Tourism-induced deforestation outside Changbai Mountain Biosphere Reserve, northeast China

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Tourism-induced deforestation outside Changbai Mountain Biosphere Reserve, northeast China

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Abstract

• ***Introduction*** Old-growth forests on Changbai Mountain are economically and ecologically important but have been fragmented outside Changbai Mountain Biosphere Reserve. The trend of forest landscape degradation on Changbai Mountain threatens forest sustainability and biodiversity conservation in the region. Previous studies have focused mainly on the structure and function of protected forests but have ignored managed forests outside the reserve border.

• ***Objectives*** In this paper, deforestation processes are studied for two forestry enterprises, namely Baihe and Lushuihe Forestry Bureaus, with different socioeconomic structure due to their differences in proximity to Changbai Mountain Biosphere Reserve, which attracts hundreds of thousands of tourists each year. Baihe's income comes from both forestry and tourism whereas Lushuihe's revenue is primarily from forest products. Land-use change was mapped using a time series of satellite images acquired in 1977, 1991, 1999 and 2007 for both forestry bureaus.

• ***Results*** It was found that Baihe experienced more severe deforestation, and more gains in cultivated and developed land than Lushuihe. The booming tourism in Baihe did not help lessen pressures on forest resources but led to increased fragmentation of forest landscapes on Changbai Mountain. While the tourism industry needs to be better regulated, it is important to create large-area, multi-use forest buffers and corridors around Changbai Mountain Biosphere Reserve.

Keywords Land use change · Deforestation · Urbanization · Spatial variation · Temporal change

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1 Introduction

Land-use change has become a focal study in the field of global change in recent decades (Lambin et al. 1999, 2003; Turner et al. 1994) as it directly or indirectly affects water cycling, soil conservation, air quality, ecosystem structure and function, biodiversity and climate (Mattison and Norris 2005). The goals of many land-use studies have been to understand the temporal dynamics and spatial variations in land use, as well as the key factors and actions that drive land-use change, and to analyze effective ways of adjusting the relationships between human activities and land resources (Deng et al. 2008; Peng and Gao 2004; Zhao et al. 2010).

Forest landscapes on Changbai Mountain, including forests inside and outside Changbai Mountain Biosphere Reserve, provide important timber resources in China, protect the source water of three major river systems in the eastern Eurasian continent, and have one of the richest biological diversities of the cold temperate zone (Wu et al. 2002). However, Changbai's forests have been degraded extensively by logging and other human activities (Tang et al. 2010), the effects of which are reflected by altered forest structure and species composition (Shao et al. 2005). Much attention has been focused on forest cover types and their dynamics within Changbai Mountain Biosphere Reserve (Shao 1996; Shao et al. 1996) but land-use change outside the protected area has received less attention. Converting forestland into other land uses is common in forested areas and has worse consequences than forest degradation (Filer et al. 2009). In this paper, we quantify land-use change among forestland, cultivated land and developed land within the Baihe and Lushuihe Forestry Bureaus adjacent to Changbai Mountain Biosphere Reserve on Changbai Mountain. We compare land-use change between the two forestry bureaus in order to discuss the probable cause of land-use change.

Baihe and Lushuihe Forestry Bureaus are state-owned forestry enterprises. In the forestry bureaus, all lands are owned by the state, but people are allowed to occupy tracts. The state employs forest management strategies such as forest tending and harvesting. Lushuihe's economic revenue comes exclusively from forest products, while Baihe's income is derived from both forestry and tourism due to its proximity to Changbai Mountain Biosphere Reserve, which is a favorite destination of Chinese and Korean visitors (Stone 2006). The number of visitors to Changbai Mountain has increased from 30,000 people per year in the early 1980s to nearly 1 million per year in 2007. The rapid urbanization and rapid population growth due to the development of the tourism industry is an indisputable fact in this area. The effects of this booming tourism industry on forest conservation on Changbai Mountain are unclear (Tang et al. 2010). The purpose of our study was to determine if there are differences in land-use change between the two forestry bureaus that may result from different socioeconomic characteristics and different degrees of related development. Our findings will improve understanding of the factors driving land-use change, which is critical to improving the sustainability of regional land use and the protection of forest resources on Changbai Mountain.

