A, V, f)$
5	data {0,1} the original data
6	binary strings {0,1} data {0,1}
7	Repeat
8	a new generation $p_c(p_c = 0.7)$,$p_m(p_m = 0.01)$
9	$F(r) = \frac{n - n_r}{n} + \lambda_c(d)$ fitness function
10	$\lambda_c(d) = \frac{pos_c(d)}{\lvert U\rvert}$ $pos_c(d)$means the positive set of decision attribute d on conditional attribute c, $\lvert U\rvert$denotes the cardinality of U
11	Until $Max\_Gen = 150$ or $\lambda_{reduct(c)}(d) = \lambda_c(d)$
12	End
13	Return $POS_c(D)$

mutation probability is p_m (p_m = 0.01). During mutation, the corresponding gene loci of an attribute remain unchanged. Following this, the fitness of each attribute in the new generation is calculated using a fitness function. The fitness function is expressed as:

$$F(r) = \frac{n - n_r}{n} + \lambda_c(d)$$

Where n_r represents the number of genes that equals 1 in chromosome$r$. $\lambda_c(d) = \frac{pos_c(d)}{|U|}$, where $pos_c(d)$means the positive set of decision attribute d on conditional attribute c, $|U|$denotes the cardinality of U. Finally, when the iteration steps reach the maximum threshold $Max_{Gen} = 150$or $\lambda_{reduct(c)}(d) = \lambda_c(d)$, the operation is stopped. Then we get the output of the cybernetic system.

Table 5 reports results of the leading indicators of the level of green development by cybernetics with the rough set method incorporated with GAs. Different from the neighborhood rough set method, there are fewer attributes selected. Compared to the method of neighborhood rough set, the method of rough set based on GAs with only two possible values for arithmetic operation: 1 or 0, limiting the accuracy and flexibility of the results. Yet the results of the rough set method based on GAs go along with the results of the method of rough neighborhood set in general. Energy consumption, waste emission, and air quality are the generally recognized essential indicators for green development.

Table 5
Output of rough set based on GAs.

Regions	Method: rough set based on GAs
Mainland	C_{12}*(decrease in energy consumption per-unit GDP)*
	C_{13}*(decrease in CO_2 emission per-unit GDP)*
	C_{14}*(water use)*
	C_{15}*(decrease in water use per ten thousand GDP)*
	C_{19}*(decrease in land use per-unit GDP)*
	C_{111}*(industrial solid waste comprehensive utilization)*
	C_{21}*(decrease in total discharge of chemical oxygen demand)*
	C_{23}*(decrease in SO_2 emissions)*
	C_{24}*(harmless treatment rate of domestic garbage)*
	C_{33}*(proportion of surface water at or above Grade III)*
	C_{36}*(pesticide consumption of per-unit land)*
	C_{43}*(proportion of nature reserves)*
	C_{44}*(proportion of newly increased governance area of soil and water loss)*
	C_{63}*(sanitary toilet in rural areas)*
East	C_{12}*(decrease in energy consumption per-unit GDP)*
	C_{13}*(decrease in CO_2 emission per-unit GDP)*
	C_{14}*(water use)*
	C_{15}*(decrease in water use per ten thousand GDP)*
	C_{19}*(decrease in land use per-unit GDP)*
	C_{110}*(output rate of comprehensive energy consumption)*
	C_{24}*(harmless treatment rate of domestic garbage)*
	C_{31}*(ratio of days with good air quality)*
	C_{32}*(decrease in PM10)*
	C_{33}*(proportion of surface water at or above Grade III)*
	C_{35}*(fertilizer consumption of per-unit land)*
	C_{44}*(proportion of newly increased governance area of soil and water loss)*
Middle	C_{12}*(decrease in energy consumption per-unit GDP)*
	C_{14}*(water use)*
	C_{19}*(decrease in land use per-unit GDP)*
	C_{110}*(output rate of comprehensive energy consumption)*
	C_{24}*(harmless treatment rate of domestic garbage)*
	C_{32}*(decrease in PM10)*
	C_{33}*(proportion of surface water at or above Grade III)*
	C_{35}*(fertilizer consumption of per-unit land)*
	C_{44}*(proportion of newly increased governance area of soil and water loss)*
West	C_{14}*(water use)*
	C_{15}*(decrease in water use per ten thousand GDP)*
	C_{111}*(industrial solid waste comprehensive utilization)*
	C_{24}*(harmless treatment rate of domestic garbage)*
	C_{25}*(environmental governance investment)*
	C_{31}*(ratio of days with good air quality)*
	C_{32}*(decrease in PM10)*
	C_{33}*(proportion of surface water at or above Grade III)*
	C_{41}*(percentage of forest cover)*
	C_{61}*(green travel)*

