Carbon Emission Effect of Land Use in Nanchang City and Its Optimization Countermeasures

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Abstract Land use/coverage change (LUCC) exerts a profound influence on global carbon emission through changing structure and functions of ecosystem. Taking Nanchang City as an example, this study determined organic carbon emission of land ecosystem by ecosystem type method. In 2005, total carbon emission of Nanchang City was 4.826 2 Tg. In 2010, it became 5.535 9 Tg, showing a growth trend of carbon emission from land use change. The carbon emission of cropland and grassland decreased in 2005 – 2010, that of garden land and construction land had increase, and carbon absorption function of water land and other unused land was weakened. Due to difference of land use structure, the carbon emission of Nanchang City is varied. In 2005 – 2010, the rank of carbon emission from high to low is as follows: Nanchang County, Xinjian County, Jinxian County and Qingshanhu District. In combination with land use change and development plan of Nanchang City, Nanchang City should take carbon emission reduction measures, including conceding the land to forestry, returning the land to water, limiting excessive expansion of construction land, optimizing distribution of urban land use, flexibly regulating land supply policies, and establishing carbon trading legal system, to reach the objective of combining land use plan with ecological construction.

Key words Land use, Carbon storage, Carbon emission, Low carbon optimization countermeasures

Land use change exerts a great influence on increase in atmospheric CO_2, and its function is only second to the burning of fossil fuels[1]. According to carbon emission calculation organized by the World Resources Institute and estimation of famous carbon cycle research experts, carbon emission resulted from land use change accounts for 1/3 of the total carbon emission from human activities (IPCC, 2000)[2]. Land use/coverage change (LUCC) changes small climate and physical and chemical properties of ecosystem through changing structure and functions of ecosystem, thus influences quality and decomposition rate of falling things, soil organism composition, and organic matter quality, and finally affects carbon distribution of ecosystem sections. Improper land use will lead to reduction of soil storage and carbon content in vegetation, and accordingly influence climate change. However, the present researches mainly focus on land ecosystem (forest and cropland), and few researches touch on carbon emission effect of various land use types[3]. Taking Nanchang City as an example, taking serving "forest city and garden Nanchang", "ecology-oriented city, green rising", and "scientific development and harmony and safety" as objectives, and combining dynamic land use change and development plan of Nanchang City, we discussed carbon emission effect of land use in Nanchang City, in the hope of providing decision support and reference for Nanchang City creating national low carbon model city.

1 Overview of the study area

Nanchang City (115°27′ – 116°35′E, 28°09′ – 29°11′N), also named Yuzhang and Hongcheng, is the capital of Jiangxi Province. It is political, economic, cultural, scientific and technological, and traffic center of Jiangxi Province, and a core city in Poyang Lake ecological economic zone. As the first low carbon pilot city in China, Nanchang is also reputed as Oriental Edinburg. Nanchang City covers a total area of 743 218.34 hm^2. According to survey of land use change, by the end of 2005, there are 473 761.62 hm^2 cropland accounting for 63.74%; 86 377.86 hm^2 construction land accounting for 11.63%; 183 078.86 hm^2 unused land accounting for 24.63%. Strategic objective of overall plan for land use in Nanchang City is to coordinate land use with ecological environment construction, speed up key ecological project construction, and build regional ecological barrier system. Therefore, analyzing carbon emission effect of land use change in Nanchang City is of certain typical significance.

2 Study method and data source

2.1 Study methods The 1996 *IPCC Guidelines for National Greenhouse Gas Inventories* divided land use change and forest related to carbon sink/source into change of forest and other woody biomass, conversion of forest and grassland, abandonment of operating land, and change of organic carbon storage in soil, including mutual conversion between forest, grassland and cropland, soil coverage change resulted from invasion of woody plant into grassland and alien species, mutual conversion between dry land and

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wetland, and mutual conversion between urban and non – urban land[4]. In comparison, the 2006 *IPCC Guidelines for National Greenhouse Gas Inventories* introduced 6 land use categories, i. e. forest land, cropland, grassland, wetland, settlement, and other land, and considered carbon emission effect of conversion of land use categories from the perspective of land use change[5]. On the basis of current land use situation in Nanchang City and *Overall Plan for Land Use in Nanchang City* (2006 – 2020), we analyzed carbon emission intensity of cropland, garden land, forest land, grassland and construction land.

