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Research on the impact path of ecological civilization construction on carbon emission based on fsQCA method

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From a theoretical point of view, promoting the construction of ecological civilization has a positive effect on reducing carbon emissions. However, ecological civilization construction has rich connotations, and the mechanism of its impact on carbon emissions is relatively complex, with regional differences. Therefore, it is necessary to further explore the influence mechanism of ecological civilization construction on carbon emissions. In order to investigate the mechanism of the effect of the construction of ecological civilization on carbon emissions. 30 provinces, cities, and autonomous regions in China were used as research objects. Based on the perspective of configuration, use the fuzzy set qualitative comparative analysis method (fsQCA), from the six dimensions of ecological civilization construction to study the configuration path of ecological civilization construction affecting carbon emissions. The findings show that the antecedent variables are related to each other and there are three types of paths to achieve low-carbon emissions, eco-economy-driven type with eco-economic construction as a key factor; eco-environmental protection type with a focus on eco-environmental protection; and land space optimization type that enhances the rational use of land resources. Comparing the low-carbon emission group pathway with the non-low-carbon emission group pathway illustrates that eco-logical management alone cannot effectively curb carbon emissions. The study explores how to promote the construction of ecological civilization and help reduce carbon emissions accordingly. To provide direction for the direction of ecological civilization construction in different regions.

KEYWORDS

ecological civilization, carbon emissions, fsQCA, configuration, eco-economic, land space optimization

1 Introduction

As global environmental issues continue to come to the fore, protecting the environment and reducing carbon emissions have become issues of concern to countries around the world. To cope with environmental changes and achieve harmony between man and nature, China has put forward the concept of ecological civilization construction

and identified it as an important strategic direction for future development. The construction of ecological civilization is to implant environmental awareness and green concepts into people's minds and thus promote green production and lifestyle. In the narrow sense, ecological civilization refers to the harmonious coexistence between man and nature, protecting the environment, conserving resources and promoting the reproduction of ecological resources and the coordinated development of the economy and society. In the broader sense, ecological civilization is not just a matter of saving resources and protecting the environment, but of integrating ecological civilization into all aspects and processes of economic, political, cultural and social construction (Li, 2014). The construction of ecological civilization is of great significance to the development of Chinese society in theory, practice and the creation of a favorable international ecological environment (Zhu, 2009). The construction of ecological civilization has been closely integrated with economic development, ecological governance, environmental protection, cultural construction, urban development, and the optimization of land space. Has become a new concept and goal to lead high-quality development in the new era, promoting green development of society and leading people to live green. In the face of the increasingly serious global climate problem, In 2020 China proposed a "double carbon" target, which sets a strategic direction for the construction of ecological civilization with a focus on carbon reduction. From a theoretical point of view, carbon emission refers to the emission of greenhouse gases (mainly carbon dioxide), the subject of which can be either a certain organism or a certain group, or the process of consumption and use of a certain type or certain substances(Wang, 2017), improving the way of production and life in society and giving green concepts to production and life are the primary measures to reduce carbon emissions. The studies on carbon emissions are mainly focused on regional carbon emissions such as: urban carbon emissions (Huang et al., 2022), national carbon emissions (Li R. et al., 2021); and industry carbon emissions such as: manufacturing industry (Liu et al., 2022), construction industry (Huo et al., 2022), transportation industry (Jiang et al., 2022), electric power industry (He Y. et al., 2022), marine fisheries (Wang and Wang, 2022), tourism (Tong et al., 2022), etc. From the perspective of influencing factors, the research mainly focuses on the influence of economy, natural resources, society, and policies on carbon emissions. From the economic perspective, the research mainly focuses on the impact of industrial structure (Zhang and Cui, 2018), financial inclusion (Shahbaz et al., 2022), digital economy (Li and Wang, 2022), and market development (Li et al., 2018) on carbon emissions. Natural resources mainly study the impact of energy efficiency (Li et al., 2022), land space (Zhang et al., 2022) on carbon emissions. The social perspective focuses on the urbanization process of cities (Wang et al., 2022), the impact of low-carbon city development (Wen et al., 2022) on carbon emissions, and the positive impact of science and technology innovation (Habiba et al., 2022) on carbon emissions. In addition, carbon emission trading policy (Dong Z. et al., 2022) also has a positive impact on reducing carbon emissions. Wang et al. (2023) emphasize on finding the factors to reduce carbon emissions from three dimensions: economic, environmental, and social. The construction of ecological civilization is promoted by the state to protect the ecological environment from economic, environmental, and social dimensions and practice green development, which is closely related to carbon emissions. Most scholars affirm the positive effect of ecological civilization construction on reducing carbon emissions and point out that reducing carbon emissions has become an important goal of ecological civilization construction, and the realization of "double carbon" has been incorporated into the overall layout of ecological civilization construction (He K. et al., 2022; Zhuang et al., 2022). From the perspective of empirical analysis (Lv et al., 2023), the relationship between ecological civilization demonstration zones and carbon emissions was analyzed based on the STIRPAT model, while Chen and Xiao (2023) suggested that the carbon reduction effect of the construction of ecological civilization demonstration zones is regionally heterogeneous.

Regarding how to reduce carbon emissions, studies have been discussed in terms of economic, natural environment, and social selection factors. And the construction of ecological civilization promotes green development from multiple dimensions of economic development, resource utilization, environmental protection, and social progress, which is important to achieve low-carbon emissions. Although the relationship between the construction of ecological civilization and carbon emission has been discussed by many scholars at the theoretical level, there are fewer empirical analyses. Although some scholars have proved that ecological civilization construction has a positive impact on reducing carbon emissions, ecological civilization construction is the injection of ecological and environmental awareness into all aspects of production and life. The focus of ecological civilization construction should be different in different regions because of the significant differences in development, population, resources and environment, and industrial structure. The studies that have been conducted do not explain how ecological civilization construction can be carried out in different regions to play a suppressive role on carbon emissions, and do not discuss the differentiated path to achieve low-carbon emission levels through ecological civilization construction. Cities have an important role to play in carbon reduction and green transformation (Zhuang and Wei, 2021). How should ecological civilization construction be carried out in different regions to achieve lower carbon emission levels? What are the specific impact pathways that existing studies have not been able to explain.