5. Discussion

According to the output of cybernetics aligning the use of rough set methods, we find that the green development was subject to a number of key indexes, including air quality, energy use, waste pollution, and economic development. We also find that environmental regulation is an important part for green development. Based on these conclusions, the resulting indicators appear in Fig. 1 and are used to construct the following index to measure the situation in China:

(1) Index for economic development (EDI):

Using the level of per capita GDP (C_{51}) expresses the level of local economic development.

(2) Index for air quality (AQI):

The rate of days with good quality (C_{31}) denotes the local air quality.

(3) Index for efficiency of energy use (EUI):

Total energy consumption (C_{11}) and decrease in energy consumption per-unit GDP (C_{12}) denote the efficiency of energy use. It can be defined as

$$EUI = -2.25 \times C_{11} + 3.39 \times C_{12}$$

$$EU = -2.25 \times C_{11} + 3.39 \times C_{12}$$

Where −2.25 and 3.39 are the weights for the index according to the green development index system.

(4) Index for pollution (PI):

This index includes industrial solid waste comprehensive utilization (C_{111}), decrease in total discharge of chemical oxygen demand (C_{21}), decrease in ammonia nitrogen emissions (C_{22}) and decrease in SO_2 emissions (C_{23}), and can be defined as:

$$PI = 1.10 \times C_{111} + 4.12 \times C_{21} + 4.12 \times C_{22} + 4.12 \times C_{23}$$

Where 1.10, 4.12 are the weights for the index according to the green development index system.

(5) Index for environmental regulation (ERI):

The environmental governance investment (C_{25}) is used to denote the level of environmental regulation.

(6) Index for green development (GDI):

This index is constructed by all the second-level indexes from the index system for green development and can be written as:

$$\begin{aligned} GDI = & -2.25 \times C_{11} + 3.39 \times C_{12} + 3.39 \times C_{13} - 2.25 \times C_{15} + 2.25 \times C_{16} \\ & + 3.39 \times C_{17} - 3.39 \times C_{18} + 2.25 \times C_{19} + 2.25 \times C_{110} + 1.10 \times C_{111} \\ & + 4.12 \times C_{21} + 4.12 \times C_{22} + 4.12 \times C_{23} + 2.74 \times C_{24} + 1.40 \times C_{25} \\ & + 4.43 \times C_{31} + 4.43 \times C_{32} + 4.43 \times C_{33} + 2.95 \times C_{34} - 1.53 \times C_{35} \\ & - 1.53 \times C_{36} + 6.18 \times C_{41} + 6.18 \times C_{42} + 2.07 \times C_{43} + 2.07 \times C_{44} \\ & + 2.30 \times C_{51} + 2.30 \times C_{52} + 2.30 \times C_{53} + 2.30 \times C_{54} + 2.20 \times C_{61} \\ & + 4.60 \times C_{62} + 2.30 \times C_{63} \end{aligned}$$