In the process of analysis, we mainly adopted the ecosystem type method to determine the carbon emission intensity of land ecosystem, compared trend of land use change in time and space during 2006 – 2020, and overviewed influence of land use change on carbon emission effect. Carbon emission of a certain land category is equal to average organic carbon density of the land category multiplied by the corresponding area, shown in equation 2 – 1.

$$T = \sum_{i=1}^{n} Ai \cdot Vi \quad i = 1, 2, 3, \cdots, n \qquad (2-1)$$

where T signifies total carbon emission of regional land ecosystem, Ai refers to area of the i – th category land, and Vi stands for carbon emission (absorption) coefficient of the i – th type land use.

2.2 Data source We adopted current land use area in the base year 2005, land area in 2010 and land area in target year 2020, current land use data of counties and districts in 2005, and land category control area of counties and districts in 2010 and 2020. Combining land use grid, we obtained carbon emission coefficient of land use categories in China: cropland -0.502 tC · ha^{-1} · yr^{-1}, garden land -0.033 tC · ha^{-1} · yr^{-1}, forest land 0.52 tC · ha^{-1} · yr^{-1}, grassland -0.191 tC · ha^{-1} · yr^{-1}, construction land -55.603 tC · ha^{-1} · yr^{-1}, water land 0.257 tC · ha^{-1} · yr^{-1}, and other unused land 0.005 tC · ha^{-1} · yr^{-1} (" – " stands for carbon emission effect)[6, 7]. According to carbon emission coefficient of land use change and land use type, we can obtain carbon emission intensity of land use change, and then calculate comprehensive carbon emission accounting list of land use types in this area[8]. On the basis of experience data of previous researchers, at the national average level, we assumed that carbon emission coefficient of various land use types is not changed, and then we obtained carbon emission intensity of different years in overall plan for land use in 2006 – 2020 based on land use change of Nanchang City.

3 Results and analyses

3.1 General characteristics of carbon emission in Nanchang City According to current land use situation of Nanchang City in 2005, and objective data of 2010 and 2020, as well as previously stated carbon emission coefficient of different land categories, we calculated carbon emission of land categories in Nanchang City in 2005, 2010 and 2020, as listed in Table 1. From land use types, it can be known that in 2005 – 2010, the total carbon emission of Nanchang City was 4.826 2 Tg in 2005, and 5.535 9 Tg in 2010, showing a growth trend of carbon emission due to land use change in this period. The carbon emission of 2010 was 0.709 7 Tg more than 2005, having an average annual increase of 0. 141 9 Tg. Therefore, in these 5 years, the total average annual increase of carbon emission reached 0.03 TgC · yr^{-1}. From the carbon emission per capita, the carbon emission per capita of Nanchang City was –1.07E – 06 Tg in 2005 and –1.10E – 06 Tg in 2010, having an increase of –2.69E – 08 Tg.

Table 1 Comparison of carbon emission effect of land use in Nanchang City in 2005 – 2010 (Tg)

Land categories	Carbon emission in 2005	Carbon emission in 2010	Increase (+)/decrease (–) compared with 2005	Carbon emission in 2020	Increase (+)/decrease (–) compared with 2010
Cropland	–0.1317	–0.1284	0.0033	–0.124	0.0044
Garden land	–3.29E –04	–3.38E –04	–8.90E –06	–3.38E –04	1.00E –07
Forest land	0.0685	0.0685	0	0.0684	–0.0001
Grassland	–1.89E –04	–1.88E –04	7.50E –07	–1.59E –04	2.93E –05
Construction land	–4.8029	–5.5157	–0.7128	–6.6815	–1.1658
Water land	0.0403	0.0401	–0.0002	0.0398	–0.0003
Other unused land	1.32E –04	1.17E –04	–1.48E –05	8.93E –05	–2.80E –05
Carbon emission per capita	–1.07E –06	–1.10E –06	–2.69E –08	/	/
Total	–4.826 2	–5.535 9	–0.7097	–6.697 7	–1.1618

Note: " – " stands for carbon emission effect.