Based on consideration of the above issues, this paper adopts a fuzzy set qualitative comparative analysis method from configuration perspective to analyze the specific paths of ecological civilization construction affecting carbon emissions. In this paper, the ecological civilization construction is divided into six areas: ecological economic construction, ecological governance, ecological environmental protection, ecological city construction, ecological culture construction, and land space optimization, explores the relationship between different groupings of six antecedent conditions and carbon emissions and explore effective pathways to achieve regional low-carbon emissions.

Compared with the existing literature, this paper specifically divides the construction of ecological civilization into six aspects and considers the interaction of six factors. Based on the group

perspective, the fsQCA method is used for the first time to empirically analyze the differentiated paths of how different regions carry out ecological civilization construction to achieve low-carbon emissions. It also explains the mechanism of the role of different combinations of variables in suppressing carbon emissions. The factors that play a central role in the construction of ecological civilization in different regions to suppress carbon emissions are identified. A path reference is provided for the future direction of ecological civilization construction in regions with higher carbon emissions.

2 Theoretical model construction

Combining existing studies (Bi et al., 2017; Liu et al., 2019; Wan et al., 2020) and the understanding of ecological civilization construction (Li, 2014), this paper measures the level of ecological civilization construction at six levels: ecological economic construction, ecological governance, ecological environmental protection, ecological city construction, ecological culture construction, and land space optimization.

2.1 Eco-economic construction and carbon emissions

The ecological economic system with industrial ecology and ecological industrialization as the main body is the material basis for the construction of ecological civilization (Huang, 2019). Ecological economy construction refers to following ecological laws to build economic development on a bearable basis and achieve a win–win situation for both economic development and ecological protection. Promoting the construction of an ecological economy requires resolving the contradictions between the current system of production and development, moral culture and ecological protection, and between scientific and technological development and natural resources (Wei, 2016). Promoting the construction of an ecological economy requires adhering to a people-centered approach and vigorously developing green industries (Bai, 2021). Ecological economy construction is the basic way to achieve green development (Huo and Liu, 2011) and adhering to the green development path is an important means to reduce carbon emissions (Huang, 2021). The core connotation of eco-economy construction is to promote the high-quality development of human society on the premise of respecting the environment (Li and Gu, 2021), which is an important link in reducing carbon emissions. Adhering to the construction of ecological economy, promoting the green transformation of enterprises, and developing a green economy will have a positive impact on reducing carbon emissions.

2.2 Eco-governance and carbon emissions

Ecological governance is an important aspect of measuring ecological civilization (Lai and Li, 2021). The construction of ecological civilization requires systematic and holistic restoration and treatment of the ecology (Wan, 2018). Ecological governance requires the scientific treatment of wastewater and waste gases as well as pollutants from production and life while developing the economy, reducing damage to the environment, and emphasizing the treatment of ecology that has already been damaged. As China's urbanization process continues to advance, the increased urbanization rate has led to more serious industrial pollution. Strengthening the top-level design of industrial pollution control investment and establishing a scientific industrial pollution control investment system will help promote China's overall green development (Xiong, 2017). At the same time, promoting green living among the public adds momentum to reducing carbon emissions (Yang, 2021).

2.3 Eco-environmental protection and carbon emissions

Ecological environmental protection refers to the scientific and effective protection, use, development of natural resources by human beings, preventing the destruction of ecosystems caused by blind exploitation and overuse. Emphasizing the prevention or stopping of serious ecological damage and activities. Eco-environmental protection reflects the idea of promoting ecological civilization and green development (Wang and Gao, 2016). With the incorporation of carbon emission control into the responsibility of ecological environmental protection (Tian and Chang, 2021). The emphasis is placed on improving the quality of the environment from focusing on end-of-pipe treatment to paying more attention to source prevention and effective conduction of treatment, so that the total amount of carbon emissions can be continuously reduced (Dong et al., 2021).

2.4 Eco-city construction and carbon emissions

Ecological city construction refers to the harmonious development of man and nature as a code of conduct, following ecological principles and economic laws, rational use of natural resources in the city while developing the economy to achieve an organic combination of ecological environment and socio-economic development. The ecological cities should reflect the sum of material, environmental and spiritual institutional achievements made by human beings, promote ecological civilization and social harmony through ecological city construction to provide citizens with Better ecological services for citizens. Eco-city construction, as a comprehensive effort that integrates ecology and aesthetics, promotes green, high-quality urban development as an important subject for reducing carbon emissions. Related studies have suggested that the greening of cities has a significant negative impact on carbon emissions (Hou et al., 2020), while improving the urban public transport system is conducive to controlling carbon emissions (Zhang et al., 2020).

2.5 Eco-culture construction and carbon emissions

Ecological culture construction refers to a kind of cultural construction expressed in the understanding, ideas, attitudes, feelings, and other views about the relationship between human society's own development and the natural world cultivated in the production activities of human material materials, as well as the ecological behavior adopted on this basis. Culture is the foundation of civilization and progress in civilization cannot be achieved without cultural support. The cultivation of ecological culture is an important connotation of ecological civilization and an important grip on ecological environmental protection. The construction of ecological culture is a booster for solving the ecological crisis and building ecological civilization (Dong and Sang, 2020). The construction of ecological culture is an inevitable requirement for development under a low-carbon economy (Zhao, 2009), guiding society to establish the correct concept of green living and helping people to establish a green lifestyle, which provides an ideological guarantee for reducing carbon emissions.

