Study on Effects of Land Use Change on Carbon Emissions in Beijing Tianjin Hebei region from 1990 to 2020

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Abstract. In order to deeply understand the impact of land use types on carbon effect, we choose the Beijing Tianjin Hebei region as the study area. By using the IPCC calculation method and the modified carbon emission calculation model, our paper estimates the carbon source and carbon sink effects of change in land use type in Hebei, Beijing and Tianjin from 1990 to 2020, and analyzes their temporal and spatial changes. The results show that: (1) Development of some factories has gradually shifted to Hebei, so its land area for industrial development has increased. The corresponding total energy consumption has also increased. (2) Construction land is the primary carbon source. The region is in the golden stage of urban construction and industrial development, and the regional infrastructure land will increase accordingly. The construction land will maintain a high growth trend over a long period. (3) Total carbon dioxide in this study area is increasing, and the massive carbon dioxide emissions of change in land use type is far greater than the amount of carbon dioxide absorbed.

Keywords: carbon effect, carbon emission, land use type, carbon source

1. Introduction

For 50 years, the global climate system has been warming rapidly. This is mainly because human activities will produce a lot of carbon dioxide, methane and other gases [1].

The land is the link between the human social economy and the natural ecosystem, which can directly reflect the impact of human activity type and intensity on local space and ecosystem. Land is the second largest source of carbon emissions as a natural carrier of carbon emissions and absorption from terrestrial ecosystems [2-5]. The change in its use mode and intensity will significantly impact the progress of development structure in different regions, local microclimate changes and regional carbon cycle benefits. Therefore, carbon emissions with land use as the core have always been the focus of academic attention. According to the research and estimation of relevant scholars, direct emissions of carbon dioxide from land use and land change were around 1/3 of the total amount of human behavior from 1850 to 1998 [6].

After China's economic reform and open up, the promotion of urbanization has led to dramatic changes in China's land use types [7]. In urban development, urban agglomerations and urban belts are developing rapidly. Beijing takes the lead in development and drives Tianjin and Hebei forward. The development of various industries is closely connected with Its land use planning. According to the data, CO_2 emissions of our study area show an upward trend, and the distribution is uneven. CO2 emissions of Hebei were 2.57 times and 4.00 times that of Beijing and Tianjin, respectively.

These places have a population of 110million. The impact of human economic and energy activities on the regional carbon cycle is primarily realized by changing the spatial layout of industries.

This study will draw conclusions based on the data of land type change in Beijing, Tianjin and Hebei, and compare the images of land type change every five years for 30 years. The IPCC carbon emission coefficient method is used to organize data, and to assess the net carbon emissions in connection with land use change.

2. Overview of the study area

Beijing Tianjin Hebei region is located between 36 ° 20 'n-42 ° 37' n and 114 ° 03 'e-119 ° 60' e. The land area is about 251800km^2.

Hebei, Beijing and Tianjin are mainly composed of Bashang Plateau, Taihang Mountains and Yanshan Mountains, North China Plain and Bohai Coastal Plain. This area is located in the middle of the Bohai Rim area, bordering Bohai Bay, Taihang Mountains, North China Plain and Yanshan Mountains in the east, west, north and south. The terrain of the Beijing Tianjin wing region is inclined from northwest to Southeast, with diverse geomorphic types and precipitation decreasing from Southeast to the northwest. The altitude of Beijing, Tianjin Hebei region, varies greatly. The plateau is 1000-1500m above sea level, the peak is more than 2000 m above sea level, and the plain is less than 50 m. There are both towering mountains and Intermountain basins in the territory; There are undulating plateaus, hills and vast plains; There are many depressions and a large number of wetlands with complete geomorphic types and distinctive characteristics. Beijing Tianjin Hebei region belongs to the mid-latitude monsoon climate in the eastern part of the mainland. In winter, it is controlled by the winter wind from the north of the mainland to the south. In summer, it is wet and rainy due to the influence of the summer wind from the low-latitude ocean surface.

3. Data and methods

3.1. Data source and processing

3.1.1. Change in land use type data

The change in land use type data selected from 1990 to 2020 are from the cloud dataset created in the research paper entitled "30 m annual land cover and its dynamics in China from 1990 to 2019", jointly written by Yang Jie and Huang Xin of Wuhan University. The current data has been updated to 2020.