Among various land use types, the carbon emission of cropland and grassland decreased in 2005 – 2010, that of garden land and construction land had increase, and carbon absorption function of water land and other unused land was weakened. In 2005 – 2010, major carbon source of Nanchang City was construction land and the next was cropland. The area of construction land gradually increased in 2005 – 2010 and the carbon emission intensity also gradually increased year by year, while cropland decreased year by year and carbon emission of cropland also decreased gradually. For forest land, water land and other unused land, the major was carbon sink. In this period, the basic area of forest land was basically not changed and the carbon absorption kept unchanged, while water land and other unused land area gradually decreased year by year and the carbon absorption also decreased accordingly (shown in Fig. 1).

In 2005 – 2020, the total carbon emission of Nanchang City was 4.826 2 Tg in 2005, and 6.697 7 Tg in 2020, showing a growth trend of carbon emission due to land use change in this period. The carbon emission of 2020 was 1.871 5 Tg more than 2005, having an annual increase of 0. 141 9 Tg. In these 15

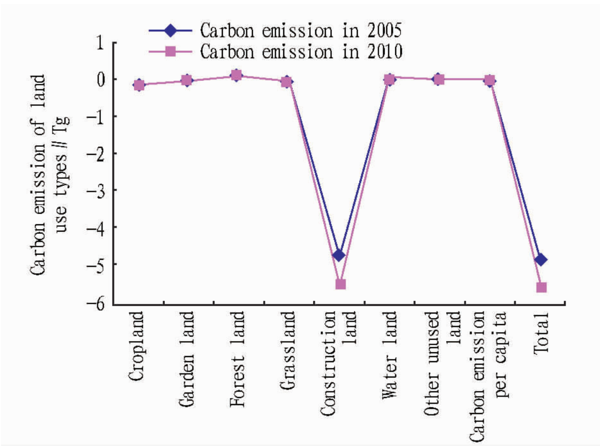

Fig. 1 Carbon emission estimation of major land use types in Nanchang City in 2005 – 2010

years, the total average annual increase of carbon emission reached 0.1248 $TgC \cdot yr^{-1}$. In 2005 – 2020, major carbon source of Nanchang City was construction land and the next was cropland. Due to increase of the area of construction land in 2005 – 2020, the carbon emission intensity gradually increased year by year, while cropland decreased year by year and carbon emission of cropland also decreased gradually. For forest land, water land and other unused land, the major was carbon sink. In this period, the basic area of forest land was basically not changed and the carbon absorption kept unchanged, while water land and other unused land area gradually decreased year by year and the carbon absorption also decreased. Therefore, if using the existing plan data, land use in Nanchang City will show carbon emission function by 2020, while carbon absorption function will weaken, as shown in Fig. 2.

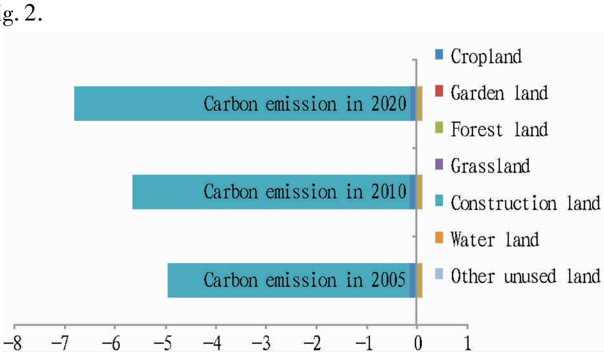

Fig. 2 Carbon emission proportion of major land use types in Nanchang City in 2005 – 2020