2.6 Land space optimization and carbon emissions

Land space optimization refers to improving the efficiency of land resource utilization, alleviating land use conflicts, promoting the harmonious development of people and land rational development. The aim is to improve the utilization of land space, improving the layout of productive forces, coordinating urban and rural development, protecting and improving the ecological environment, allocating and utilizing limited land space rationally to meet current and future population development needs. The basic principles of optimizing land space are "ecological priority, arable land protection, conservation and intensive use, and coordination between people and land" (Xia et al., 2014). There are two main ways to achieve low-carbon spatial development: carbon emission reduction and carbon sink enhancement. The former takes "source" as the starting point, reducing carbon emissions from anthropogenic sources; while the latter considers from the perspective of "sink", adopting reasonable and effective measures to fix more carbon in the latter is from the perspective of "sink", using reasonable and effective measures to fix more carbon in terrestrial ecosystems (Huang et al., 2021). The reduction of non-construction land due to the expansion of construction land and the decline of forest cover are important reasons for the increase of carbon emissions due to unreasonable land use. Optimizing the allocation of land space, expanding forest cover, and increasing forest coverage are important measures to reduce carbon emissions in an economically feasible and low-cost way (Zhu and Liang, 2012; Huang and Wu, 2019).

In summary, the impact of ecological civilization construction on carbon emissions is the result of the joint action of many factors and there are links among them. Based on this, this paper selects six directions of building ecological civilization from a configuration perspective and uses the fuzzy set qualitative comparative analysis method to explore the influence path of ecological civilization construction on carbon emissions. The model building flow chart is shown in Figure 1. The research framework is shown in Figure 2.

3 Materials and methods

3.1 Materials

FsQCA, a fuzzy set qualitative comparative analysis method, is a case-oriented research method based on set theory and histological thinking, effectively linking qualitative and quantitative analysis. The basic idea is to adopt a holistic perspective of histological analysis and examine the relationship between antecedent conditions and combinations of conditions and outcomes from a set perspective with the help of architecture theory and Boolean algebra operations. It argues that outcomes are often produced by the joint action of multiple factors rather than the action of a single factor, focuses on asymmetric causality, and reveals multiple equivalence paths for the same outcome, thus explaining the complex causal relationships behind the phenomena. It provides an analytical tool that goes beyond qualitative and quantitative methods to explore complex causal issues such as multiple causes and effects, equivalence, and asymmetry in the social sciences. The article adopts the fuzzy set qualitative comparative analysis (fsQCA) method to explore the influence mechanism of regional ecological civilization construction on regional carbon emissions. The qualitative comparative analysis method achieves sufficient comparison and analysis of cases through algebraic and Boolean logic and is suitable for research designs with small and medium sample sizes and complex explanatory conditions of the research objects. This paper adopts the fuzzy set qualitative comparative analysis method for the following reasons: Firstly, the grouping of carbon emissions affected by the construction of ecological civilization is a complex process, which is influenced by a variety of factors, and the elements are not independent of each other. Secondly, the fuzzy set qualitative comparative analysis method is a combination of qualitative and quantitative methods and differs from traditional regression methods in that it emphasizes the causal asymmetry and substitutability, finds multiple paths to achieve the goal. Thirdly the condition variables involved in this study are all continuous variables and therefore do not lend themselves to the clear set comparative analysis method (csQCA) and the multiple value set comparative analysis method (mvQCA).

3.2 Variable selection and data source

3.2.1 Variable selection

With reference to existing studies (Bi et al., 2017; Liu et al., 2019; Wan et al., 2020) and considering the availability of data, this paper interprets the construction of ecological civilization by selecting indicators from six aspects: ecological economic construction, ecological governance, ecological environmental protection, ecological city construction, ecological culture construction, land