Where −2.25, 3.39, 2.25, … and 2.30 are the weights for the index

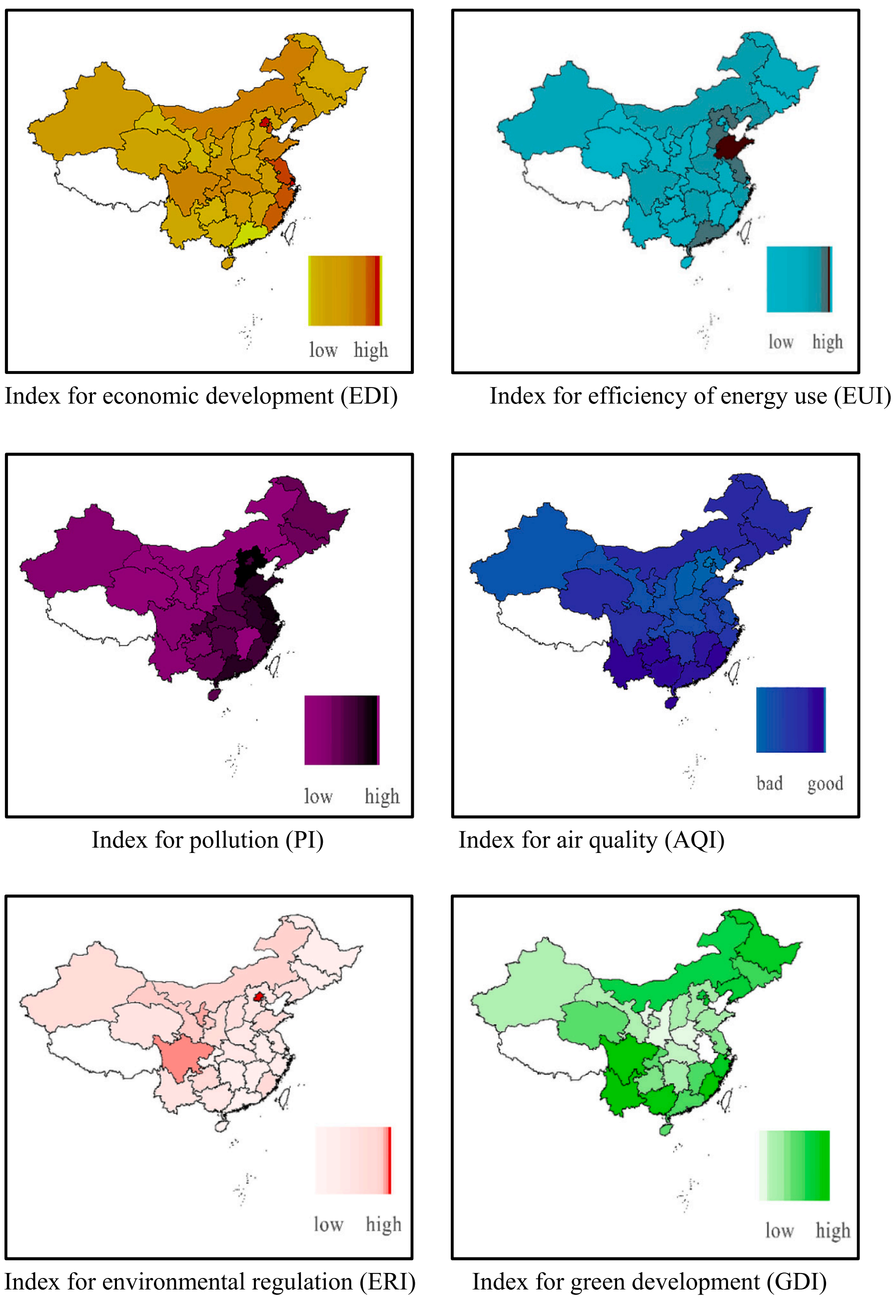

Fig. 3. Results for EDI (Index for Economic Development), EUI (Index for Efficiency of energy Use), PI (Index for Pollution), AQI (Index for Air Quality), ERI(Index for Environmental Regulation) and GDI (Index for Green Development)
Note: Data for indicators are from 30 regions in mainland China, and the data represented in the maps are the average data of 2003–2022.

calculated based on the "green development index system" published by China National Development and Reform Commission. The spatial results of the six indexes are shown in Fig. 3.

Fig. 3 reveals a significant spatial difference exists between the economic development, air quality, efficiency of energy use, pollution, environmental regulation, and green development levels across the country.