In the plan period, construction land gradually increased due to occupying cropland, forest land, grass land and unused land. In the whole plan period, the highest carbon emission intensity of land use type in Nanchang City is also construction land. In 2005, it was up to 99.52%; in 2010, it reached 99.64%; in 2020, it will reach 99.76%. Grassland and garden land take up the smallest part. Forest land, water land and unused land show carbon absorption, and carbon absorption intensity of these three land use types gradually decreases. In the plan period, carbon emission of cropland and grassland gradually decreases year by year, and construction land increases year by year. To optimize carbon emission of Nanchang City, the major way is to limit conversion of cropland into construction land and control expansion of construction land. Compared with carbon emission generated from current land use plan, the carbon emission will increase by 1.871 5 Tg if using the overall plan for land use in 2020. From the perspective of carbon emission reduction, total carbon emission will increase if using the overall plan for land use in 2020. Thus, Nanchang City is faced with serious carbon emission reduction task.

3.2 Characteristics of carbon emission of land use in counties and districts of Nanchang City Due to difference of land use structure, the carbon emission of Nanchang City is varied in counties and districts. In 2005 – 2010, the rank of carbon emission from high to low is as follows: Nanchang County, Xinjian County, Jinxian County and Qingshanhu District. Southern Nanchang is the largest carbon emission area, and Nanchang County is the most outstanding. As one of the top hundred powerful counties of China, Nanchang County ranks the first in Nanchang City for construction land. Construction land is the land use type that has the largest carbon emission coefficient, accounting for 88.00% of the total carbon emission, leading to carbon emission of Nanchang County ranking the first in Nanchang City. Compared with Nanchang County, Jinxian County is lower in carbon emission, and it ranks the third in Nanchang City. In northern Nanchang City, the carbon emission is relatively lower. But there is an exception, Xinjian County. Along with development of Honggutan and Hongjiaozhou new area, the construction land demand of Xinjian County gradually increases. As a result, the total carbon emission of Xinjian County ranks the second in Nanchang City. In downtown Nanchang, the carbon emission is lower, mainly Wanli District, Donghu District and Xihu District.

Table 2 indicates that counties and districts of Nanchang City in 2005 manifested carbon emission effect: Nanchang County has highest carbon emission effect with carbon emission of 1.63161 Tg; the next is Xinjian County; Qingyunpu District has the lowest carbon emission effect with carbon emission of only 0.11323 Tg. In the unit area carbon emission, Donghu District and Xihu District have the highest value in 2005, up to 4.1E – 05 Tg, the next is Qingshanhu District, and the lowest is Anyi County, only 3.3E – 06 Tg. As regards land use types, construction land has the largest contribution to total carbon emission, not only because construction land has the highest carbon emission coefficient, but also because construction land is the major land use type in all counties and districts. Forest land area ranks in the middle, but because its carbon absorption coefficient is low, its absorption function is not sufficient to offset the carbon emission. The area of land use type determines land use structure of counties and districts. Thus, the task of carbon emission reduction lies in adjustment of land use structure.

In 2010, except in Qingyunpu District, Xihu District and Donghu District, cropland area in other counties and districts is larger than their construction land, and some even 2 – 3 times higher than construction land. However, the carbon emission of cropland is much lower than that of construction land, as listed in Table 3. The area of construction land has increase in all counties and districts, so their carbon emission also increases. In comparison, the carbon absorption of forest land decreases in Nanchang County, Jinxian County, Qingshanhu District, Donghu District and Xihu District with decrease of forest land; in other counties and districts, carbon absorption increases with increase of forest land. In Qingyunpu District, the garden area and forest land area decreased from 56.23 hm^2 and 60.21 hm^2 in 2005 to 0 hm^2, and the carbon emission and absorption decreased to 0 Tg accordingly. Donghu District and Xihu District, situated in downtown Nanchang City, are main construction land. In 2005 – 2010, their construction land area was not changed, so the carbon emission was not changed either. From the table, it can be seen that in 2005 – 2010, Nanchang County has the highest total carbon emission and unit area carbon emission, and the next is Jinxian County. Donghu District, Xihu District and Qingyunpu District are lower. As to the unit area carbon emission, Donghu District and Xihu District rank the first.

