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Effects of Tourism Land-use and Land-cover Change on Vegetation Carbon Stocks of National Water Park of Inner Mongolia, China*

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Abstract: Since the late 1978s, China has undergone one of the highest tourism growth rates in the world, which in turn has driven extensive land－use and land－cover change. The aim of this research is to assess land cover change dynamics and temporal and spatial variability in C stored in vegetation of a tourism destination. We have developed high resolution vegetation maps based on field observation and large scale topographic maps. Carbon vegetation densities were related to land cover, and C vegetation stocks for2004and 2010 were calculated by multiplying C density for each land cover type with land cover areas. This study demonstrates the importance of tourism industry for land cover change and C stock in vegetation. The land use and land cover change induced by the development of tourism industry have been significant. The change trajectory results illustrate the dynamic and heterogeneous nature of the park landscape. Grass land cover has dominated the park throughout the observed period, but majority of the land area has been continuously transforming between grass land and shrubbery areas and forest. Although there were about 52ha of land was used for tourist accommodation establishments, infrastructure development and leisure activities. Land cover changes have lead to a C sequestration of 442.47 Mg, mainly due to conservation measures to increase tourist value of the environment. The information generated in this research will contribute to better local C inventories and will assist in establishing the basis for future studies on C emissions, baselines and mitigation scenarios associated with the land－use change processes of tourism industry.

Key words: land use/cover change; vegetation carbon stocks; tourism industry; Inner Mongolia; China

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1 Introduction

Evidences of accelerating global climate change have increased the urgency withwhich the world considers the importance to reduce and mitigate greenhouse gas emissions[1]. Carbon dioxide is the most important anthropogenic greenhouse gas[2]. The use of fossil fuel is the primary source of the increased atmospheric concentration of carbon dioxide since the pre-industrial period, and the land use change is another significant but smaller contributor[3]. Accurately quantifying land use related changes in vegetation carbon stocks are important for assessing the anthropogenic fluxes of greenhouse gases to the atmosphere.

China has been experiencing explosive tourism growth rates and this trend is expected to continue in the

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future[4]. In 2008, the total number of tourist was 1.8 billion, of which 95% are domestic tourists and 5% were inbound visitors[5]. With the development of tourism industry there follows an inevitable increase in carbon dioxide emissions[6-8]. According to the World Tourism Organization (WTO), carbon dioxide emissions from tourism industry will become increasingly significant[9]. International attention is being given to quantifying such emissions. The existing literature of carbon emission of tourism sector has mainly focused on fossil energy requirements and resultant emissions. For example, Gössling (2002) stated that global energy requirement of tourism and recreation industry is about 14 000PJ[10]. Sanjay analyzed energy consumption patterns in tourist lodges in Nepal's Annapuran region[11]. More recently, Peeters & Dubois (2010) found that the tourism industry cause 4.4% of global CO_2 emissions and these emissions were projected to rise at an average rate of around 3.2% per year up to 2035[12]. For tourism-reliant country, the emissions intensity of greenhouse gas of tourism industry is more than four times the national average[13].

Land use change in tourism industry is not a newphenomenon; several experimental studies have demonstrated the direct and indirect impacts of tourism sector on land use and land cover[14-17]. Tourist accommodation establishments, infrastructure development and leisure activities are found to be principal agents in the land alteration process. Grenon & Batisse 1989 estimated areas of 25～100 m^2 required per bed in hotels and other accommodation businesses. On a global scale, there were nearly 35 million beds in accommodation establishments in the end of the 1990s and approximately 1 450 km^2 of land was used[18]. Gössling estimated that there was about 500 000 km^2 of land could be occupied globally for traffic infrastructure, such as airport, highways, parking sites, ports, etc. The area used by leisure activities, such as golf course, in the world is about 13 500 km^2[10]. Since carbon densities in different land cover show significant differences, land use and cover conversion from forest into other usage causes tremendous losses of carbon. It is then important to assess the effects of land cover changes on sequestrations and losses to the carbon stocks of a tourism destination. A standardized and accurate tourism related land cover database is critical to assess the carbon stocks of the tourism destination. However, calculations presented above are estimates of the most important land use types and information on land cover is not included. It is thus not possible to estimate the land use related vegetation C dynamics. Unfortunately, despite the increasing recognition of the importance of tourism land use and land cover change, there are few research on the land use related emissions reported.