3.1.2. Energy consumption data

The energy consumption data of Beijing Tianjin Hebei region from 2010 to 2020 are from:

(1) Csamar economic and financial research database. In order to learn from the professional standards of CRSP of the University of Chicago, Standard & Poor's Compustat, Taq of the New York Stock Exchange, i/b/e/s, Thomson and other internationally renowned databases, and in combination with China's actual national conditions, the economic and financial database is developed.

(2) China energy industry research database. The China energy industry research database contains statistical data from the National Bureau of Statistics, the energy administration, the world energy organization and other major energy-producing and consuming countries on the energy of oil, natural gas, coal, electricity, nuclear energy and other energy varieties. It includes data by country, region and industry, including statistics on energy production, consumption, inventory, elasticity coefficient, energy balance, import and export, and economic indicators of the energy industry.

3.2. Research methods

3.2.1. Land use carbon emissions estimation model

Soil carbon emissions attribute is determined by land use type, which affects atmospheric greenhouse gases through carbon emissions or carbon absorption. Its direct effect is to reduce carbon dioxide emissions; Indirect effects include soil respiration, vegetation species, soil environmental

temperature and so on [8]. The intensity of human activities also directly affects land use types and greenhouse gas emissions.

The IPCC list method is the methodological basis for countries to prepare light and has strong compatibility [9]. Therefore, the land-use carbon emissions in the Beijing Tianjin Hebei region will also be calculated using the IPCC list method.

The mathematical formula of net carbon emissions is as follows:

$$C_n = \sum_{i=1}^{5} A_i \times B_i + \sum F_j \times N_j \times C_j \times O_j \times 10^{-3} \times 44/12 \quad (1)$$

Where C_n is the net carbon emission (T), A_i is the area of class (I) land use type, B_i is the carbon emission (absorption) coefficient of class (I) land use type, F_j is the consumption of class J fossil energy (T), N_j is the net calorific value of class J energy(tC/TJ,1Gg=10^3), C_j is the carbon content of class J fossil energy (kg/gt), O_j is the default oxidation rate of class J fossil energy N, C, O are IPCC values and 10^{-3} is the unit conversion coefficient, 44/12 is the ratio of molecular weight to C.

Construction land and cropland mainly cause carbon emissions in the carbon cycle, that is, carbon sources; Forest, grass, water area and unused land mainly absorb carbon in the process of the carbon cycle, that is, carbon sink.

Carbon emissions are estimated indirectly through direct calculation of land carbon emissions and the carbon emission coefficient of energy consumption in the process of using construction land.

Table 1. Total energy consumption from 1990 to 2015

Year	Total energy consumption / 10000 tons of standard coal	Coal/104 tons	Coke/104 tons	Ral oil/ 104 tons	Gasline/ 104 tons
1990	10904	12076	927.69	1398.87	190.23
1995	15076.25	16103.57	1785.95	1641.54	282.50
2000	18133.42	17307.57	1820.61	2211.84	355.47
2005	29382.20	27412.81	5225.39	2666.03	576.10
2010	41303.24	34906.13	8203.36	4079.73	815.40
2015	46159.00	37404.51	8810.73	4275.08	1135.29

Table 2. Carbon emission coefficient (fossil energy)

Energy name	Net calorific value /(TJ/Gg)	Conversion coefficient of standard coal/(kgce/kg)	Unit carbon content/(tC/TJ)	Carbon oxidation rate	Carbon emission coefficient	Reference source
raw coal	20.908	0.7143	26.37	0.94	0.7559	China Energy Statistics Yearbook
coke	28.435	0.9714	29.5	0.93	0.8550	
crude oil	41.816	1.4286	20.1	0.98	0.5854	
gasoline	43.070	1.4714	18.9	0.98	0.5532	
kerosene	43.070	1.4714	19.5	0.98	0.3416	

3.2.2. Carbon emission coefficient

(1) Carbon emission factor of cultivated land:

Cultivated land mainly shows carbon emissions, and carbon sink effect is very weak. After absorbing carbon, crops will soon release carbon into the air. The carbon emission coefficient of cultivated land in Beijing-Tianjin-Hebei region is determined to be 0.481.