Table 2 Carbon emission effect of land use types in counties and districts of Nanchang City in 2005 (Tg)

Land use types	Nanchang County	Xinjian County	Jinxian County	Anyi County	Wanli District	Qingshanhu District	Qingyunpu District	Donghu District and Xihu District
Cropland	–0.04041	–0.03925	–0.0346	–0.01277	–0.00168	–0.00256	–0.0004	– –
Garden land	–7.3E–05	–5.5E–05	–0.00013	–2.7E–05	–1.6E–05	–2.9E–05	–1.9E–06	– –
Forest land	0.001997	0.020547	0.023022	0.012807	0.008798	0.00129	3.13E–05	– –
Grassland	–1.4E–06	–0.00012	–3.1E–05	–2.1E–06	–1.4E–05	–1.9E–05	– –	– –
Construction land	–1.61214	–1.01725	–0.89426	–0.30844	–0.11339	–0.54277	–0.11335	–0.20128
Water land	0.01895	0.00062	0.01042	0.00868	5.99E–06	0.00084	0.00049	0.00026
Other unused land	6.9E–05	1.76E–05	3.04E–05	4.96E–06	1.81E–06	2.59E–06	4.31E–06	1.45E–06
Total	–1.63161	–1.03549	–0.89554	–0.29975	–0.10629	–0.54325	–0.11323	–0.20102
Unit area carbon emission	–8E–06	–7.2E–06	–5E–06	–3.3E–06	–4.6E–06	–2.5E–05	–2E–05	–4.1E–05

In 2005 – 2010, total carbon emission in all counties and districts of Nanchang City took on a growth trend. Nanchang County, Xinjian County and Qingshanhu District rank the top three, respectively increased 0.178 81 Tg, 0.183 43 Tg and 0.181 44 Tg. Qingshanhu District and Xihu District have the lowest increase of only 4.59E – 05 Tg. Donghu District and Xihu District are mainly construction land, water land and other unused land, the construction land area was basically the same as in 2005, so the total carbon emission has little change. For the unit area carbon emission, except Anyi County, other counties and districts had increase, with Xinjian County, Qingshanhu District and Qingyunpu District ranking the top three. Anyi County decreased by 7.954E – 07 Tg, Xinjian County increased by 5.62E – 06 Tg, Qingshanhu District increased by 6.56E – 06 Tg, and Qingyunpu District increased by 6.98E – 06 Tg. Wanli District had the lowest unit area carbon emission, as low as 5.88E – 07 Tg, as listed in Table 2 and Table 3.

Table 3 Carbon emission effect of land use types in counties and districts of Nanchang City in 2010 (Tg)