2 Materials and methods

2.1 Study sites

With a total area of 1,213 km^2, Lushuihe Forestry Bureau was founded in 1958; Baihe Forestry Bureau is 1,899 km^2 and was established in 1971. Both forestry bureaus are part of China's state-owned forestry enterprises and the motivation for their establishment was to harvest timber from forests on Changbai Mountain, which was previously undisturbed (Tang et al. 2009). Bureau employees and their families were brought in from outside regions; their population was rather low in the beginning but increased rapidly. By design, the forestry bureaus' revenue was from timber sales, and excessive logging used up the majority of timber sources for the forestry bureaus by the 1980–1990s. A common practice then adopted by the timber-lacking forestry bureaus was to pursue forest by-products, and growing ginseng has been popular on Changbai Mountain since the 1980s. The two forestry bureaus are located north of Changbai Mountain Biosphere Reserve (Fig. 1). The northern route to the mountain top, a favorite destination of tourists, is next to the Baihe Forestry Bureau. This makes Baihe more convenient than Lushuihe for providing services to tourists. Both forestry enterprises contain conifer-broadleaf mixed forest as the dominant forest type.

2.2 Image data and classification

Landsat images acquired in 1977 (MSS), 1991 (TM), 1999 (ETM+) and 2007 (TM) were used to develop time series datasets of land use for Baihe and Lushuihe Forestry Bureaus between 1977 and 2007. Data processing included three steps: (1) registration and geometric correction of the original imagery into UTM WGS84; (2) classifying the rectified images with unsupervised classification methods and recoding spectral classes into cultivated land, forestland, developed land and water with ERDAS IMAGINE using the general national land-use classification system (Liu 1997); and (3) post-classification processing and accuracy assessment with ERDAS IMAGINE. In addition to the original Landsat data bands, the Normalized Difference Vegetation Index (NDVI) was included in image data classification. NDVI was computed as follows:

$$\mathrm{NDVI} = (\mathrm{NIR} - \mathrm{RED}) / (\mathrm{NIR} + \mathrm{RED}) \quad (1)$$

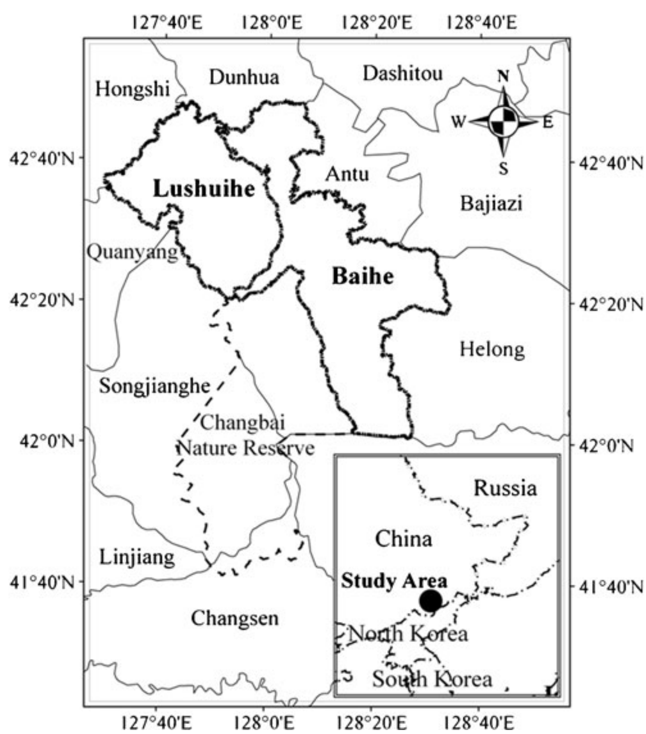

Fig. 1 Location of the study area

where NIR and RED represent red and near infrared bands, respectively (Jensen 2004).