Fig. 3 also reveals how the prodigious growth of China's economy through the last 40 years has influenced the environment of east China. This region is the most developed part of the nation's economy, followed by middle China and west China. The per capita GDP in the east China is significantly higher than that in the middle and west China, probably due to the complexity of the economic development of China and the general movement of labor from the west to the east. The movement of people from the west to the east has caused a population increase with consequent urbanization and industrialization in the east.

The impacts are evident. First, urbanization and industrialization promotes local economic development, and increases local residents' wages and income levels. With the increasing gap in economic development between cities and towns, production factors such as labor and capital in surrounding areas continue to gather in the city. Second, the development of urbanization and industrialization promotes technological innovation, with impacts that are spread to surrounding areas through factors such as population movement, promoting the development of the surrounding areas and leading to the upgrading of the industrial structure in the surrounding areas.

The subsequent upgrading of industrial structure helps transform production centers from labor driven industries to technology driven industries, as well as from pollution intensive industries to clean production industries. The economy further evolves from low value-added industries to high value-added industries. In this transformation process, resource utilization efficiency and economic development gradually improves, which has a positive effect on green development. At the same time, the quantity of advanced industrial structure leads to the shift of production factors to higher-level industries. This in turn leads to an improvement in the quality of advanced industrial structure and thus reduces energy consumption.

However, the rapid economic development in east China has affected the consumption of natural resources, decelerated the self-restoration capacity, and reduced overall environmental stability. Rapid economic development in east China has created more inter-connected ecological problems, such as waste pollution. Fortunately, eastern China has realized the importance of the environment and has invested more in environmental regulation. As a result, east China exhibits high pollution but also high economic development and high efficiency of energy use.

The situation is both similar and different for middle China. The middle China exhibits a more complex set of ecological conditions, where soil and water loss in the two major water systems, the Yellow River and the Yangtze River basins, are quite severe. The natural conditions in these areas tend to mitigate efforts at green development. Transforming the ecological conditions in this region into industrial advantages in grain production while building a feasible path between "green mountains and clear waters" is a key challenge. Further, middle China is one of the main raw material bases in the nation, and it faces a series of thorny problems, such as resource depletion and environmental pollution. This reveals how it is necessary to explore innovative solutions.

The main problem in western China is the region's many fragile ecological areas. Desertification in western China, such as Xinjiang, Inner Mongolia, Gansu, and Qinghai, are all manifestations of China's fragile ecological environment. The ecological self-restoration ability for these regions is fragile, and these areas are characterized by a poor ecological environment, hostile conditions, and a lack of basic facilities. All contribute to the low living standards of the local population. Indeed, over an extended period, the combination of fragile ecosystems and underdeveloped economies has posed significant challenges to local economic and social progress. Due to limited options, many residents are compelled to engage in direct exploitation of raw natural resources, inadvertently exacerbating the fragility of the environment. For western China, the development of tertiary industry is an excellent catalyst for green development since it can improve the living condition of people.

6. Suggestion and conclusion

Green development is aiming at efficiency, harmony and sustainability. It is a comprehensive development pattern that considers both economic growth and environmental protection. While a comprehensive index system is one main way to measure the level of green development, the complexity of creating such an index system itself can induce greater uncertainty and randomness in the assessment process. To fill the gap of capturing the complexity and uncertainty of the green development level, this study views the green development as a cybernetic system and uses rough set theory as an efficient tool for dealing with inexact and uncertain information.

Compared with previous studies, the research novelty of this study can be summarized as follows:

(1) This study views green development in China as a cybernetic system and constructs a comprehensive index system for green development, including resource utilization, green development governance, green development quality, environmental protection, growth quality, and green lifestyle. The leading indicators for green development are also identified among these many attributest. This comprehensive view uses the leading indicators of green development to bring a more appropriate evaluation method to the study of green development.

(2) This study integrates the methodology of neighborhood rough sets based on genetic algorithms (GAs) into cybernetics. Such an approach overcomes the uncertainty encountered when estimating the output of a cybernetic system. Mathematical programming combines the use of cybernetics and rough sets to reduce random errors caused by complexity and randomness. The combination of these two methods also makes the results more robust and effective.