(2) Carbon emission factor of forest land:

Because the shrub land in our study area covers a small area and has no crop attributes, the shrub land is divided into forest land. The carbon emission coefficient of forest in Beijing-Tianjin-Hebei region is determined to be -0.612.

(3) Grassland carbon emission actor:

On the basis of Wu Jianguo, Fang Jingyun and Xiao Hongyan, the grassland carbon emission coefficient is -0.021; On the basis of Li Ying and suyali, the carbon emission coefficient of grassland is -0.020. Therefore, the average value of grassland carbon emission coefficient in Beijing Tianjin Hebei region is -0.0205.

(4) Carbon emission factor of water area:

The carbon sink effect of water area is stronger than the carbon source effect. According to the research of Su Yali et al, the carbon emission coefficient of water area in this region is determined to be -0.253.

(5) Carbon emission factor of unused land:

A large proportion of the unused lands in Beijing-Tianjin-Hebei region are wetlands, marshes, barren grasslands, bare rocks and other types. Their carbon effects are both carbon emissions and absorption, but the intensity of participation in the carbon cycle is very weak. According to Lai Li's research, the carbon emission coefficient of unused land in this region is determined to be -0.0005.

Table 3. Carbon emission coefficient (main land-use types)

Land-use type	Carbon emission factor/$(t \cdot hm^{-2})$	Reference source
cultivated land	0.4810	Shi Hongxin et al [10]
woodland	-0.6120	Fang Jingyun, Xiao Hongyan, etc [11]
meadow	-0.0205	Wu Jianguo, Fang Jingyun, Xiao Hongyan, Li Ying, Su Yali, etc [12]
waters	-0.2530	Research on Su Yali et al [13]
Unused land	-0.0005	Research on Lai Li [14]

4. Results and analysis

4.1. Land use change

4.1.1. Change rate and trend of land use area

In 1990, the land use in Beijing-Tianjin-Hebei region was mainly cultivated land, forest land and grassland, accounting for 91% of the whole area.

During these three decades, the area of grassland and unused land decreased uninterruptedly every year, while the district of forest land increased. Cultivated land in this region in 2020 decreased by 17.3% compared with 1990, and the unused land decreased by 80.13% year-on-year. At first, construction land accounted for only 7.49% of the total land use area in this region in 1990. By 2020, it has accounted for 14.94% of the total area, reaching 32190, an increase of 99.45% year-on-year, with significant changes. The area of shrub land has experienced a process of decreasing year by year from the previous two decades to increasing in 2010, and its area has decreased in 2020 compared with 1990. The water area began to decrease in 2000 after the growth of the first decade, while the water area in 2020 was still higher in 1990. Other land use types accounted for too little and basically remained unchanged.

Table 4. Area of different land types from 1990 to 2020 (km^2)

Time/Year	cultivated land	Forested land	meadow	waters	land used for building	Unused land
1990	114053	43256	38228	2744	16139	319
1995	109877	46127	36298	3014	19450	241
2000	106007	47418	36542	2995	21784	225
2005	102221	48946	36525	3117	23848	189
2010	98281	50595	36258	2892	26761	178
2015	94651	52122	34752	3013	30179	128
2020	94317	53946	32165	2852	32190	63

4.1.2. Analysis of spatial distribution changes of land use types

Beijing-Tianjin-Hebei are dominated by cultivated land, mainly concentrated in the southeast of this region, including Tangshan, Cangzhou and Hengshui; With the passage of time, the phenomenon

of returning farmland to forest and grassland is most obvious in Zhangjiakou in the north. At the same time, the construction land is gradually transferred to Hebei, and more areas originally dominated by cultivated land are transformed into areas that dominated by construction land, which is specifically reflected in the sustaining increase in the district of construction land in Hebei Province.

