Research on Carbon Emission Calculation and Influencing Factors of Rural Human Settlements Based on the Background of Rural Revitalization

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Abstract. Based on the background of rural revitalization, this study aims to measure the carbon emissions of rural human settlements and study the influencing factors. Through collecting relevant data and statistical analysis, the level and changing trend of carbon emission in rural human settlements were revealed. At the same time, the influence mechanism of energy structure, lifestyle, transportation mode and architectural design on carbon emissions of rural human settlements is analyzed. The research results can provide scientific basis for carbon emission reduction in rural human settlements and promote the organic combination of rural revitalization and low-carbon development.

Keywords: rural revitalization; Rural human settlements; Carbon emissions; Influencing factors; Low carbon development

1. Introduction

In the context of rural revitalization, carbon emissions from rural living environments have become an important research field.With the rapid development of China's rural economy and the gradual narrowing of the urban-rural gap, more and more people are paying attention to the sustainable development of rural areas and the improvement of the ecological environment. However, due to traditional agricultural production methods and low-level rural economic development, environmental problems in rural areas are becoming increasingly serious, especially carbon emissions. In terms of energy structure, promoting the use of clean and low-carbon energy, and reducing the proportion of fossil fuels are important ways to reduce carbon emissions.In terms of lifestyle, advocating low-carbon diet, energy conservation, and reducing waste can effectively reduce individual and household carbon emissions. In terms of transportation modes, encouraging the use of public transportation and non motorized transportation, and reducing the use of private cars are important ways to reduce carbon emissions related to transportation. In architectural design, promoting the use of energy-saving building materials, improving the insulation performance of buildings, and promoting the utilization of renewable energy can effectively reduce the energy consumption and carbon emissions of rural buildings[1].

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2. Calculation method of carbon emission in rural human settlements

2.1 Definition and scope of carbon emissions from rural human settlements

The carbon emission of rural residential environment refers to the greenhouse gas emission generated by rural residents' life, including carbon dioxide, methane and nitrous oxide. Its scope covers energy consumption, transportation, biomass combustion and so on.

2.2 Common methods and index system for measuring carbon emissions of rural human settlements

Commonly used calculation methods include bottom-up method and -down method. Based on a survey and statistics on energy consumption, transportation, and biomass combustion among rural residents, a bottom-up approach is used to determine the total carbon emissions of rural living environments. The law of diminishing carbon emissions in rural living environments is estimated through macro statistical data and model analysis[2].

2.3 Data collection and processing methods for carbon emission calculation of rural human settlements

Data can be collected through questionnaire survey, on-site observation and data provided by government departments. Data processing should consider the correlation and weight between different factors and adopt appropriate statistical methods for analysis. To evaluate the carbon emissions level of rural living environment, calculations and data statistical analysis can be conducted. The following table 1 presents the calculation results of carbon emissions in rural living environments over the past five years, and compares the corresponding national average levels[3].

Table 1. Calculation and evaluation of carbon emission level of rural human settlements

age	Carbon emission from rural human settlements (10,000 tons CO2 equivalent)	National average level (ten thousand tons of CO2 equivalent)
2015	500	600
2016	550	610
2017	520	620
2018	480	630
2019	510	640

The data shows that in the past five years, the carbon emissions of rural human settlements have shown a fluctuating upward trend. Among them, the carbon emission in 2016 was the highest, reaching 5.5 million tons of CO2 equivalent, while the carbon emission in 2018 was the lowest, only 4.8 million tons of CO2 equivalent. Compared with the national average, the carbon emission level of rural human settlements is slightly lower, but the gap is gradually narrowing[4].

3. Data and models

At present, there are methods such as carbon emission coefficient method, input-output method, and consumer lifestyle analysis method.The carbon emission coefficient method is used to calculate the carbon emissions of various energy sources based on the carbon emission calculation guidelines of the Intergovernmental Panel on Climate Change (IPCC), and is often used to calculate the carbon emissions of direct energy consumption by residents. The input-output method measures indirect carbon emissions based on the input-output table. Most of these types of data are averages and are mainly applicable to macro level research of countries and cities. From the perspective of residential consumption, the consumer lifestyle analysis method calculates indirect carbon emissions by studying consumption behaviors closely related to residential life. This article uses Wei's consumer lifestyle analysis method to calculate the indirect carbon emissions in the daily lives of residents in X province.

3.1 Data source and processing

Firstly, according to the statistical yearbook of X province and the statistical yearbook of China energy, the living consumption expenditure of rural residents in X province is divided into 21 related industries in 8 categories, as shown in Table 2. Then calculate the carbon emission intensity of eight categories of departments respectively; Finally, the indirect carbon emissions of rural residents' life in X province from 2006 to 2015 are obtained by multiplying it with the consumption data of residents.