We present a quantitative case study where the contribution that tourism related land use makes to China's greenhouse gas profile is calculated. The main purpose of this study is to assess the dynamics of land use and land cover change at local level of classification in Inner Mongolia between 2004 and 2010 and to estimate the temporal and spatial variability of vegetation carbon stocks during that period. For this purpose, the specific objectives of this work are to analysis (1) the changes in land use and land cover, (2) the change trajectories of land cover types, (3) the dynamics of vegetation carbon stocks, sinks and sources. The results generated from this study will contribute to better local carbon budget and will be used for future studies on land use related carbon emissions, baselines and mitigation scenarios of tourism industry.

2 Study Areas

Sanshenggong national water park is located on the main stream of the Yellow River. The geographical location of the park is confined between 39°56′1″N and 40°20′41″N latitude and 106°43′48″E and 107°3′13″E longitude. The park is characterized by a north temperate continental monsoon climate with average annual precipitation of 142.9 mm, average annual temperature of 7.6℃, mean annual sunshine time of 3 209.5 hours (Fig. 1).

The park was built based onSanshenggong key water control project of Yellow river which was built in 1959. The project is an exceptionally large-scale project aiming to provide irrigation to 570 000 ha of fields of Hetao plain, one of the most important agricultural regions in China. The project also pursues other comprehensive benefits like supplying water and generating electricity for the Cities along the Yellow River.

Situated on the climatic boundary between monsoon and non-monsoon climate, the park is a land of extreme contrasts in climate and geography. The 700 ha park has been listed in the National Water Park by the Ministry of Water Resources of the People's Republic of China in 2005.

With the development of tourism industry, the demand on land for accommodation, traffic, leisure activities has increased dramatically. The tourism related land use and land cover change has both negative and positive effects on the vegetation carbon stocks. Vegetation clearance accompanied by the construction of tourist and recreational facilities has caused great carbon loss from the tourism destination. At the same time, revegetation measure has been taken to increase aesthetic value of the environment, and this can offset the carbon loss from the construction of the tourism facilities.

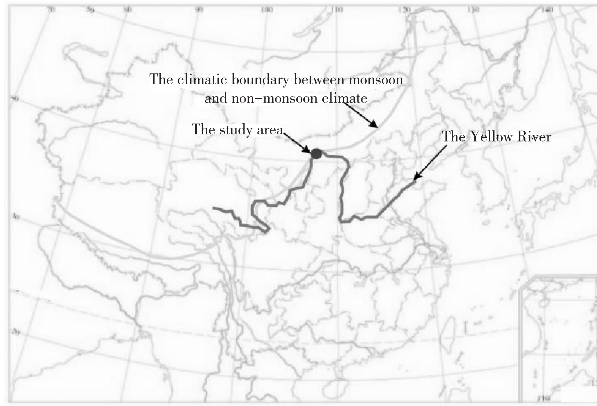

Fig. 1 Location of the study area

3 Materials and Methods

3.1 Materials

For the study, topographic maps of the Sanshengong National WaterPark (1:2 500) were collected from the Bureau of Yellow River Management of Inner Mongolia in 2005. Scanned topographic maps (in TIFF format) of the park were digitized. The geographic information such as vegetation lines, country boundaries and topological information such as contour lines (elevation) were digitized in specified layers of the topography maps.

To reconstruct the land use/land cover patterns of the park before and after the development of tourism industry, a field observation team was formed to collect data on the land use/land cover of the park in 2005 and 2010 respectively. To assure the quality of the data, several training courses were held for personnel of the observations. These courses covered methods for field observation, procedure of land use/land cover mapping, analysis of vegetation data, software training and fieldwork safety.

