Green Space Ecological Planning Based on Carbon-oxygen Balance in Shenyang, China

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Abstract. Carbon-oxygen balance in urban areas refers to the income and expenditure of carbon and oxygen in urban ecosystem. Shenyang city is choosing as the study object to get the carbon gap index. Carbon emission and the carbon sequestration of Shenyang city are studied with the indicators of the GDP, unit GDP energy emissions and green areas of Shenyang during 2006 – 2015. The result shows that the carbon gap in Shenyang is huge with the data analysis. Ecological planning for green space is urgent to apply to enhance the carbon absorption capacity. Ecological land is needed to increase.
Keywords: carbon-oxygen balance, green space, ecological planning, Shenyang city.

1. Introduction

Carbon-oxygen balance in urban areas refers to the income and expenditure, spatial distribution and adjustment of carbon and oxygen in urban ecosystem within a certain region. Urban became carbon sources because they consume a lot of fossil energy. Carbon dioxide is being accumulated too much which has seriously affected the urban environment and people's lives. Green space in urban is not enough to sequestrate the Carbon dioxide. Study on urban Carbon-oxygen Balance is becoming more and more important.

In the present studies, Wang et al. (2002) [1] studied the relationship between carbon dioxide emissions and oxygen supply, and ensured the virtuous recycle of urban oxygen emissions and oxygen production by urban green space system planning, which help for decision-making for urban green space system quantification. Zhang Ying (2007) [2], Niu Yanqiong (2011) [3], Lin Gang (2010) [4], Ma Jinying (2011) [5], Chen Yanfei (2010) [6], Li Mengxue (2013) [7], respectively, based on the theory of carbon and oxygen balance, analyzed the carbon-oxygen income and expenditure of Zhengzhou, Shijiazhuang, Guiyang, Xiamen, Kunshan and Dezhou, and then the demand of ecological land for urban carbon-oxygen balance which is the reference for quantitative analysis of low-carbon city development.

Shenyang is located in the northeastern of China, which is the capital of Liaoning Province, with a population of about 6.5 million. It is at 41.8N°,123.4°E. Shenyang is the economic, cultural, transportation, financial and commercial center of northeast China. It is also the important industrial base and historical and cultural city of China. Shenyang's climate belongs to the north temperate monsoon-influenced semi-humid continental climate. It is selected as the study object. The carbon emissions are bigger than many Chinese cities because it is a national old industrial base.

2. Methods and Materials

2.1. Data of Case Study

The data of this paper are mainly derived from the statistical yearbook of Shenyang City from 2006 to 2015, including the indicators of the GDP (GDP), energy emissions, and the green area. The research area includes the 9 Districts including Heping, Shenhe, Dadong, Huanggu, Tiexi, Sujiatun, Dongling, Shenbei ,Yuhong of Shenyang. The carbon emissions, carbon absorptions, carbon gaps and other indicators of Shenyang city during 2005-2014 are chosen to analyze the carbon-oxygen balance of Shenyang city.

2.2. Methodology

The carbon gap index, the difference between carbon emission and carbon absorption, is used to measure the carbon balance. The smaller the carbon gap is, the more the urban carbon cycle tends to balance. The ratio of carbon gap is calculated with formula (1) in this paper [8]:

$$R_{CO2} = (C_e - C_a) / Cc \cdot 100\% \quad (1)$$

Where R_{CO2} is the ratio of carbon gap; C_e is the carbon emissions; C_a is the carbon absorptions.

The method of carbon emissions calculated is improved from the carbon emissions calculating model of Chinese Academy of Sciences Sustainable Development Strategy Research Group [9]. The model is

$$CO_2 = \mathrm{K}\, E \quad (2)$$

Where CO_2 is the of CO_2 emission; the coefficient K is the carbon emission intensity. It is depending on technical level, countries, regions and energy composition. The "energy and fuel conversion standard coal CO_2 emissions coefficient" which is used in China is 2.42-2.72. During the study, in order to simplify the calculation K is assumed to be a constant of 2.62. It means 2.62 ton of CO_2 would be emitted by burning 1 ton of standard coal; E is the consumption of different types of energy. It is converted into standard coal. According to the degree of regional economic development, the value of E is calculated from the regional GDP and energy consumption per unit of GDP. The formula is as follows:

$$CO2 = GDP \cdot (E/GDP) \cdot K \quad (3)$$

Where CO_2 is the carbon emissions; GDP is the regional GDP of Shenyang city; E/GDP is the energy consumption per unit of Shenyang city GDP; K is the carbon emission intensity.

The calculation of carbon absorption is based on an average of 1.767 t $ha^{-1}$of green space per day [10], and an annual CO_2 absorption of 644.96 t ha^{-1}in North China. The annual CO_2 absorption in Shenyang would be the product of the green area and the annual CO_2 absorption of 644.96 t ha^{-1}.