The accuracy of land-use data in 2007 was assessed by comparing it directly with in situ ground data. The land-use data in 1977, 1991 and 1999 were assessed with forest inventory data and/or aerial photographs depending on availability. We established a minimum accuracy of 90% for the purpose of landscape quantifications (Shao and Wu 2008). Image data classification processes were enhanced by increasing the number of spectral classes until omission and commission errors were balanced (Shao et al. 2003) and the highest overall accuracy was obtained (Lang et al. 2008).

2.3 Land-use data analysis

The rate of land-use change was computed as follows:

$$K = (S_b - S_a) \ / \ S_a \ / \ (T_2 - T_1) \ \times \ 100 \tag{2}$$

where K is the land-use dynamic rate (%) within the given time period; S_a and S_b are the areas of a given land use type in the beginning (T_1) and end (T_2) of a study period.

A land-use intensity comprehensive index is expressed as follows (Quan et al. 2006).

$$I = 100 \times \sum_{i=1}^{n} (G_i \times C_i) \tag{3}$$

where I is the land-use intensity comprehensive index, the higher the value of I, the more land use suffers from human activities; G_i is a land use intensity grade value of the ith land use type—the higher the value, the higher the degree of human disturbances. Land-use types can be divided into several grades according to their change intensity to natural "equilibrium status" (Quan et al. 2006). In this study, forestland was assigned grade 1; cultivated land was assigned grade 2; and developed land was assigned grade 3; C_i is area percentage of the ith land-use type; and n is the number of land-use types.

Spatial overlay analysis was performed to create transition matrixes and to derive more detailed information about land-use change.

3 Results and analyses

3.1 Land-use change for both forestry bureaus

The water cover type consisted only of rivers and small ponds, and was relatively stable over time. Therefore, to simplify land-use-change analysis, water was excluded from change analysis in this study.

For both the Baihe and Lushuihe Forestry Bureaus, forestland was the dominant land-use type throughout the study period, but the cover of forestland decreased steadily from 307,089 ha in 1977 to 293,081 ha in 2007 (Table 1). The other two land-use types accounted for only a small fraction of the total land area but the area of cultivated land increased ten-fold (from 1,229 to 12,293 ha) and developed land doubled (from 2,230 to 4,874 ha) between 1977 and 2007. As a result, the ratio of cultivated land to developed land increased from 0.6 to 2.5 (Table 1). Cultivated land expanded faster than developed land in both forestry bureau areas.

From 1977 to 1991, forestland decreased by 4,492 ha whereas other land-use types increased in area (Table 2). Cultivated land gained 3,922 ha, much more than developed land, as 87% of the lost forestland was converted into cultivated land but only 7% was converted

Table 1 Proportions of different land-use types (water area was constant: 658 ha for Lushuihe; 320 ha for Baihe each year) and population density (persons/km^2) between 1977 and 2007

	Forestry bureau	Forestland (ha)	Cultivated land (ha)	Developed land (ha)	Population density
1977	Baihe	187,489	892	1,219	7
	Lushuihe	119,300	337	1,012	13
	Total	306,789	1,229	2,230	9
1991	Baihe	183,886	4,215	1,499	18
	Lushuihe	118,411	936	1,301	37
	Total	302,297	5,151	2,800	25
1999	Baihe	181,330	6,514	1,755	22
	Lushuihe	117,966	1,281	1,401	39
	Total	299,296	7,795	3,157	29
2007	Baihe	177,025	9,312	3,263	37
	Lushuihe	116,055	2,982	1,611	35
	Total	293,081	12,293	4,874	36