Table 2. Classification of industrial sectors related to residents' living consumption

department	Involved in industry
food	Food manufacturing industry, tobacco products industry
dress	Textile industry. Textile and garment industry, leather, fur, feathers and their products and footwear industry
Zhujian	Construction industry, water production and supply industry, electricity and heat production and supply industry, gas production and supply industry, non-water forbidden mineral products industry.
Daily necessities and services	Wood processing and bamboo, rattan, palm and grass products industry, furniture manufacturing industry, rubber and plastic products industry, metal products industry.
medical care	Health, social security and welfare industries
Traffic communication	Transportation equipment manufacturing industry. Computer, communication and other electronic equipment manufacturing industry
Education, culture and entertainment	Paper and paper products industry, printing and recording media reproduction industry, cultural, educational, industrial and artistic, sports and entertainment products manufacturing industry.
Other supplies and services	Wholesale, retail and accommodation, catering.

The specific model is

$$\mathrm{EI_i} = \frac{\mathrm{E_i}}{\mathrm{G_i}}$$

Where: I represents the categories of 8 consumer departments; EIi refers to the energy intensity of Class I departments; Ei refers to the energy consumption of Class I departments (tons); Gi refers to the annual output value of Class I department (ten thousand yuan).

$$\mathrm{CIi} = \mathrm{EIi} \cdot \mathrm{CFStandard\ coal}$$

Where: CIi is the carbon emission intensity of Class I department; Carbon emission coefficient of CF standard coal as standard coal. The conversion coefficient recommended by the Energy Research Institute of the National Development and Reform Commission is 2.456 7 (that is, 2.456 7 tons of CO2 are emitted during the consumption of each ton of standard coal).

$$\mathrm{RE} = \sum_{i=1}^{8} \mathrm{RP} \cdot \mathrm{X_i} \cdot \mathrm{EI_i}$$

Where: RE is the indirect energy consumption of rural residents in X province (tons); RP refers to the rural population of X province (ten thousand people); Xi is the per capita consumption expenditure of residents in category I department (RMB/person).

$$\mathrm{C} = \sum_{i=1}^{8} \mathrm{RP} \cdot \mathrm{X_i} \cdot \mathrm{CI_i}$$

Where: C is the indirect carbon emission of rural residents in X province.

3.2 Building decomposition model

At present, the main research methods of influencing factors of carbon emission of residents' life are exponential decomposition method (IDA), econometric method and structural decomposition method (SDA). Exponential decomposition method was first proposed by Laspeyres in 1871, and then improved by Ang et al. by using the "analytical limit" method, logarithmic mean Dirichlet exponential decomposition method (LMDI)[5] was put forward, which dealt with the problems of zero value and negative value that the model could not solve at first, and had the advantages of no residual, complete decomposition and easy operation, and was widely used.

Based on Kaya's identity theory, the influencing factors of carbon emissions are linked to CO2 emissions generated by human activities, and the LMDI method is used to decompose the incremental indirect carbon emissions of rural residents in X Province from the perspective of household consumption. The size of rural population and consumption level are important factors affecting the indirect carbon emissions of rural residents.However, there are significant differences in consumption concepts and preferences between urban and rural residents[6]. Therefore, changes in consumption structure will also have a significant impact on indirect carbon emissions. Consumer carbon emission intensity refers to the carbon emissions generated by rural residents in meeting their living needs through unit consumption expenditures in various departments, which can objectively reflect the indirect carbon emissions generated by their daily lives. Therefore, the influencing factors of indirect carbon emissions among rural residents in X Province are decomposed into four categories: consumption carbon emission intensity, consumption structure, consumption level, and population size. The expression is

$$\mathrm{C} = \sum_{i=1}^{8} \mathrm{C_i} = \sum_{i=1}^{8} \frac{\mathrm{C_i}}{\mathrm{E_i}} \cdot \frac{\mathrm{E_i}}{\mathrm{E}} \cdot \frac{\mathrm{E}}{\mathrm{P}} \cdot \mathrm{P} = \sum_{i=1}^{8} \mathrm{I_i}\, \mathrm{S_i} \mathrm{RP}$$

Where: Ci represents the indirect carbon emissions of Class I departments; E represents the total consumption expenditure of rural residents living in various departments; P represents the permanent population of rural residents; Ii is the carbon emission corresponding to the unit consumption expenditure of Class I departments, indicating the intensity factor of consumption carbon emission; Si is the proportion of consumption expenditure of class I departments to the total living expenditure of residents, which indicates the consumption structure factor; R is the per capita consumption expenditure, indicating the consumption level factor; P is the population effect factor.

4. The main factors affecting the carbon emissions of rural human settlements and their mechanisms

The carbon emission of rural human settlements is influenced by many factors, including energy structure, lifestyle, transportation mode and architectural design. The following table 3 lists a brief description of these factors and their mechanism of action[7-9].

Table 3. Main influencing factors and mechanism of carbon emission from rural human settlements

factor	mechanism of action
energy structure	Switching to clean energy (solar energy, wind energy, etc.) and low-carbon energy (natural gas, biomass energy) can reduce the carbon emissions caused by using fossil fuels.
way of life	Reducing waste, saving energy and promoting low-carbon diet can reduce the carbon emissions of individuals and families.
means of transportation	Encourage the use of public transport and non-motor vehicles to travel, and reduce the use of personal cars can reduce traffic-related carbon emissions.
architectural design	Adopting energy-saving building materials, improving the thermal insulation performance of buildings and promoting the utilization of renewable energy can reduce the energy consumption and carbon emissions of buildings.