3. Results and Discussion

3.1. Carbon Emissions of Shenyang City

According to the formula (3), the carbon emissions of the Shenyang during 2005 to 2014 are calculated respectively to get the carbon emission status of Shenyang city (Table 1).

Table 1. CO_2 Emissions and Carbon Emissions Converted of Shenyang City

Year	GDP (10^6 yuan)	E/GDP (t Standard Coal /10^3yuan)	K (CO_2/E)	CO_2 Emissions (10^3 t)	Carbon Emissions (10^3 t)
2005	181,732	0.247	2.62	117,606.4	32,074.5
2006	228,172	0.221	2.62	132,116.3	36,031.7
2007	281,383	0.191	2.62	140,809.7	38,402.6
2008	330,615	0.164	2.62	142,058.7	38,743.3
2009	426,839	0.144	2.62	160,926.0	43,888.9
2010	405,000	0.130	2.62	137,943.0	37,620.8
2011	473,310	0.109	2.62	135,167.9	36,864.0
2012	526,690	0.097	2.62	133,853.0	36,505.4
2013	571,170	0.094	2.62	140,667.7	38,363.9
2014	575,080	0.094	2.62	142,082.7	38,749.8

Data Source: 2006-2015 Statistical Yearbook of Shenyang City

3.2. Carbon Absorptions of Shenyang City

The total areas of green space of Shenyang from 2005 to 2014 are obtained respectively according to the Statistical Yearbook of Shenyang City. With the average CO_2 absorption index of 644.96 t $ha^{-1}yr^{-1}$, the carbon absorptions of green space in Shenyang since 2006 is calculated (Table 2).

According to Table 2, the green area of Shenyang City has gradually increased from 20,718 ha in 2005 to 29,482 ha in 2014. The net increasing is about 8,764 ha with a 42.3% growth. The carbon absorptions by green space increased simultaneously.

Table 2. CO_2 absorptions and Carbon Absorptions Converted of Shenyang City

Year	Area of Green space(ha)	Absorptive capacity (t $ha^{-1}yr^{-1}$)	CO_2 absorptions (10^3 t)	Carbon absorptions (10^3 t)
2005	20,718	644.96	13,362.3	3,644.3
2006	22,482	644.96	14,500.0	3,954.5
2007	23,350	644.96	15,059.8	4,107.2
2008	23,886	644.96	15,405.5	4,201.5
2009	23,886	644.96	15,405.5	4,201.5
2010	27,328	644.96	17,625.5	4,807.0
2011	27,328	644.96	17,625.5	4,807.0
2012	29,192	644.96	18,827.7	5,134.8
2013	29,219	644.96	18,845.1	5,139.6
2014	29,482	644.96	19,014.7	5,185.8

Data Source: 2006-2015 Statistical Yearbook of Shenyang City

3.3. Indicators of Carbon Gap in Shenyang City

The carbon gap and the carbon gap ratio in Shenyang since 2006 are calculated by the difference between carbon emission and carbon absorption in Shenyang and formula (1) (Table 3).

As can be seen from Table 3, the carbon gap in Shenyang in 2006 is the smallest, $28,430.2 \times 10^3$ t. In 2009 reached a peak, $39,687.4 \times 10^3$ t. After that the carbon gap showed a wavy downward trend (Figure 1, 2). The carbon gap in 2012 reached a minimum of $31,370.6 \times 10^3$ t, and in 2013 and 2014 went up to $33,224.3 \times 10^3$ t and $33,564.0 \times 10^3$ t.

Table 3. The Carbon Gap of Shenyang City

Year	Carbon Emissions (10^3 t)	Carbon absorptions (10^3 t)	Carbon Gap (10^3 t)	Ratio of Carbon Gap (%)
2005	32,074.5	3,644.3	28,430.2	88.64%
2006	36,031.7	3,954.5	32,077.2	89.02%
2007	38,402.6	4,107.2	34,295.4	89.30%
2008	38,743.3	4,201.5	34,541.8	89.16%
2009	43,888.9	4,201.5	39,687.4	90.43%
2010	37,620.8	4,807.0	32,813.8	87.22%
2011	36,864.0	4,807.0	32,057.0	86.96%
2012	36,505.4	5,134.8	31,370.6	85.93%
2013	38,363.9	5,139.6	33,224.3	86.60%
2014	38,749.8	5,185.8	33,564.0	86.62%