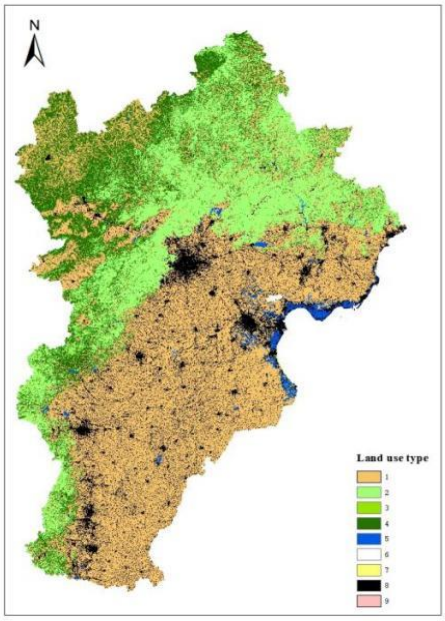


Figure 1. land distribution in 1990

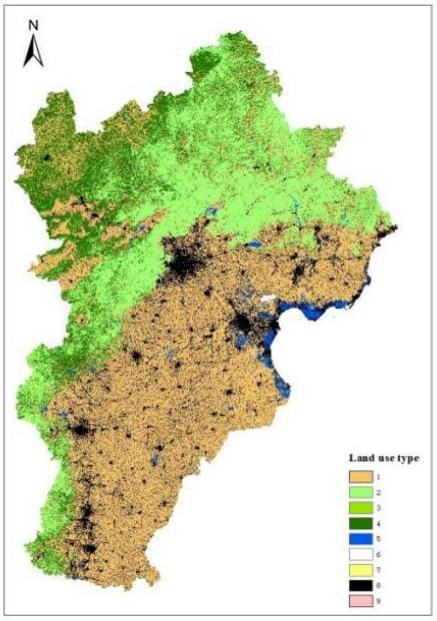


Figure 2. land distribution in 2000

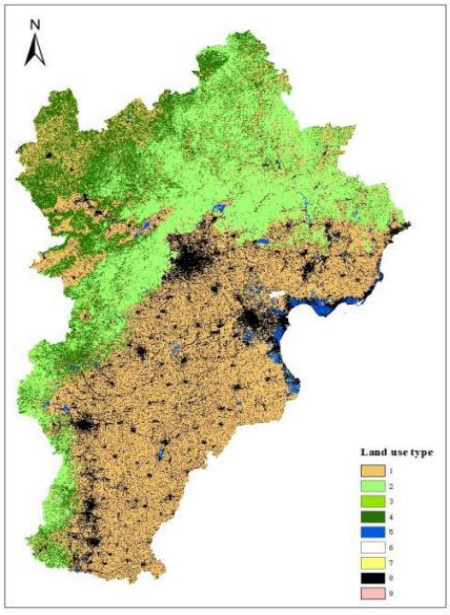


Figure 3. land distribution in 2010

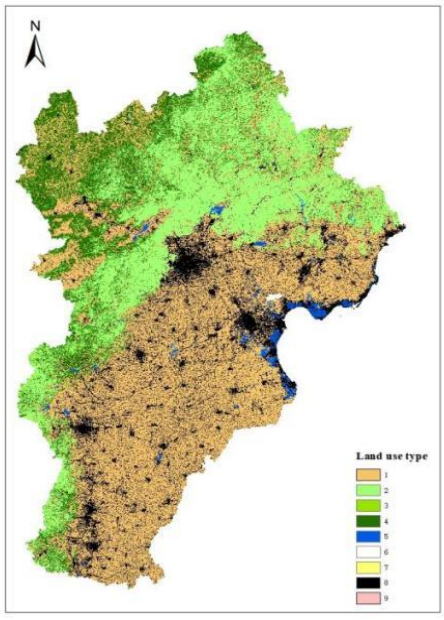


Figure 4. land distribution in 2020

(1 cropland, 2 woodland,3 shrub land, 4 grasslands, 5 water area,6 glacier, 7 unused, 8 construction land, 9 swamp wetland)

4.1.3. Carbon emissions of different land use types

Table (5) shows the zone change of different land use models and the emissions of carbon in this region, in the period of 1990 to 2020.