Land use types	Nanchang County	Xinjian County	Jinxian County	Anyi County	Wanli District	Qingshanhu District	Qingyunpu District	Donghu District and Xihu District
Cropland	–0.03921	–0.01275	–0.03464	–0.03925	–0.00158	–0.00196	– –	– –
Garden land	–7.06E–05	–6.71E–05	–0.000132	–2.97E–05	–1.81E–05	–2.07E–05	– –	– –
Forest land	0.00194	0.02056	0.02323	0.01294	0.00887	0.00101	– –	– –
Grassland	–1.39E–06	–0.000131	–3.05E–05	–2.15E–06	–1.44E–05	–9.06E–06	– –	– –
Construction land	–1.79207	–1.22713	–0.96530	–0.34138	–0.12851	–0.72454	–0.13548	–0.20128
Water land	0.01894	0.00059	0.01009	0.00853	5.991E–06	0.00083	0.00044	0.00021
Other unused land	6.215E–05	1.604E–05	2.72E–05	4.148E–06	1.628E–06	2.484E–06	4.51E–06	1.571E–06
Total	–1.81042	–1.21891	–0.96676	–0.35919	–0.12125	–0.72469	–0.13504	–0.20107
Unit area carbon emission	–8.95E–06	–1.28E–05	–5.37E–06	–2.49E–06	–5.16E–06	–3.11E–05	–2.68E–05	–4.23E–05
Increase of total carbon emission than 2005	–0.178 81	–0.183 43	–0.07121	–0.05944	–0.01496	–0.181 44	–0.02181	–4.59E–05
Increase of unit area carbon emission than 2005	–9.13E–07	–5.62E–06	–3.99E–07	7.954E–07	–5.88E–07	–6.56E–06	–6.98E–06	–1.34E–06

According to area of land use types obtained from *Overall Plan for Land Use in Nanchang City* (2006 – 2020), and combining carbon emission coefficient of the above land use types, we predicted carbon emission of major land use types in all counties and districts of Nanchang City, as listed in Table 4. Prediction results: all counties and districts of Nanchang City in 2020 will show carbon emission effect; Nanchang County has the highest total carbon emission (as high as 2.201 97 Tg) and it has the highest carbon emission effect; the next is Xinjian County; Wanli District is the lowest in total carbon emission (as low as 0.14874 Tg) and has the lowest carbon emission effect. Among all land use types of counties and districts in Nanchang City, construction land still makes the largest contribution to total carbon emission. Water land, other unused land and forest land take up a large portion of total area. Although as major carbon source, they still finally fail to offset carbon emission effect generated from construction land. Therefore, in the plan, it should properly reduce area of construction land, and increase area of forest land and water land. In the unit area carbon emission, Qingshanhu District has the highest carbon emission effect, with unit area carbon emission of 3.89E−05 Tg; the next is Donghu District and Xihu District, having 3.28E−05 Tg; Anyi County has the lowest unit area carbon emission, as low as 2.89E−06 Tg.

In 2020, the total carbon emission will increase in all counties and districts except Donghu District and Xihu District. Nanchang County has the highest increase (0.39156 Tg), the next is Xinjian County (0.31072 Tg), while Donghu District and Xihu District decrease by 0.000 18 Tg. In the process of planning, due to adjustment of land use types, except Donghu District and Xihu District, the construction land increases in other counties and districts. In addition to increase of water land and other unused land in Donghu District and Xihu District, it leads to decrease in total carbon emission in Donghu District and Xihu District. Besides, cropland in all counties and districts is decreasing, so the carbon emission of cropland is also decreasing. In Nanchang County, Jinxian County and Anyi County, the carbon absorption has increase, while the carbon absorption of forest land in other counties and districts is decreasing. As to the total carbon emission, the carbon emission of all counties and districts in 2020 has certain increase compared with 2010, and the unit area carbon emission is also increasing. The highest increase appears in Nanchang County, Xinjian County and Qingshanhu District, while in Donghu District, Xihu District, Qingyunpu District, Wanli District, Anyi County and Jinxian County, the increase is relatively lower, as listed in Table 3 and Table 4.

Table 4 Carbon emission effect of land use types in counties and districts of Nanchang City in 2020 (Tg)