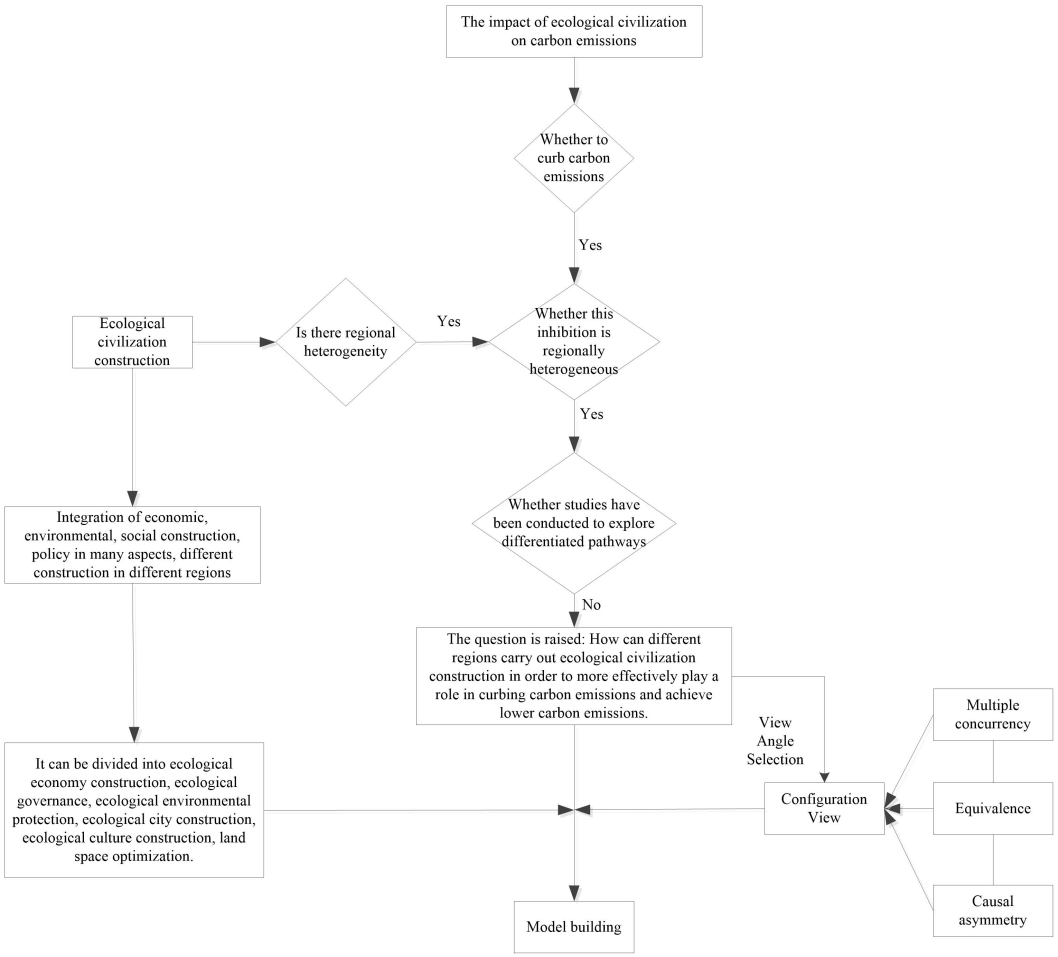

FIGURE 1
Model building flow chart.

space optimization, and establishes an indicator system. The evaluation indicators are shown in Table 1.

Eco-economy construction: In this paper, the level of per capita GDP, disposable income of urban residents, disposable income of rural residents, the proportion of tertiary industries, water consumption per unit of GDP and electricity consumption per unit of GDP are selected to measure the level of ecological economic construction, which reflects both the state of economic development and the level of development of green economy.

Eco-governance: emphasizing the management of waste pollution generated in production and life, to achieve scientific, green emissions, industrial pollution, wastewater, and exhaust gas are the main pollutants that damage the ecological environment. This paper selects industrial pollution treatment completed project

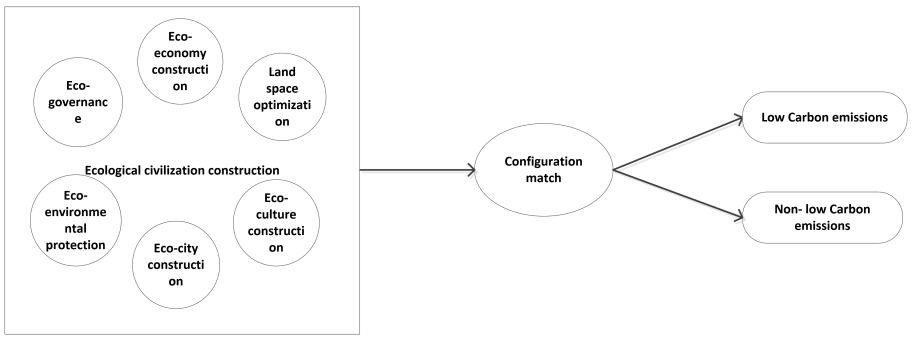

FIGURE 2
Theoretical model.

TABLE 1 Ecological civilization indicators.

Tier 1 indicators	Secondary indicators	Tertiary indicators	Characteristic
Ecological civilization construction	Eco-economy construction	GDP per capita	Positive
		Disposable income of urban residents	Positive
		Disposable income of rural residents	Positive
		Share of tertiary sector	Positive
		Water consumption per unit of GDP	Negative
		Electricity consumption per unit of GDP	Negative
	Eco-governance	Industrial pollution control completed project investment	Positive
		Project investment completed for wastewater treatment	Positive
		Treatment of exhaust gases completed project investment	Positive
	Eco-environment construction	Percentage of expenditure on environmental protection	Positive
	Eco-city construction	Green space coverage in built-up areas	Positive
		Public transport vehicles per million	Positive
		Household waste treatment capacity	Positive
	Eco-culture construction	Expenditure on education and science and technology as a proportion of budgeted expenditure	Positive
	Land space optimization	Forest cover	Positive

investment, treatment of wastewater completed project investment, treatment of waste gas completed project investment, reflecting the strength of ecological governance.

Eco-environmental protection: Local government's expenditure on environmental protection is the main driving force to promote environmental protection behavior. In this paper, the proportion of expenditure on environmental protection in the general budget of the local government is chosen to reflect the strength of the local government's environmental protection efforts.

Eco-city construction: The ecological city construction emphasizes the construction of a green and low-carbon city, urban greening, public transportation system, and harmless waste treatment are factors that effectively help cities develop in a low-carbon way. In this paper, we choose the green area coverage rate, the number of public transport vehicles per million, and the capacity for harmless treatment of domestic waste to reflect the level of ecological construction in the city.

Eco-culture construction: The ecological culture construction emphasizes the cultivation of the concept of harmony between humans and nature, the improvement of the relationship between humans and nature, the exploration of ways to live in harmony with nature, and ecological behaviors based on this, such as green innovation, thought education etc. People's education level affects people's recognition and understanding of ecological concepts, while scientific and technological innovation is an ecological behavior that promotes green concepts to improve production and lifestyles. In this paper, the proportion of expenditure on education and science and technology in the general budget expenditure of local finance is chosen to reflect the strength of ecological culture construction.

Land space optimization: The land space optimization emphasis is placed on the rational use of land resources to meet the needs of productive life and to avoid over-exploitation of land resources. In this paper, forest cover is selected to respond to the spatial structure of land.

Drawing on the meaning of " Carbon peaking ". In this paper, we use carbon emissions as an indicator to reflect the level of carbon emissions. The lower the carbon emissions, the lower the level of carbon emissions, and the higher the carbon emissions, the higher the level of carbon emissions.