Our results obtained from the cybernetic system suggest ways to further develop the green level in China. Once the output of the cybernetic system is known, we are then able to adopt measurements to the system's future state and ultimately develop interventions to control the system. Practices prove that suitable interventions can effectively reduce the cost of environmental regulation and improve the ecological situation. This study implies that there are four specific ways to improve green development.

First, establish a man-green development system. This requires establishing a scientific thought pattern of green development view for human beings. It is essential to improve the environmental protection concept of the man himself. China has a relatively high population density globally, and man plays an essential role in the ecosystem. On the one hand, man purchases natural resources. On the other hand, man can make green development through green technology. Man's role in the ecosystem attached more importance to the level of self-awareness in choosing their behavior, based on improving green development. Insights into how improving the environment will enable man to better understand his existential situation and position in the ecological environment. Man can then adjust his behavior to protect the environment when he seeks to maximize his self-interest. All of China, not only the east and middle China, should enhance public exposure and education of green development concept. This will lead to a much healthier consumption habit and greener lifestyle of the general public, which will then ensure a much greener society can be achieved in the near future.

Second, establish an economy-green development system, which is especially important for west China. Along with the widespread economic development, green development has become more widespread in the contemporary world than ever before. While green and economic development seems controversial, it is essential that the economy and the ecosystem are both coordinated developed to gain the attention of sustainable development. Economic policy innovations can offer fundamental incentives for promoting green growth, such as by green bonds and green investment incentives. In this way, an ecosystem offers a material fundamental for the economy via sustainable natural resources. Based on the founding of the west China, and for the underdeveloped regions, the level of green development can be determined by the reasonable flow and optimal allocation of both resources and facilities. This implies that the reconstruction of basic facilities and sustainable economic growth mechanisms can effectively promote green development.

Third, establish a living-green development system. Green development should consider the comforts essential to a prosperous lifestyle. A green standard evaluation system should be used to promote the construction of green cities and towns. Such green communities and green tourist areas can effectively guide people to practice green travel and green living. Indeed, a living-green development system can be gradually constructed across the whole country. For example, air quality is one of the main challenges to urban health and green development, especially in middle China. Policies can be designed to improve China's air quality, such as reducing carbon dioxide and sulfur dioxide emissions from the use of fossil fuels. Further, policies that assign monetary values to the long-term and short-term waste gas emissions can be essential to promoting both economic efficiency and social equity.

Fourth, establish a green technology-green development system. This will create innovations in green technologies and facilitate social green production. Further, a recycling economy can be developed that largely improves the efficiency of energy and reduce pollution. R&D efforts also play a strong and positive role in improving resource production efficiency. With a relatively large population and well-developed economy, fostering R&D is one of the best choices for China to strengthen its green development. This is especially true in the west, where the fragile ecological environment is threatened by a backward economy with a lower standard of life. This situation reveals an urgent need to improve the R&D and strengthen environmental monitoring. Although the technology of simple monitoring environment of water, air, and industrial pollution in China has become more mature, ecological technology is still in its infancy. There is still a lack of a systematic and complete monitoring network. Improving green technology can vastly improve the level of green development in China.

This paper proposes a framework to study green development in China based on cybernetics. Rough set methods are used in the cybernetic system to identify the main aspects of green growth in various regions in China, and then corresponding measurements to develop the green level are suggested. Rough set computing helps cybernetics improve the efficiency of interpretation of the available data. While our work has focused empirically on green development in mainland China, we believe that the proposed framework broadly applies to other countries and regions.

CRediT authorship contribution statement

Aihua Lin: Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Pierluigi Toma:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Minfeng Zhang:** Writing – review & editing, Writing – original draft, Supervision, Resources, Data curation. **Giulio Fusco:** Writing – review & editing, Validation, Formal analysis, Policy implication.

Data availability

Data will be made available on request.