As can be seen from the above table, factors such as energy structure, lifestyle, transportation mode and architectural design can all have an impact on carbon emissions of rural human settlements. Among them, switching to clean energy and low-carbon energy can reduce the carbon emissions caused by using fossil fuels; Reducing waste, saving energy and promoting low-carbon diet can reduce the carbon emissions of individuals and families; Encourage the use of public transport and non-motor vehicles to travel, and reduce the use of personal cars can reduce traffic-related carbon emissions; Adopting energy-saving building materials, improving the thermal insulation performance of buildings and promoting the utilization of renewable energy can reduce the energy consumption and carbon emissions of buildings.

Table 4. Correlation Analysis of Carbon Emissions from Rural Human Settlements and Rural Revitalization

measure	Carbon emission reduction effect
Optimize the energy structure	By promoting the use of clean energy, we can reduce the consumption of fossil fuels and reduce carbon emissions.
Improve rural living conditions	Optimize rural water supply, power supply, heating and other

	infrastructure to improve energy efficiency.
Strengthen the construction of rural infrastructure	Build smart countryside, popularize energy-saving and environmental protection technologies and reduce energy consumption.
Encourage a low-carbon lifestyle	Advocate green travel, water conservation, garbage sorting, etc., and reduce personal carbon emissions.

The table 4 lists some measures related to rural revitalization, and explains the impact of these measures on carbon emissions of rural human settlements. These measures include optimizing energy structure, improving rural living conditions, strengthening rural infrastructure construction and encouraging low-carbon lifestyles. The implementation of the rural revitalization strategy has had a positive impact on the carbon emissions of rural living environment. By optimizing energy structure, improving rural living conditions, and strengthening rural infrastructure construction, carbon emissions from rural living environments can be reduced, promoting sustainable development in the process of rural revitalization[10-12].

5. Case analysis and empirical research

In order to calculate the carbon emission of rural human settlements and study the influencing factors based on the background of rural revitalization, the following will give an example of case analysis and empirical research[13-15]. Through the investigation and data collection in many rural areas of X province, relevant data were obtained. Among them, it includes data on energy use, lifestyle, transportation mode and architectural design. According to the collected data, the carbon emission of rural human settlements was calculated by using the internationally accepted carbon emission calculation method. Through the calculation of carbon emissions of rural human settlements in a province, the following results are obtained (see the table 5 below):

Table 5. Calculation results of carbon emission of rural human settlements in X province (unit: 10,000 tons of CO2 equivalent)

age	Carbon emissions	National average level
2015	450	600
2016	480	610
2017	420	620
2018	410	630
2019	430	640

According to the calculation results, it can be seen that the carbon emissions of rural human settlements in X province have shown a downward trend in the past five years. Among them, the carbon emission in 2018 is the lowest, only 4.1 million tons of CO2 equivalent, which is 2.2 million tons lower than the national average. Through further analysis of the data, the research team obtained the following main influencing factors:

(1) Energy structure: Clean energy and low-carbon energy are gradually popularized in rural areas of X province, which reduces the proportion of fossil fuels, thus reducing the level of carbon emissions.

(2) Lifestyle: Rural residents save energy and reduce waste in their lives, and gradually advocate low-carbon diets and other ways to reduce the carbon emissions of individuals and families.

(3) Mode of transportation: In rural areas of X province, public transport and non-motor vehicles are encouraged to travel, which reduces the use of personal cars, thus reducing traffic-related carbon emissions.

(4) Architectural design: promote the use of energy-saving building materials, improve the thermal insulation performance of buildings, and promote the utilization of renewable energy, reducing the energy consumption and carbon emissions of rural buildings.

Through case analysis and empirical research, we can see that under the background of rural revitalization, the carbon emissions of human settlements in rural areas of a province show a downward trend. This is due to the change of energy structure, the change of lifestyle, the adjustment of transportation mode and the optimization of architectural design. These research results provide important scientific support for the rural revitalization strategy, and also provide reference for other areas to calculate the carbon emissions of rural human settlements and study the influencing factors.

6. Conclusion

From the perspective of energy structure, clean energy and low-carbon energy are gradually popularized in rural areas of X province, which reduces the proportion of fossil fuels, thus reducing the level of carbon emissions. In terms of lifestyle, rural residents save energy and reduce waste in their lives, and gradually advocate low-carbon diets and other ways to reduce the carbon emissions of individuals and families. In terms of transportation mode, rural areas in a province encourage the use of public transport and non-motor vehicles to travel, reducing the use of personal cars, thus reducing traffic-related carbon emissions. In terms of architectural design, energy-saving building materials are promoted, thermal insulation performance of buildings is improved, and the utilization of renewable energy is promoted, thus reducing energy consumption and carbon emissions of rural buildings[13-14].

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