3.2.2 Data source

This paper uses 30 provinces, municipalities, and autonomous regions in China as the research sample (Tibet is not used as the research sample due to missing data), and the data is obtained from the China Statistical Yearbook and the China Carbon Accounting Database CEADs.

4 Empirical analysis

4.1 Data standardization

In this paper, the method of Li Zhijun (Li Z. et al., 2021) was used to standardize the data using the utility value method, with a value close to 1 indicating a higher score for the indicator. After the experts' discussion, the final method of calculating the scores of the second level indicators is to sum and take the average of the third level indicators. The standardized processed data are shown in Table 2, and the descriptive statistics are shown in Table 3. The average score

TABLE 2 Standardized data.

Region	Eco-economy construction	Eco-goernance	Eco-environment protection	Eco-city construction	Eco-culture construction	Land space optimization	Carbon emission levels
Beijing	0.96	0	0.49	0.72	0.69	0.63	0.98
Tianjin	0.63	0.1	1	0.15	0.32	0.12	0.94
Hebei Province	0.39	0.36	0.85	0.38	0.57	0.35	0.67
Shanxi Province	0.34	0.41	0.61	0.29	0.31	0.25	0
Inner Mongolia Autonomous Region	0.33	0.23	0.27	0.25	0.04	0.28	0.44
Liaoning Province	0.43	0.12	0.12	0.33	0.12	0.55	0.65
Jilin Province	0.39	0.05	0.41	0.18	0.13	0.59	0.91
Heilongjiang Province	0.34	0.03	0.5	0.29	0	0.63	0.82
Shanghai	0.93	0.26	0.12	0.13	0.37	0.15	0.93
Jiangsu Province	0.63	0.54	0.25	0.6	0.76	0.17	0.64
Zhejiang Province	0.7	0.32	0.2	0.59	0.8	0.88	0.77
Anhui Province	0.44	0.26	0.5	0.41	0.73	0.38	0.79
Fujian Province	0.54	0.09	0.36	0.51	0.73	1	0.86
Jiangxi Province	0.41	0.19	0.27	0.32	0.67	0.91	0.91
Shandong Province	0.48	1	0.23	0.6	0.82	0.2	0.28
Henan Province	0.41	0.41	0.35	0.34	0.6	0.31	0.75
Hubei Province	0.46	0.13	0.37	0.23	0.48	0.56	0.86
Hunan Province	0.47	0.05	0.26	0.55	0.45	0.72	0.88
Guangdong Province	0.57	0.31	0.52	0.64	1	0.79	0.68
Guangxi Zhuang Autonomous Region	0.37	0.04	0.01	0.21	0.5	0.89	0.89
Hainan Province	0.41	0	0.36	0.33	0.33	0.85	0.99
Chongqing	0.48	0.03	0.37	0.23	0.35	0.62	0.95
Sichuan Province	0.44	0.12	0.18	0.4	0.38	0.53	0.86
Guizhou Province	0.35	0.08	0.29	0.21	0.59	0.63	0.85
Yunnan Province	0.39	0.11	0.27	0.29	0.35	0.81	0.92
Shaanxi Province	0.39	0.23	0.51	0.36	0.45	0.62	0.66
Gansu Province	0.28	0.04	0.2	0.19	0.37	0.1	0.92
Qinghai Province	0.18	0.03	0.4	0.18	0.04	0.01	1
Ningxia Hui Autonomous Region	0.1	0.05	0.41	0.28	0.2	0.12	0.88
Xinjiang Uyghur Autonomous Region	0.16	0.16	0	0.35	0.38	0	0.71

of eco-economic construction is 0.4467, with a standard deviation of 0.18804. The average score of eco-governance is 0.1917, with a standard deviation of 0.20780. The average score of eco-environmental protection is 0.3560, with a standard deviation of 0.21511. The average score of eco-city construction is 0.3513, with a standard deviation of 0.16012. The average score of eco-culture construction is 0.4510, with a standard deviation of 0.25506. The average score of national spatial optimization is 0.4883 with a standard deviation of 0.29945. The average score of carbon emission level is 0.7797 with a standard deviation of 0.21919.

TABLE 3 Results of descriptive analysis of variables after standardization.

	Eco-economy construction	Eco-governance	Eco-environmental protection	Eco-city construction	Eco-culture construction	Land space optimization	Carbon emission levels
Average value	0.4467	0.1917	0.3560	0.3513	0.4510	0.4883	0.7797
Standard deviation	0.18804	0.20780	0.21511	0.16012	0.25506	0.29945	0.21919
Maximum value	0.96	1.00	1.00	0.72	1.00	1.00	1.00
Minimum value	0.10	0.00	0.00	0.13	0.00	0.00	0.00

Positive indicator standardization formula.

$$y = \frac{x - x_{min}}{x_{max} - x_{min}}$$

Negative indicator normalization formula.

$$y = \frac{x_{max} - x}{x_{max} - x_{min}}$$

4.2 Data calibration

This paper uses the direct calibration method to calibrate the data, using three anchor points for structured calibration. The three anchor points for the six conditional and outcome variables are set at 25%, 50% and 75% of the sample data, and the anchor points for each variable after calibration are shown in Table 4.

4.3 Necessity analysis

The purpose of the necessary condition analysis for each variable is to identify the necessary conditions that affect the outcome variable (Ragin, 2008). It is usually considered that when the consistency is greater than 0.9, the variable is a necessary condition for the outcome variable and a single condition can lead to the outcome. With the software fsQCA 3.0, the test results are shown in Table 5, where the consistency of all the antecedent variables affecting the level of low-carbon emissions versus non-low-carbon emissions is less than 0.9, so there are no necessary conditions that cause low-carbon emissions versus non-low-carbon emissions.

4.4 Configuration analysis

The data were processed using the software fsQCA 3.0, setting the original consistency threshold to 0.8 and the case frequency to 1 (Cheng and Jia, 2016). Referring to the study of Du and Jia (2017) the PRI threshold was set to 0.75 in this paper.