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Appendix A

Table. Level of green development for different regions.

regions	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
beijing	28.62817	29.64948	30.63912	30.03893	30.95535	31.35579	31.88086	32.24124	31.59634	31.496
tianjin	28.41112	28.88633	31.78527	31.94685	32.07172	32.99126	33.14303	32.12183	32.8083	32.81868
hebei	25.70955	25.09338	25.41821	26.01627	25.8496	26.65382	26.96012	28.12435	28.44485	28.5204
shanxi	25.87427	25.51061	24.71786	25.31835	26.52152	26.22251	25.43441	28.44327	29.29696	27.91963
innermogolia	25.89132	25.7248	27.35387	27.12027	27.69602	28.62925	29.2414	30.03509	30.96542	31.17782
liaoning	30.19392	29.51389	30.38073	29.75074	29.83235	30.71892	30.70057	31.46201	31.19205	32.42266
jilin	27.005	27.22383	26.58428	26.41219	28.08677	28.15383	27.80585	29.76758	30.82919	30.53948
heilongjiang	28.54759	28.27015	28.31375	28.35202	28.5828	29.22409	28.58619	31.40277	30.93472	31.18641
shanghai	26.7214	26.97772	27.15992	28.32162	29.21545	28.70701	28.17189	28.88336	29.21109	29.21004
jiangsu	25.84473	26.62181	27.67611	27.27688	28.54586	28.18165	29.18622	29.6823	30.09525	29.47928
zhejiang	29.55929	29.58606	30.16705	30.31252	30.51097	31.46689	32.27982	32.3707	31.97562	31.97225
anhui	21.34949	23.5078	22.227	22.84656	23.83927	22.87591	24.4119	26.03214	26.36837	27.06863
fujian	28.8086	29.58676	30.77062	30.60159	31.79814	31.77878	32.29938	33.55287	33.68852	33.92731
jiangxi	25.28756	25.81108	26.18635	26.58747	26.86816	27.77317	27.84483	29.29631	30.88265	30.94279
shandong	27.32689	27.21474	26.20612	26.17209	28.80128	28.89279	28.86314	29.47795	28.92829	29.26454
henan	23.70245	24.22698	24.94506	23.99302	25.74399	25.66553	25.60902	27.59893	26.38264	26.48995
hubei	24.78502	25.08291	24.78138	23.32355	24.26182	25.09611	25.86715	27.5168	27.87793	27.96212
hunan	23.22872	23.59253	23.77993	24.90506	26.69224	27.69515	28.00098	29.11845	29.16276	29.35096
guangdong	27.46308	26.18581	26.55148	26.40641	28.93273	29.99084	30.1948	31.2668	31.6951	32.15006
guangxi	28.54668	31.36693	31.04139	31.05292	29.53605	30.45861	31.25937	33.13209	32.68052	33.00371
hainan	26.13681	27.25647	28.26496	25.83555	28.1078	28.2811	27.70419	29.83602	29.46198	29.73472
chongqing	23.11757	23.54249	25.87007	27.37644	28.99799	29.90471	30.37384	31.29	31.76377	31.71202
sichuan	27.60983	29.97937	29.38793	29.13052	30.20955	31.91794	31.86498	33.02005	34.22961	34.03905
guizhou	23.4785	24.16122	26.27879	24.85878	25.37496	26.76942	26.41204	27.95695	28.62035	29.3473
yunnan	30.349	31.6566	30.98666	30.20895	31.47366	31.56517	31.51365	32.93541	32.65399	32.88153
shaanxi	21.90399	23.23057	23.47128	24.55659	24.42173	26.84938	27.01345	27.80085	28.0594	27.51806
gansu	24.04887	26.35127	23.92376	24.49394	25.26878	25.67	24.96343	26.26202	27.40914	27.65113

(*continued on next page*)