In 2005, the first field observation was carried out to identify the land use and land cover of the park before the development of tourism industry. According to the Current Land Use Classification of the Ministry of Land and Resources of People's Republic of China, an initial classification included eight land uses. Based on the field survey maps prepared using the topographic maps, the current land use/cover in the park was recorded and delineated in detail. By interviewing the local governors and local people, the properties of the current lands before the development of tourism industry were identified. Another observation conducted in 2010 served as getting the information of the land use and land cover of the park after the development of tourism industry. Additionally, several Sanshengong National Water Park government publications on vegetation cover and land uses were used. The vegetation carbon densities for each land cover type were estimated in Mg/ha using values based on the scientific literature on the study region.

3.2 Methods

3.2.1 Analysis of patterns, change trajectories and transitions. Before operating the change detection, the land use/cover maps of the two dates were produced separately. Through comparing the past condition with the recent one, the environmental change characteristics during this period can be revealed. A post-classification change analysis was conducted to identify spatial and temporal distribution patterns changes in the landscape of the park. Transition matrices were built based on GIS to analyze losses; gains and persistence of land use/cover categories of the study area, and identify net changes and total changes in the landscape. Total change for a land cover class is the sum of loss and gain, and net changes are differences in the quantities of each category between two adjacent time layers. Land cover change trajectories were produced for each lattice point using land cover maps developed from field observation, which illustrated individual land cover change trend of the point through 2004 to 2010.

3.1.2 Carbon Stock assessment Vegetation. Carbon stocks were calculated separately for each of 3 land cover types in the National Water Park. In line with other carbon assessment studies, the following land use/land cover categories were not considered for carbon accounting: construction land, water body, road, beaches, dry land, and bare land[18]. The biomass carbon stock change of the Sanshenggong National Water Park can be calculated, according to formula (1):

$$\delta C = C_B - C_A \quad (1)$$

δC represents the change of the biomass carbon stock of the park; C_B is the biomass carbon stock of the park before the development of tourism; C_A is the biomass stock of the park after the development of the tourism.

The biomass carbon stock of the park before the development of the tourism can be calculated by multiplying the carbon density of the vegetation with the area of the vegetation.

$$C_B = \sum_{i}^{3} D_i \times S_{Bi} \quad (2)$$

Where D_i is the average carbon density of i type of vegetation; S_{Bi} is the area of i type of vegetation of the park before the development of tourism.

The biomass carbon stock of the park after the development of the tourism can be computed as in Eq. (3):

$$C_A = \sum_{i}^{3} D_i \times S_{Ai} \quad (3)$$

S_{Ai} is the area of i type of vegetation of the park after the development of tourism. The average carbon densities of the vegetations were based on Fang, Yang, Ma, Maimaiti & Shen, 2010[19]; Hu, Wang, Liu & Fu, 2006[20]; Huang, Zhang, Yang & Tang, 2008[21]. These values take into account both belowground and aboveground biomass of the vegetation, but do not include the soil organic carbon (Tab. 1).

Tab. 1 The average carbon densities of the vegetations

Vegetation	Forest	Shrubbery	High cover grassland	Moderate cover grassland	Low cover grassland
Average carbon density(Mg/ha)	41.66	6.24	3.48	3.00	2.16

4 Results

4.1 Land use change of Sanshenggong National Water Park between 2004 and 2010

The main land use and land cover types in theSanshenggong National Water Park included "grass land, bare land, dry land, shrubbery, water body, construction land, transportation and forest". Land cover dynamics induced by tourism industry in the park between 2004 and 2010 have been significant. Grass land cover has dominated the park throughout the study period, with 67.26% and 50.61% respectively for 2004 and 2010, but its proportion has declined nearly 17% in the course of the development of tourism industry. Besides, the proportion of the forest, transportation, construction land, shrubbery, bare land tend to increase while the water body, dry land and grass land tend to decrease. In 2004 (before the development of tourism industry), water body makes up the next largest land cover while the transportation is the smallest (Fig. 2, and Fig. 3-4 on the inside back cover of the issue).