Land use types	Nanchang County	Xinjian County	Jinxian County	Anyi County	Wanli District	Qingshanhu District	Qingyunpu District	Donghu District and Xihu District
Cropland	−0.03915	−0.01265	−0.03486	−0.03925	−0.00157	−0.00093	−−	−−
Garden land	−6.98E−05	−6.76E−05	−0.000136823	−3.01E−05	−1.64E−05	−1.74E−05	−−	−−
Forest land	0.00224	0.02022	0.02326	0.01298	0.00880	0.00089	−−	−−
Grassland	−1.39E−06	−0.000104624	−2.81E−05	−2.14E−06	−1.39E−05	−8.94E−06	−−	−−
Construction land	−2.18398	−1.53763	−1.02636	−0.39422	−0.15595	−1.01313	−0.16895	−0.20128
Water land	0.01894	0.00058	0.00994	0.00806	5.99E−06	0.00083	0.00081	0.00039
Other unused land	5.27E−05	1.15E−05	2.02E−05	2.02E−06	9.94E−07	2.39E−06	1.90E−06	4.94E−06
Total	−2.201 97	−1.52964	−1.02817	−0.41246	−0.14874	−1.01238	−0.16814	−0.20089
Unit area carbon emission	−1.06E−05	−1.55E−05	−5.72E−06	−2.89E−06	−6.29E−06	−3.89E−05	−2.56E−05	−3.28E−05
Increase of total carbon emission than 2010	−0.39156	−0.31072	−0.06142	−0.05327	−0.02749	−0.28769	−0.03310	0.000 18
Increase of unit area carbon emission than 2010	−1.64E−06	−2.67E−06	−3.49E−07	−3.94E−07	−1.13E−06	−7.71E−06	1.17E−06	9.45E−06

4 Low carbon optimization countermeasures

In 2005−2010, Nanchang City was in rapid development period of industrialization and urbanization. Land use change plays significant role in increase of atmospheric CO_2. In this study, we make simple analysis only from the perspective of land use, and do not touch upon other aspects of social economic operation. In general, decrease in forest land and cropland and increase in construction land will definitely bring about increase in carbon emission. Therefore, building low carbon oriented land use system can be started from following aspects.

4.1 Moderately conceding cropland to forest land and water land In land use types, forest land and water land are shown as carbon sink, while cropland is shown as carbon source. According to requirement of ecological construction, on the precondition of ensuring certain quality and quantity of cropland, it is feasible to moderately concede cropland from occupying lakes, rivers and forests to water and forest, to make original carbon source land convert into carbon sink[9]. In the plan period, forest land and water land of Nanchang City constantly decrease and cropland reduction is mainly resulted from occupation of construction land. In consequence, land use types start to convert to carbon source land, which leads to increase of carbon emission year by year. In line with difference of unit area carbon emission in counties and districts of Nanchang City, Nanchang County and Qingshanhu District are faced with arduous task of carbon emission reduction in the whole plan period. With grain security and cropland protection guaranteed, Nanchang City should formulate regulations on area of land use types for each county and district, to further achieve effect of low carbon land use.

4.2 Limiting excessive expansion of construction land As the major carbon source, construction land is the highest in both total carbon emission and intensity. The annual average carbon emission of Nanchang City reaches 0.125 3 Tg, which is dozens or hundreds of times other land use types. Thus, construction land is the major point of controlling and reducing carbon emission. Controlling scale of construction land and intensive use of construction land are favorable for realizing low carbon economic development. At present, Nanchang City remains at the rapid development stage of urbanization. The expansion speed of its construction land is high. For example, in Nanchang County, Xinjian County and Qingshanhu District, the annual average growth of construction land is higher than 550 hm^2 in the plan period. Healthy development of economy needs proper allocation and distribution of various land use types. Therefore, Nanchang City should further strengthen land management, optimize construction land of all counties and districts, and control the area of construction land occupying agricultural land and other land on the condition of guaranteeing economic development and social construction of all counties and districts, to facilitate to adjust carbon emission of future land use.

4.3 Optimizing distribution of urban land use Through optimizing distribution of urban land use, it is able to strengthen joint construction and share of major infrastructure, and avoid carbon emission resulted from excessive expansion of construction land for low level repetitive construction. According to calculation of carbon emission of counties and districts in Nanchang City, Nanchang County, Xinjian County and Jinxian County are major carbon emission counties. Thus, land administration authorities should take carbon emission as an important indicator for evaluation of land use plan, and reinforce carbon emission control in the planning period.