The simple solution, intermediate solution and complex solution were obtained through the operation of fs QCA3.0 software. The conditions that appear in both the intermediate and simple solutions are regarded as core conditions, and the conditions that appear only in the intermediate solution are regarded as auxiliary conditions (Fiss, 2011). The results of the analysis are shown in Table 6 below, with four groupings achieving low-carbon emission levels, an overall consistency of 0.907473 greater than the consistency threshold, and an overall solution coverage of 0.506623, covering 50.66% of the cases. Four groupings achieved non-low-carbon emission levels, with an overall consistency of 0.965768 greater than the consistency threshold and an overall solution coverage of 0.624 832, covering 62.48% of the cases.

TABLE 4 Variable anchor points.

Study variables		Anchor points		
		Fully subordinate	Intersections	Completely unaffiliated
Conditional variables	Eco-economy construction	0.4950	0.4100	0.3475
	Eco-governance	0.2725	0.1200	0.0475
	Eco-environmental protection	0.4925	0.3550	0.2225
	Eco-city construction	0.4350	0.3250	0.2250
	Eco-culture construction	0.6750	0.4150	0.3175
	Land space optimization	0.7375	0.5550	0.1925
Resulting variables	Carbon emission levels	0.9200	0.8600	0.6775

TABLE 5 Necessity analysis.

Conditional variables	Resulting variables	
	Low-carbon emission levels	Non-low-carbon emission levels
Eco-economy construction	0.571523	0.565101
~Eco-economy construction	0.524503	0.532215
Eco-governance	0.329139	0.813423
~Eco-governance	0.805298	0.322819
Eco-environmental protection	0.513245	0.528859
~ Eco-environmental protection	0.619868	0.60604
Eco-city construction	0.364238	0.685235
~Eco-city construction	0.721854	0.402013
Eco-culture construction	0.429801	0.642282
~Eco-culture construction	0.683444	0.472483
Land space optimization	0.637748	0.478523
~ Land space optimization	0.503311	0.66443

4.5 Pathway analysis

4.5.1 Analysis of low-carbon emission pathways

1. Eco-environmental protection type, the group conforming to this type is H1. The group H1 is a group composed of high eco-environmental protection, non-high eco-governance and non-high land space optimization as core conditions, and non-high eco-city construction and non-high eco-culture construction as auxiliary conditions. It indicates that some provinces and cities can achieve low-carbon emissions by actively promoting ecological environmental protection under the conditions of low ecological governance, low land space optimization, imperfect ecological city construction and ecological culture construction. Regions that fit this category: Ningxia and Qinghai. These areas have a low level of industrialization and urbanization, with less production and living waste. They focus on environmental protection while producing and living, maintaining a healthy, good and beautiful ecological environment, prohibiting environmentally damaging behaviors or activities from the source. Such as prohibiting the random discharge of wastewater and waste gas, promoting the use of clean energy in rural areas (Wang and Gao, 2016) and the scientific treatment and reuse of agricultural waste, thus achieving a lower carbon emission.

TABLE 6 Configuration analysis.

Conditional variables	Low-carbon emission levels				Non-low-carbon emission levels			
	H1	H2	H3	H4	N1	N2	N3	N4
Eco-economy construction		●	●	⊗		⊗	⊗	•
Eco-governance	⊗	⊗	⊗	⊗	●	●	●	•
Eco-environmental protection	●	•		⊗	●		⊗	
Eco-city construction	⊗	⊗	•	⊗	●	⊗		●
Eco-culture construction	⊗	⊗	•	⊗	•	⊗	⊗	●
Land space optimization	⊗		•	●		⊗	⊗	⊗
Consistency	0.947368	0.971326	0.892744	0.854478	0.933333	0.988406	0.986111	0.992771
Original coverage	0.238411	0.17947	0.187417	0.151656	0.291275	0.228859	0.190604	0.27651
Unique coverage	0.112583	0.021192	0.14702	0.050331	0.147651	0.048322	0.024161	0.119463
Consistency of overall solution	0.907473				0.965768			
Overall solution coverage	0.506623				0.624832			

● and • indicate that the condition exists, ⊗ and ⊗ indicate that the condition does not exist, ● and ⊗ indicate the core condition, • and ⊗ indicate auxiliary conditions, and blank indicates that the condition may or may not be present in the configuration.

2. Ecological economy-driven, the groupings that fit this category are H2 and H3. The group H2 is composed of high ecological economy construction, non-high ecological governance as the core condition, high ecological environmental protection, non-high ecological city construction, and non-high ecological culture construction as the supporting conditions. It indicates that some provinces and cities can achieve low-carbon emissions by promoting eco-economy construction as the core and focusing on eco-environmental protection, under the condition of low eco-governance, imperfect eco-city construction and eco-culture construction. H3 is a group with high eco-economic construction, non-high eco-governance as the core condition, and high eco-city construction, high eco-culture construction and high land space optimization as the supporting conditions. It indicates that some provinces and cities can achieve low-carbon emissions with low ecological governance, by promoting eco-economic construction as the core while focusing on eco-city construction, eco-culture construction and land space optimization. Areas that fit into this category are, Tianjin, Chongqing and Beijing. These areas have a more complete ecological economy, economic green development, green transformation of enterprises, green reform of industrial structure, ensuring economic development while reducing the generation of wastewater, waste gas and industrial waste in the production process. Promoting the reduction of carbon emissions with a green development model, in conjunction with environmental protection or ecological city and ecological culture construction, and land space optimization, thus achieving lower carbon emission levels.
3. Land space optimization type, which corresponds to this type of grouping is H4. The group H4 is composed of high land space optimization, non-high ecological environmental protection, and non-high ecological culture construction as core conditions, and non-high ecological economic construction, non-high ecological governance and non-high ecological city construction as supporting conditions. It shows that some provinces and cities can achieve low-carbon emissions by actively carrying out spatial optimization of the land under the condition of imperfect ecological economy construction, ecological city construction and ecological culture construction, low ecological governance and ecological environmental protection. Typical area: Yunnan. Such areas have higher forest coverage, more reasonable use of national land resources and a better ecological environment, which greatly stops the over-exploitation of land resources for production and living (Huang and Wu, 2019), stimulate the reform of advanced industrial structure, improves the quality of land use (Zhang et al., 2022), reduces the production and living waste and CO2 emissions brought about by social development, thus achieves a lower level of carbon emissions.