Table 5. Carbon emissions of different land types from 1990 to 2020 10^4(T)

Time/year	cultivated land	Forested land	meadow	waters	land used for building	Unused land	carbon source	Carbon sink	Net carbon emissions
1990	548.59	-264.73	-7.84	-6.94	29864	-0.0016	30413	279	30133
1995	528.51	-282.30	-7.44	-7.63	40925	-0.0012	41454	298	41156
2000	509.89	-290.20	-7.49	-7.58	45249	-0.0011	45759	305	45454
2005	491.68	-299.55	-7.49	-7.89	76009	-0.0009	76501	315	76186
2010	472.73	-309.64	-7.43	-7.32	103594	-0.0008	101067	324	103742
2015	455.27	-318.99	-7.12	-7.62	111567	-0.0006	112022	334	111689
2020	453.66	-330.15	-6.59	-7.22	111525	-0.0003	111979	344	111635

4.2. Analysis of carbon emission effect of land use

According to the calculation, the source, sink and the emissions of carbon as land use in the Hebei district between 1990 and 2020 are obtained, as presented in chart (6).

During the period in these decades, the carbon emissions in the area increased, and the net emissions increased from 30133×10^4t in 1990 increases to 111635×10^4t in 2020. They were increasing net carbon emissions by 81502×10^4t. The growth rate reached 270.47%.

The total carbon emissions from land use are affected by its carbon sources and sinks. Among the two principal carbon sources of the usage of land in these cities, the emissions from construction land are mainly increasing during the study period, accounting for more than 98.7% of the total.

Its change trend has affected the summational emissions of carbon in these cities. Therefore, as the primary source of carbon, construction land plays a vital role in carbon emission reduction in the district. Attribute to the cultivated land district decreased, the carbon emissions of cultivated ground showed a decreasing trend. The emissions of carbon source as cultivated land decreased in the period of study, with the emission load of carbon from 548.59×10^4t in 1990 decreased to 453.66×10^4t in 2020. 94.93% in 30 years. The average annual decrease of 3.16×10^4t. The changing trend is similar with the trend of cultivated land reduction.

The change in energy consumption structure is mainly related to the increase in construction land. The emissions of carbon from energy consumption generally depend on the change in total energy consumption, and gasoline and coal dominate.

The energy consumption in the region has maintained a continuous growth trend, increasing from 254970600 tons in 1990 to 980534800 tons in 2019. The corresponding carbon emissions peaked between 2011 and 2013 and fluctuated little in the following six years. It reflects that construction land plays a vital role as a carbon source.

4.2.1. Spatiotemporal pattern analysis of land use carbon emissions effect

Ascribe the diversity in land area and population distribution, the net carbon emissions in Hebei Province are significantly exceed those in the other two cities. In contrast, the net carbon emissions in Beijing are similar to those in Tianjin, and the carbon emissions in Tianjin are slightly higher than those in Beijing. The net carbon emissions of Beijing, on the other hand, are the lowest among the three regions. In the first eight years, it experienced a decline, from 1004055486 tons in 2010 to 471685642 tons in 2019, then increased and retreated to 953862495 tons in 2020. The carbon emissions in Tianjin are slightly higher than those in Beijing. From 1626372854 tons in 2010 to 1558014360 tons in 2019, it increased to 1766985593 tons in 2020, and the total regional value increased by 14602739 tons.

4.2.2. Analysis of land use change causes

The main reason for the change is the rapid increase of the population in the district, which reached 107.47 million in 2020, an increase of 62.05% compared with 1990, while a large number of new populations has guided to an soar in the require for construction ground [15]. Meanwhile, the course of urbanization and industrialization has accelerated. Since 2000, the economy of Beijing Tianjin Hebei metropolitan area has developed rapidly, especially with the rapid population growth, industrial

upgrading and industrial transfer in Beijing and Tianjin. In 2020, the urbanization rate of the region reached 70%, which also reflects the rapid growth of construction land scale caused by the migration of industrial land in the city of Beijing and Tianjin to various districts and counties in Hebei Province, because a large number of arable land is occupied in this process, A mass of land used in cultivate has been converted into which use in construction. In addition, the policy direction of returning farmland to forest has further led to the decline of cultivated land area and the increase of forest land area.