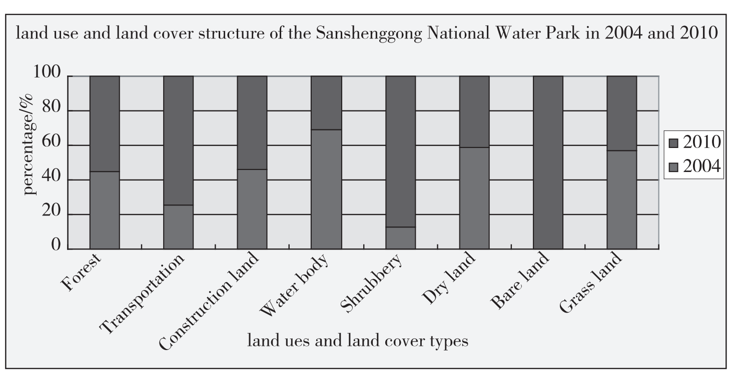

Fig. 2 land use and land cover structure of the Sanshenggong National Water Park in 2004 and 2010

Several distinct change trajectories were detected based on the land use/cover change database of the tourism destination. Major changes include transformation from grass land to shrubbery areas (55.96 ha, 11.7% of grass land areas in 2004), grass land to forest (45.04 ha, 9.42% of grass land areas in 2004), and grass land to dry land (37.63 ha, 7.87% of grass land areas in 2004). Other significant transitions are those from forest areas to dry land areas (5.66 ha, 52.17% of forest areas in 2004), grass land areas to road (2.16 ha, 4.12% of grass land areas in 2004), water body to shrubbery areas (1.62 ha, 22.08% of water body areas in 2004), and forest areas to grass land areas (1.57 ha, 32.08% of the forest areas in 2004).

The areacovered by “forests” increased by 22.25% occupying more than 59.99 ha (8.44% of the study area in 2010). A forest area of 42.35 ha was transformed mainly to “dry land” and “grass land”. Nevertheless, “forests” regained 53.22 ha from “grass land” and “water body”, which resulted in a total increase of 10.87 ha from 2004 to 2010. Meanwhile, the area of “shrubbery” increased from 10.81 ha in 2004 to 75.15 ha in 2010, mainly due to transition from “grass land” (55.96 ha) and “water body” (16.20 ha). On the contrary, A grass land area of 220.66 ha was converted mainly to “shrubbery”, “forest”, “bare land” and “dry land”, which resulted in a net loss of 16.65 ha (23.4% of the study area) (Tab. 2).

Tab. 2 Change transition matrices of the Sanshenggong National Water Park from 2004 to 2010

	2010/ha								Tot/ha	
2004(ha)	Forest	Road	Construction land	Water body	Shrubbery	Bare land	Dry land	Grass land	2004	Loss(ha)
Forest	6.62	0.01	0.00	0.00	1.07	0.01	25.55	15.71	48.97	42.35
Road	0.48	5.53	0.39	0.02	1.00	3.01	0.61	0.33	11.36	5.84
Construction land	0.13	0.45	8.04	1.29	0.49	2.21	3.04	0.27	15.92	7.88
Water body	5.66	4.86	0.16	20.60	16.20	4.59	0.23	21.06	73.38	52.77
Shrubbery	1.80	0.07	0.38	0.00	0.18	0.40	6.99	1.01	10.81	10.64
Dry land	0.12	0.72	0.27	0.07	0.26	0.29	6.30	63.92	71.95	65.64
Grass land	45.04	21.64	9.35	10.91	55.96	40.15	37.63	257.58	478.24	220.66
Tot. 2010	59.84	33.27	18.59	32.90	75.15	50.66	80.35	359.87		
Gain	53.22	61.02	10.54	12.29	74.98	50.66	74.05	102.30		

4.2 The biomass carbon dynamics in SNWP between 2004 and 2010

The difference between vegetationcarbon stocks of the park in 2004 and 2010 is shown in table 3. Positive values of the vegetation carbon stocks indicate sinks while negative values mean sources of vegetation carbon. Between 2004 and 2010, with the development of the tourism industry, the total vegetation C stocks in Sanshenggong National Water Park have increased from 3 771.83 Mg to 4 214.30 Mg. Land use and cover change of the park have originated a vegetation carbon sequestration of 442.47 Mg.