4.5.2 Analysis of non-low-carbon emission pathways

The group N1 is a grouping consisting of high ecological governance, high ecological environmental protection, and high ecological city construction as the core conditions, and high ecological culture construction as the supporting conditions. It indicates that some provinces and cities will also produce higher carbon emissions when ecological governance and ecological environmental protection are stronger and ecological city construction and ecological culture construction are more complete. Typical areas: Guangdong, Hebei, and Shaanxi.

The group N2 is a grouping consisting of high ecological governance, non-high ecological economy construction as the core condition, non-high ecological city construction, non-high ecological culture construction, and non-high land space optimization. It indicates that some provinces and cities will produce higher carbon emissions if they rely only on ecological governance under the condition of poor ecological economy construction, ecological city construction, ecological culture construction and low land space optimization. Typical areas: Inner Mongolia Autonomous Region and Shanxi.

The group N3 is a grouping consisting of high ecological governance, non-high ecological economy construction as the core condition, non-high ecological environmental protection, non-high ecological culture construction, and non-high land space optimization. It indicates that some provinces and cities will produce higher carbon emissions if they rely only on ecological governance under the condition of imperfect ecological economy construction, ecological culture construction, low ecological environmental protection and low land space optimization. Typical area: Xinjiang Uygur Autonomous Region.

The group N4 is a grouping consisting of high ecological city construction, high ecological culture construction, non-high land space optimization as the core condition, high ecological economy construction and high ecological governance as the supporting condition. It indicates that some provinces and cities will produce higher carbon emissions even if the ecological economy construction, ecological city construction and ecological culture construction are more perfect and ecological governance is stronger under the condition of low land space optimization. Typical regions: Jiangsu, Shandong, and Anhui.

In summary, in the non-low-carbon emission ecological civilization construction grouping, high ecological governance is prevalent in the four paths as a core condition or auxiliary condition. At the same time, by comparing the low-carbon emission ecological civilization construction with the non-low-carbon emission ecological civilization construction grouping, it is found that those who unilaterally emphasize ecological governance and neglect ecological economy construction, ecological environmental Protection and land space optimization cannot achieve lower carbon emissions. Compared with the results of existing studies, the analysis results of this study show three differentiated paths of ecological civilization construction to inhibit carbon emissions and the asymmetric relationship of the driving paths, which is an extension and expansion of the

relationship between ecological civilization construction and carbon emissions.

4.6 Robustness tests

To explore the robustness of the results, two methods, adjusting the consistency threshold and adjusting the PRI, were used to test the robustness of the results. Firstly, the original consistency threshold was increased from 0.8 to 0.85 (Dong J. et al., 2022), and the adjusted results did not differ from Table 6: secondly, the PRI value was increased from 0.75 to 0.8 (Wei and Chen, 2022), and the adjusted configuration results were a subset of the original configuration, indicating that the results passed the robustness test and the study results were more reliable.

5 Conclusions and enlightenment

5.1 Conclusions

The construction of ecological civilization, as an important element of the development strategy of socialism with Chinese characteristics in the new era, has a significant role to play in reducing carbon emissions (Yu et al., 2022). This paper interprets the construction of ecological civilization in six aspects and studies the configuration analysis of the six aspects on the level of carbon emissions. The combination of antecedent conditions for the construction of an ecological civilization with low-carbon emissions and for the construction of an ecological civilization with non-low-carbon emissions is obtained. Compared with the existing studies, this study does not take the ecological civilization construction as a whole as the research object but splits it into six aspects to study the differentiated paths of ecological civilization construction to suppress carbon emissions under the configuration perspective and conducts a deeper analysis of the relationship between ecological civilization construction and carbon emissions. The conclusions of the study are as follows.

1. Single condition does not achieve low-carbon emission levels. There are no necessary conditions to promote low-carbon emissions in eco-economic construction, eco-governance, eco-environmental protection, eco-city construction, eco-cultural construction, and land space optimization. The achievement of low-carbon emission levels is the result of the combination of six antecedent variables. Different states of the same variable produce different path outcomes in combination with different states of other variables, there is no unique path, and multiple paths of the same outcome are equivalent to each other (Liao and Phan, 2016). Only one construction direction cannot effectively play a suppressive role, and giving full play to the suppressive effect of ecological civilization construction on carbon emissions requires choosing a differentiated path for local ecological civilization construction according to the local economic development and industrial base.
2. There are four groupings of states to achieve low-carbon emissions, summarized in three types. The eco-economy-driven type with high eco-economic construction and non-high eco-governance as the core; the eco-environmental protection type with high eco-environmental protection, non-high eco-governance, and non-high land space optimization as the core; the land space optimization type with high land space optimization, non-high eco-environmental protection, and non-high eco-cultural construction as the core. Different types correspond to different groupings, and the focus of ecological civilization construction is not the same. All three types of ecological civilization construction can play a suppressive role on carbon emission and achieve lower carbon emission.
3. High eco-governance as a core condition or auxiliary condition commonly exists in the path of non-low-carbon emission ecological civilization construction, which has a general effect on non-low-carbon emission. It shows that ecological civilization construction that only emphasizes ecological governance and ignores the positive role of other factors cannot fully play the role of curbing carbon emissions and achieving low-carbon emissions.
4. The provinces with faster development and higher population density can effectively curb carbon emissions by actively promoting industrial structure upgrading, developing tertiary industries, maintaining green economic growth, actively promoting ecological economy construction.
5. In provinces with low levels of industrialization and urbanization, although economic development is slow, there are fewer heavily polluting enterprises, as long as they pay attention to ecological environmental protection and reduce unnecessary waste generation in production and life, carbon emissions can be effectively curbed.
6. The provinces with rich natural resources can effectively curb carbon emissions by making full use of natural resources, developing green industries corresponding to them, and maintaining efficient use of land resources.