5. Conclusion

The carbon emissions in Beijing Tianjin Hebei area exhibit an upward trend year by year, with an increase of 81502×10^4t from 1990 to 2020. Carbon sources and sinks increased by 81566×10^4t、65×10^4t growth rate reached 268.19% and 23.29%, respectively, which led to the carbon source impact the usage in the region being far greater than the carbon sink effect. Construction land is the primary carbon source of the region, while its carbon emissions due to more than 98.7% of the summation. The emissions from construction ground increased by 81502×10^4t from 1990 to 2020. Beijing Tianjin Hebei district is in the stage of rapid development of urbanization and industrialization, also the regional infrastructure land will increase accordingly. The construction land will maintain a high growth trend over a long period. The focus of industrial development in Beijing Tianjin Hebei district has gradually shifted to Hebei. The land used in construction in Hebei began to increase around 2000, and the corresponding total energy consumption has also increased.

References

[1] Goldewijk K K. Three Centuries of Global Population Growth: A Spatial Referenced Population Density Database for 1700-2000 [J]. Popul Environ, 2005, 26(5): 343-367.

[2] Yang Quntao. Construction and Application of Compreehensive Evaluation Model of Carbon Offset Based on Land Use Change [D]. Henan: Henan University, 2016.

[3] Pacala S W, Hurtt G C, Baker D, et al. Consistent Land and Atmosphere-based US Carbon Sink Estimates [J]. Science, 2001, 292(5525): 2316-2340.

[4] Houghton R A. Why are Estimates of the Terrestrial Carbon Balance so Different? [J]. Glob Change Biol, 2003, 9: 500-509.

[5] Schimel D S, House J I, Hibbard K A, et al. Recent Patterns and Mechanisms of Carbon Exchange by Terrestrial Ecosystems [J]. Nature, 2000, 414: 169-172.

[6] Jing Yong, Zuo Lingli, Peng Wenfu. Spatial-temporal Change Analysis of Carbon Emission from Land Use in Mianyang: The Case Study of Mianyang [J]. Environmental Science&Technology, 2021, 44(6): 172-185.

[7] Wang Leqin. Land Use Conflict and Its Management in the Process of the Urbanization [D]. Nanjing Agricultural University, 2015.

[8] Zhao Hui, Wang Yufen. Characteristics and effect of carbon emission in Shanxi Province based on land use change [C]. Proceedings of the 2022 Annual Conference of Science and Technology of the Chinese Society for Environmental Sciences (I), 2022: 140-145.

[9] Dai Lijuan, Ma Qiong, Hou Yulong. Analysis of carbon emission status based on IPCC inventory [J]. Chinese market, 2022(19): 16-18.

[10] Shi Hongxin, Mu Xingmin, Zhang Yinglong, Lv Mingquan. Effects of Different Land Use Patterns on Carbon Emission in Guangyuan City of Sichuan Province [J]. Bulletin of Soil and Water Conservation, 2012, 32(3): 101-106.

[11] Fang Jingyun, Guo Zhaodi, Pu Shilong, Chen Anping. Estimation of carbon sequestration of terrestrial vegetation in China from 1981 to 2000 [J]. Science in China Press (Series D: Science of Earth), 2007(06): 804-812.

[12] Xiao Hongyan, Yuan Xingzhong, Li Bo, Yan Wentao. Study on the Carbon Emission Effects of Land Use Change——the Case Study of Chongqing [J]. Journal of Chongqing Normal University (Natural Science), 2012, 29(01): 38-42+115.

[13] Su Yali, Zhang Yanfang. Study on Effects of Carbon Emission by Land Use Patterns of Shaanxi Province [J]. Journal of Soil and Water Conservation, 2011, 25(1): 152-156.

[14] Lai Li. Study on The Carbon Emission Effect of Land Use in China [D]. Jiangsu: Nanjing University, 2010.

[15] Liu Yuyan, Fu Qiang, Zhao Lina. Impact of Population and GDP Growth in Land Use / Land Cover Change in the Beijing-Tianjin-Hebei Region [J]. Journal of North China Institute of Aerospace Engineering, 2019, 29(6): 26-28.