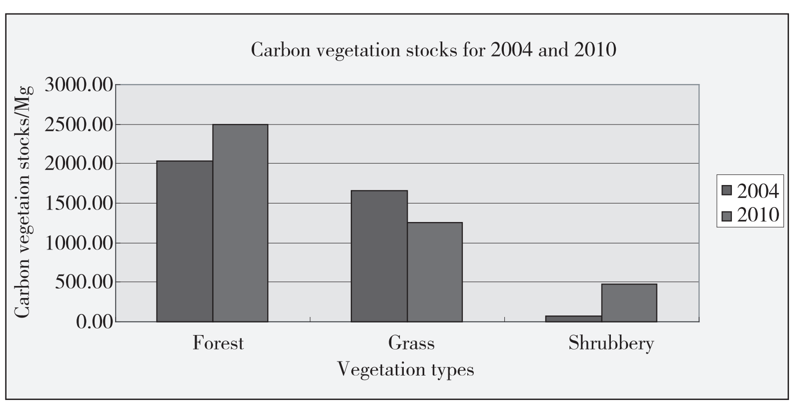

Fig. 5 Carbon vegetation stocks for 2004 and 2010

The increase in forest and shrubbery areas between 2004 and 2010 resulted in a total carbon stock of 2 961.94 Mg. The decrease in grass land areas between 2004 and 2010 resulted in a loss of 111.09 Mg vegetation carbon. The forest is the largest contributor among the land cover types, while the shrubbery is the smallest. In total, forests comprise 54.09% of the total vegetation carbon stock in 6.90% of the tourism destination in 2004 and 59.16% of total vegetation carbon stock in 8.44% of the park in 2010. In addition, the percentage of the total carbon storage in the forest and shrubbery tends to increase while the grass land tends to decrease (Fig. 5).

The greatest loss invegetation carbon results from the transition of forest to dry land. From 2004 to 2010, there are 25.55 ha of forest in the park have converted to dry land, which translated in a total carbon loss of vegetation of 1 064.31 Mg. In contrast, the greatest gain in vegetation carbon results from the transition of grass land to forest. The park has 478.24 ha of grassland in 2004, of which 45.04 ha have replaced forest in 2010. The conversion increases the amount of vegetation carbon contributing with 1 719.50 Mg.

It is worth noticing that more than 7.36% of the total areas of the park correspond to "infrastructure development and accommodation establishments", resulted in a total loss of 111.09 Mg vegetation carbon. "landscape construction" involved 36.33% of the total areas of the park and contributed to a sink of 1 935.12 Mg C in vegetation (Tab. 3).

Tab. 3 Vegetation carbon stocks dynamics of the Sanshenggong National Water Park for 2004 and 2010

	2010/Mg								
2004/Mg	forest	Road	Construction	Water	Shrubbery	Bare land	Dry land	Grassland	Loss/Mg
Forest	—	−0.49	0.00	0.00	−37.84	−0.49	−1 064.31	−599.76	−1 702.89
Road	20.05	—	0.00	0.00	6.23	0.00	0.00	1.14	27.42
Construction land	5.38	0.00	—	0.00	3.08	0.00	0.00	0.94	9.40
Water body	235.75	0.00	0.00	—	101.10	0.00	0.00	73.30	410.15
Shrubbery	63.63	−0.44	−2.34	0.00	—	−2.49	−43.59	−2.79	11.97
Dry land	4.89	0.00	0.00	0.00	1.61	0.00	—	222.43	228.93
Grass land	1 719.50	−75.30	−32.52	−37.96	154.44	−139.73	−130.95	—	1 457.48
	2 049.20	−76.23	−34.87	−37.96	228.61	−142.71	−1 238.84	−304.74	

5 Discussion

5.1 Concerns about the used methodologies

For this study, changes in vegetation carbon pools were measured using stock-difference method, which has been recommended by Houghton, Ding, Griggs, Noguer, Linden & Dai, (2001) and IPCC (2007) for greater accuracy[22-23]. We do not intend to yield accurate absolute values but to identify the change trend of the carbon pools of tourism destination under the background of rapid expansion of tourism and recreation industry.