(*continued*)

regions	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
qinghai	27.60501	25.96631	28.01307	27.64779	28.34773	27.99605	27.87449	28.79504	29.88797	30.64802
ningxia	21.61128	23.63207	22.51877	23.29048	24.38911	25.42114	24.44172	27.2082	27.38764	27.50415
xinjiang	23.59404	22.6775	23.2116	24.94213	25.61123	26.57212	26.28959	29.12376	29.43159	28.92939

regions	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
beijing	29.61263	30.37753	31.33085	31.12513	31.48673	31.51953	31.48975	31.42421	33.47567	32.44935
tianjin	30.71411	29.30736	29.17592	30.42661	31.06012	31.56675	32.44021	32.45884	33.01993	33.67897
hebei	27.85921	27.13267	27.58519	28.03281	27.03714	27.53424	40.41044	28.4659	30.03185	30.01694
shanxi	26.38173	27.59733	27.15783	29.49548	29.31248	29.42946	29.39439	30.13537	33.3667	31.3531
innermogolia	33.12379	32.73922	30.8714	31.42298	33.25527	33.79109	34.78484	34.09584	35.84468	35.37267
liaoning	33.53432	33.30517	32.50269	29.94128	32.03326	32.57029	31.17724	31.53589	33.08891	32.90808
jilin	32.52063	31.11437	31.11439	31.25578	32.45175	33.26816	32.64574	33.3065	34.32228	33.54976
heilongjiang	32.85655	33.14183	32.33884	32.95832	33.60962	33.85404	36.28344	35.5438	36.81477	37.46286
shanghai	27.91047	29.50869	28.83478	28.91385	28.17176	28.76699	30.07485	31.17481	32.82401	32.92958
jiangsu	28.13437	28.24872	29.00171	29.1275	29.53733	29.49097	29.60728	29.91113	31.37782	30.6713
zhejiang	30.4511	30.87869	32.57051	34.12015	33.18017	32.81633	33.69967	33.48604	34.61446	33.89191
anhui	27.50647	28.25124	26.65191	27.00376	27.04474	27.38651	27.3715	27.41655	28.69592	27.77996
fujian	34.45985	34.47338	34.61509	35.26293	34.94234	34.8736	34.61644	34.15879	35.14583	34.84175
jiangxi	31.26113	31.13342	31.14082	30.41106	32.55086	32.59065	33.15922	33.374	34.11282	33.24737
shandong	31.25751	30.04829	29.59152	29.53639	26.69825	26.49758	26.33242	26.67607	27.72363	27.44529
henan	27.43521	28.24816	27.16312	26.50908	26.93585	27.4037	27.75668	27.59264	28.67479	28.18523
hubei	29.74428	28.60205	27.46222	27.70949	29.64714	29.58276	30.5368	28.66184	29.91634	29.11567
hunan	29.61279	29.56492	29.85866	29.06625	29.38766	29.44571	29.66857	27.31118	30.21306	30.28894
guangdong	31.27272	31.24351	30.78851	31.53013	31.55967	30.40921	31.01719	31.48253	32.47558	30.767
guangxi	33.46519	33.73811	33.68303	33.94913	33.46879	33.38926	33.16174	34.34632	33.38377	33.73298
hainan	30.40213	29.95002	29.6627	30.41642	32.31432	32.59965	32.04388	32.21529	33.15342	32.65987
chongqing	30.52218	30.03647	31.45539	31.69621	31.28303	31.00333	31.66002	31.90271	32.49806	31.51456
sichuan	34.63755	35.31407	33.57558	33.49705	33.41194	35.04436	34.54972	34.30414	34.39181	34.28316
guizhou	31.58897	30.89862	31.98828	32.43215	31.84472	32.78773	32.50178	31.09354	30.91937	30.32926
yunnan	34.23506	33.56335	33.62702	33.681	34.33537	35.029	34.61789	34.60745	34.93451	32.96072
shaanxi	28.30571	25.43987	25.3774	25.93991	27.11987	27.9476	27.94125	28.32869	29.1721	28.67314
gansu	27.16369	27.366	27.37312	29.4623	30.36549	31.52647	31.90417	31.49714	31.99828	31.52276
qinghai	30.68498	31.11439	30.00653	30.81123	31.19658	30.69673	31.87451	31.49614	31.71291	31.93408
ningxia	28.44365	28.19546	27.38298	28.10267	27.0721	27.19495	27.67048	27.70231	29.16161	30.08496
xinjiang	29.40913	30.11344	29.02886	32.21071	25.37264	28.76176	30.04889	30.50243	29.65686	30.34277

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