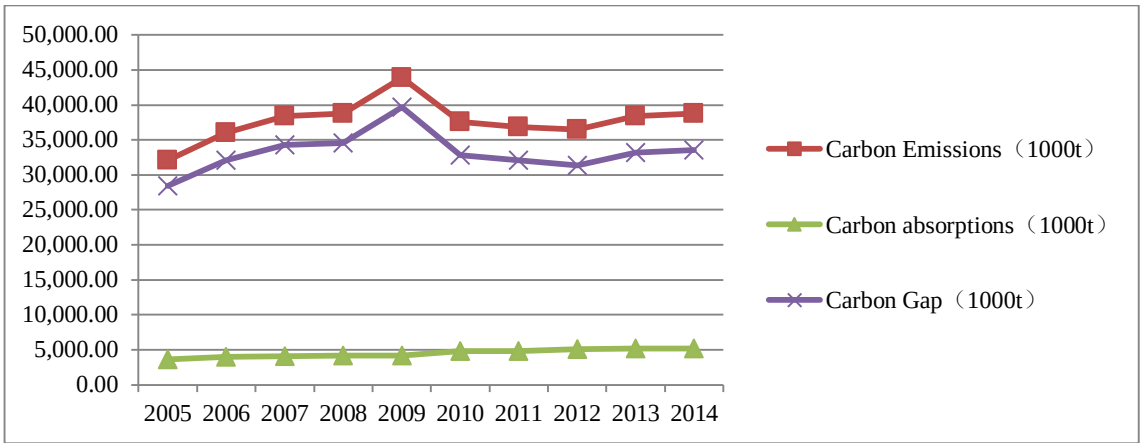

Figure 1. Carbon Emission, Carbon Absorption and Carbon Gap of Shenyang 2005-2014

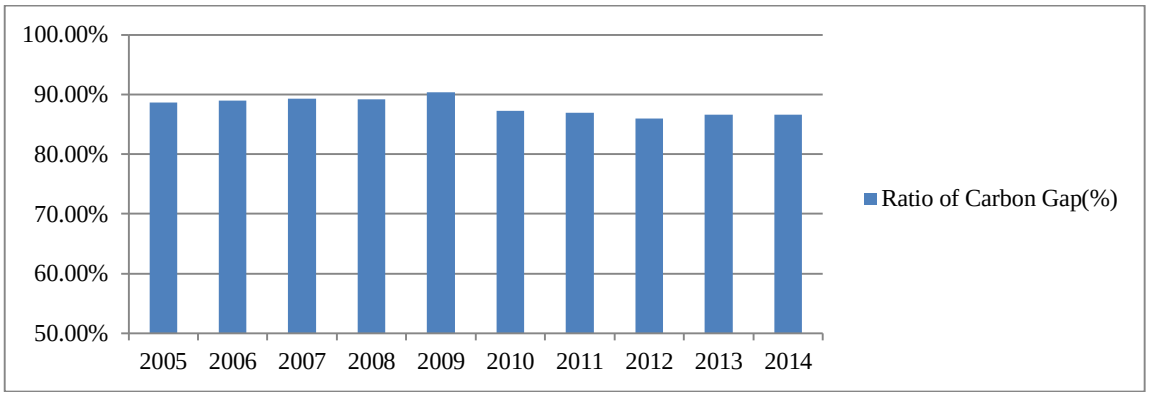

Figure 2. Carbon gap ratio of Shenyang 2005-2014

4. Conclusion

The carbon-oxygen balance of Shenyang is analyzed with the status of economic development. It is necessary to adjust the energy structure, to improve energy efficiency, and to adjust the urban industrial structure to reduce carbon emissions. Simultaneously, ecological planning for urban green space is urgent to improve the carbon absorption capacity.

4.1. Increasing Ecological Land and Optimizing Ecological Pattern

Through the analysis, it is found that the carbon gap index is relatively large. It would depend on the green space of forest and farmland around the city to absorb CO_2.At the same time, it is necessary to optimize the ecological pattern of the city to enhance the green space capability for carbon sequestration. It includes forming a green ecological network system and coordinating the green patches, corridors and matrix, Strengthening the ecological nature reserve of Qipanshan Forest Park, enhancing the ecological function of urban green parks such as Youth park and Zhongshan park in the city; increasing urban green space such as the green belt of the Hun river and the Canal in Shenyang.

4.2. Enhancing the Urban Green Space Carbon Sequestration Capacity

In the spatial distribution of urban green space, rational arrangement of "green space of oxygen source", "green space near carbon source" and "green space of carbon source" and other low carbon green layout [11].

In the central area of the wind direction, the area around the center of the city is arranged with "oxygen source green space". The tree species mainly choose high-density shrub with strong ability of releasing oxygen and carbon fixation. The carbon source green space is arranged in the downwind of the city. The tree species are mainly tall carbon fixation Arbors. In the near-source green area, the carbon-bearing ability of the plant can be increased effectively. "Oxygen source green space" is arranged around the center of Shenyang with high-density shrub with strong ability of releasing oxygen and carbon fixation. "Green space of carbon source" is arranged in the downwind of Shenyang with tall Arbors which have high carbon fixation capability. "Green space near carbon source" is arranged in Shenyang industrial districts (Yuhong District) with combination plants of Arbors, shrub and grass.

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