In agreement with, Newton & Hill, (2010) and Muñoz-Rojas, Rosa, Zavala, Jordán & Anaya-Romero, (2011)[24-25], we have assumed that the land cover alteration is the only cause of the changes in vegetation carbon stocks of the tourism destination. Consequently, vegetation carbon pools from areas where land cover categories have not changed between 2004 and 2010 are assumed to have no carbon loss and sequestration over time. It must be pointed out that, the age of plants, diseases or logging can result in appreciable biomass carbon changes in these stable areas[26-27]. Further work is required to estimate the possible changes in vegetation carbon stock in areas where land cover remains stable in a period of time for greater accuracy.

5.2 Concerns about the quality and use of land use and land cover maps

The quality and reliability of land cover mapping has considerable influence over the accuracy of assessment of vegetation carbon stocks of the tourism destination. Some landscape of tourism destination is small scale and can hardly been identified from the remote sensing data. We have been developing the land cover mapping with large scale topographic maps (1 : 2 500) and field observation. Data from field observation are of greater spatial resolution than the remotely sensed data but, this technique is expensive and difficult to apply at large scale.

6 Conclusion

This study demonstrates the importance of tourism industry for land cover change and vegetation carbon stocks. The land use and land cover change induced by the development of tourism industry have been significant. With transition matrices, several change trajectories are identified to illustrate the landscape dynamics.

Grass land cover has dominated the park throughout the observed period, but majority of the land area of the tourism destination has been converting between grass land and shrubbery areas and forest.

Although there were about 52 ha of land was used for tourist accommodation establishments, infrastructure development and leisure activities. Land cover changes have resulted in a carbon sink of 442.47 Mg, mainly due to "landscape construction" measures to increase aesthetic value of the environment. The increases in vegetation C stocks of the park are politically interesting, because vegetation in tourism destination can make a significant contribution to carbon storage and, could lock away even more carbon if local authorities planted and maintained more trees. However, it should be noted that vegetations are not permanent carbon sinks because they will release their carbon to the atmosphere when they die.

The results generated from this study will contribute to better local carbon budget and will be used for future studies on land use related carbon emissions, baselines and mitigation scenarios of tourism industry. The proposed methodology can be applied to other tourism destination easily, and our research presents first assessment of land use related vegetation carbon stocks of tourism destination.

There are some limitations to this research. First, this paper mainly discusses the vegetation carbon stocks, but do not include soil organic carbon which contains about three times the amount in vegetation[23]. Further work is conducted to estimate the effect of land cover change on soil organic carbon stocks. Second, the carbon density of the vegetation adopted is based on the literature. However, the carbon density of the vegetation shows significant regional difference, which causes uncertainty of the result. We will perform more work to improve the accuracy of vegetation densities to the park[28]. It also has been pointed out that a long-term of monitoring on the historical land cover changes is necessary to improve the accuracy of the carbon-flux estimate in the future research[29].

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旅游驱动的土地利用与覆被变化对景区植被碳库的影响
——以中国内蒙三盛公水利风景区为例

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摘要: 土地利用与覆被变化是仅次于化石能源消耗的第二大碳排放源。1979年以来,中国旅游业保持高速增长,旅游发展所需的交通、住宿、娱乐等基础设施建设将导致显著的土地利用与覆被变化。为测算旅游业发展驱动的土地利用与覆被变化对旅游景区植被碳库的影响,研究通过多次田野调查重建了景区尺度的土地利用格局,利用土地转移矩阵明确了景区土地利用动态演变路径,结合研究区植被碳密度计算了2004—2010年景区植被碳库的变化。研究结果表明旅游业的发展导致景区土地利用格局显著变化。在研究期内草地是景区主要植被,但随着旅游的发展,草地与灌丛、林地等用地之间不断相互转换。尽管有约52 ha土地用于旅游住宿、基础设施及休闲活动设施,但景区内植被碳库不但没有减少,反而增加了442.4 Mg,这主要是因为景区为提高旅游环境质量采取了植被保护措施。这表明旅游业可以通过良好的景观营造等土地管理措施,增加景区碳汇,用以"中和"旅游业能源消耗引起的碳排放。

关键词: 土地利用/覆被变化; 植被碳库; 旅游业; 内蒙古; 中国

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