4.4 Flexibly adjusting land supply policy Different industrial sectors have different influence on carbon emission of land use, while the participation of land supply in carbon emission reduction is mainly in supply of construction land. On the one hand, it should limit total construction land projects with high carbon emission, and increase support for low carbon industrial projects[10]. On the other hand, it should take appropriate land supply policy in accordance with actual conditions, to effectively guide investment direction[11]. For new high technology, low energy consumption and high added value industries, it should guarantee their land supply, and at the same time simplify the approval procedure for low carbon industrial projects. For traditional high energy consumption and high emission steel, cement, and petrochemical industries, it should increase threshold of land supply. Through flexible adjustment of land supply policy, it is able to promote intensive use of various resources, and increase resource utilization efficiency, so as to realize carbon emission reduction.

4.5 Building carbon trading legal system Carbon trading or emissions trading is the transaction of carbon emission right. As a type of market mechanism, it adopts economic incentive to promote emission reduction of global greenhouse gases and reduce global CO_2 emission. Legal foundation of carbon trading is carbon emission right. At the market of carbon emission right, emission entities decide their greenhouse gas emission degree, to buy in or sell emission right of greenhouse gases[12]. Nanchang County, Xinjian County and Jinxian County are counties with high carbon emission, while Anyi County, Wanli District, Donghu District and Xihu District are low in carbon emission. Therefore, on the condition of ensuring no increase in carbon emission of other counties and districts, it is recommended to limit carbon emission right in Nanchang County, Xinjian County, and Jinxian County, to make contribution to carbon emission of Nanchang City.

References

[1] Houghton RA, Temporal patterns of land use change and carbon storage in China and tropical Asia[J]. Science in China(Life Science), 2002: 45.
[2] Houghton J.T. , Meira Filho L.G. Lim B. , TreantonK. Mamaty I. Bonduki Y. Griggs, *et al*. IPCC guidelines for greenhouse gas, 2000[Z] The Intergovernmental Panel on Climate Change, 2001. (in Chinese).
[3] Houghton J.T. , Meira Filho L.G. Lim B. , TreantonK. Mamaty I. Bonduki Y. Griggs D.J. *et al*. IPCC guidelines for greenhouse gas, 1996[Z] The Intergovernmental Panel on Climate Change, 1997. (in Chinese).
[4] LI Y, HUANG XJ, ZHEN F. Effect of land use patterns on carbon emission in Jiangsu Province[J]. Transactions of the Chinese Society of Agricultural Engineering, 2008, 24(2): 102 – 107. (in Chinese).
[5] Eggleston H.S. , Buendia L. , Miwa K. , *et al*. IPCC guidelines for greenhouse gas, 2006[Z] The Intergovernmental Panel on Climate Change, 2007. (in Chinese).
[6] FANG JY, GUO ZD, PIAO SL, CHEN AP. Estimation of plant carbon storage in China during 1981 – 2000[J]. Science in China Series D: Earth Sciences, 2007, 37(6): 804 – 812. (in Chinese).
[7] LI KR, WANG SQ. China vegetation and soil carbon storage[J]. Science in China Series D, 2003, 33(1): 73 – 80. (in Chinese).
[8] Lal R, Griffin M, Apt J, *et al*. Managing soil carbon[J]. Science, 2004, (304): 393.
[9] HUANG CT, LIU B, LUO JW. Control strategies of land use change for carbon emission reduction in Guangdong Province[J]. Corporation Research, 2011(18): 165. (in Chinese).
[10] ZHU YF, *et al*. How low carbon economy affect land management[J]. China Land, 2010(6): 43 – 44. (in Chinese).
[11] PENG H. Study on urban land use in China from a low-carbon economy perspective[D]. Journal of Hunan University, 2010. (in Chinese).
[12] ZHENG LL. Legal construction of carbon trading in low carbon economy [J]. Legal Forum, 2011(1): 59 – 64. (in Chinese).