5.2 Enlightenment

Based on the above conclusions, this paper puts forward the following revelations.

5.2.1 Accelerate the construction of ecological economy and develop a green economy

Each province and city should adjust promote the construction of an ecological economy, considering their own industrial structure, while encouraging scientific and technological innovation, using scientific and technological means to achieve

green output in the economy, helping enterprises to transform green, coordinating the synergistic relationship between economic development and green ecology, and guiding the green and healthy development of the economy.

5.2.2 Actively promote the optimization of national land space

Each province and city should do a good job of optimizing national land space according to their own conditions, taking relevant measures such as returning farmland to forests and grass, adjusting the relationship between ecological environment and agricultural development, coordinating the relationship between construction land and non-construction land, exploring the balanced relationship between agricultural space and ecological space. Building a national land space with efficient carbon sinks and ecological purification, strictly prohibiting the over-exploitation of national land resources for production and living.

5.2.3 Raising the importance of ecological environmental protection

Each province and municipality should improve ecological environmental protection according to its own situation, supervise enterprises to improve wastewater and waste gas treatment measures to achieve scientific waste disposal and prohibit random emissions; promote photovoltaic power generation, hydroelectric power generation and wind power generation. Promote use clean energy, improve the situation of burning wood for heating and burning wood for cooking in rural areas, promote use clean energy. We will also promote the use of clean energy, improve the situation of burning wood for heating and burning wood for cooking in rural areas, and promote the reuse of agricultural waste to solve the problem of carbon emissions at source.

5.2.4 Establishing a green development concept

Provinces and municipalities should solve the carbon emission problem from production and lifestyle. Only emphasizing the carbon reduction treatment of production and lifestyle waste and strengthening the treatment of wastewater, waste gas and industrial pollution will not achieve the desired carbon reduction effect. Should establish the concept of green development, promote the green upgrading of industries and green lifestyles, reduce carbon emissions from the process of production and life.

5.2.5 Adapt to local conditions and choose the right path

The construction of ecological civilization varies greatly from province to province, and the economic development, resource utilization and industrial structure of different provinces also vary, so each province should choose a suitable path according to its own situation. The provinces with faster economic development should focus on a green economy, encourage scientific and technological innovation, balance the relationship between economic development and the environment, and promote the ecological and green transformation of the economy; at the same time, they should consider ecological environmental protection, ecological city construction, ecological culture construction and the optimization of national land space. For provinces with slow economic development should focus on ecological environmental protection and the optimization of land and space. For provinces with greater economic development potential, they should choose a suitable development path by considering the actual situation of industrial structure and land resource use in the province, starting from both ecological economic construction and land space optimization.

5.3 Suggestion

1. For provinces with a large proportion of industry in their industrial structure, manufacturing, light industry and heavy industry, which are important pillar industries in these provinces, are also the main cause of large amounts of carbon dioxide emissions. These provinces should carry out industrial adjustment, timely deal with industries with serious pollution but low returns, focus on ecological culture construction, promote green upgrading of industrial technology, green transformation of business model, and accelerate green technology innovation to achieve the purpose of reducing carbon emissions.
2. The provinces with rich mineral resources, especially those rich in coal resources, should speed up the research and development of key core technologies such as carbon capture, sequestration and utilization, while promoting the establishment of a perfect carbon market and accelerating land greening science to promote key projects such as natural forest protection, returning farmland to forest, artificial afforestation and wetland vegetation restoration.
3. The provinces with high population density should actively promote the transformation of industrial structure and the development of tertiary industry to drive green economic development. At the same time, we should accelerate the construction of ecological cities, enhance public transportation facilities, promote people to travel green, and reduce carbon emissions from production and life.
4. Remote areas, with lower population density, weaker infrastructure and industrial base, most of these provinces are dominated by agriculture and animal husbandry, and need to focus on ecological protection, accelerate the use and promotion of clean energy, or avoid the reckless exploitation of land resources for production and living.

5.4 Limitations and future prospects

In this paper, the construction of ecological civilization is divided into six aspects from the perspectives of economy,

society, culture, policy, and environment to find the realization path to promote the construction of ecological civilization to suppress carbon emission at the present stage. It reveals the direction of ecological civilization construction in different regions at this stage. Extends the study of the relationship between ecological civilization construction and carbon emission. But with the progress and development of society, the focus of future ecological civilization construction may change accordingly. At present, fsQCA is mostly applied to static level analysis, and the future research and application of dynamic fsQCA will show the results of path analysis in different stages.

With the continuous improvement of science and technology in the future, the key construction direction of ecological civilization construction in the future will also be influenced by advanced technology such as: artificial intelligence. Moreover, the birth rate has been gradually decreasing in recent years, and the movement of people will also affect the development pattern of the region. To achieve a continuous reduction of carbon emissions, the direction of ecological civilization construction should be changed accordingly. In the future, specific paths to reduce carbon emissions can be explored based on demographic changes and scientific and technological developments.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author contributions

Conceptualization, RC; methodology, RC; formal analysis, RC; investigation, RC; resources, RC; project administration, PC; funding acquisition, PC. Both authors agree to be accountable for the content of the work. Both authors contributed to the article and approved the submitted version

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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