Table 2 Dynamic rates of different land-use types

	Forestry Bureau	Forested Land		Cultivated Land		Developed Land	
		Area change (ha)	Dynamic rate (%)	Area change (ha)	Dynamic rate (%)	Area change (ha)	Dynamic rate (%)
1977–1991	Baihe	-3,603	-0.14	3,323	26.61	280	1.64
	Lushuihe	-889	-0.05	599	12.7	290	2.05
	Total	-4,492	-0.1	3,922	22.79	570	1.83
1991–1999	Baihe	-2,556	-0.17	2,299	6.82	256	2.14
	Lushuihe	-445	-0.05	345	4.61	100	0.96
	Total	-3,001	-0.12	2,644	6.42	356	1.59
1999-2007	Baihe	-4,305	-0.3	2,797	5.37	1,508	10.74
	Lushuihe	-1,911	-0.2	1,701	16.6	210	1.87
	Total	-6,216	-0.26	4,498	7.21	1,717	6.8

into developed land (Table 3). Cultivated land had the highest dynamic rate (Table 2). The *I* value increased from 101.46 to 103.10 (Table 4), indicating that the developed land area was increasing and human land use was becoming more intense.

From 1991 to 1999, forestland lost 3,001 ha and its dynamic rate was −0.12%, a rate similar to that of the previous period. Cultivated land still had the highest dynamic rate and gained 2,744 ha from forestland. The *I* value increased from 103.1to 104.23 (Table 4), suggesting that land-use change was still affected greatly by human factors during this period. However, the roles played by the increase in cultivated land and developed land were smaller than those in the earlier period (Table 2).

From 1999 to 2007, forestland lost 6,216 ha, i.e., twice as much as in the previous period. The rate of deforestation was the greatest among the three periods, and developed land increased more than any previous period (Table 2). The *I* value reached 106.81 from 104.23 (Table 4), i.e., higher than that in any earlier period, implying that the study area was affected more highly by human factors during this period.

Table 3 Matrix of land use/land cover (LULC) type changes

		LULC types	LULC types 1	
			Cultivated land	Developed land
77-91	Baihe	Cultivated land		106
		Forested land	3,429	174
	Lushuihe	Cultivated land		0
		Forested land	899	290
	Total	Cultivated land		106
		Forested land	4,328	464
91-99	Baihe	Cultivated land		70
		Forested land	2,370	186
	Lushuihe	Cultivated land		29
		Forested land	374	71
	Total	Cultivated land		99
		Forested land	2,744	257
99-07	Baihe	Cultivated land		910
		Forested land	3,707	598
	Lushuihe	Cultivated land		101
		Forested land	1,802	109
	Total	Cultivated land		1,011
		Forested land	5,509	706

Table 4 Land use intensity comprehensive index (*I*)

	1977	1991	1999	2007
Baihe	101.56	103.61	105.12	108.16
Lushuihe	101.15	102.35	102.80	104.61
Total	101.46	103.10	104.23	106.81

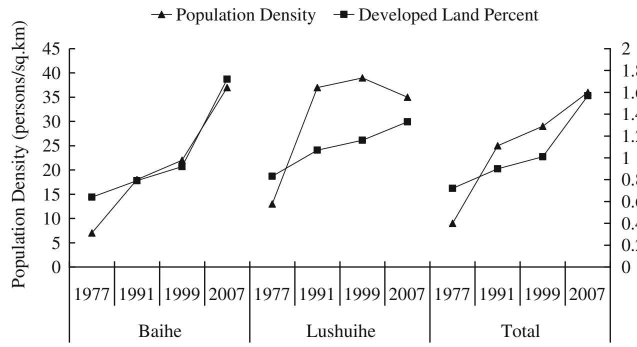

Fig. 2 Comparison between population density and developed land percent

3.2 Differences in land-use change between the two forestry bureaus

There were obvious differences in land-use change between Baihe and Lushuihe Forestry Bureaus (Tables 1, 2, 3 and 4).

From 1977 to 1991, Baihe Forestry Bureau lost more forestland than Lushuihe Forestry Bureau. Baihe's lost forestland was largely converted into developed land, and even part of its cultivated land was converted into developed land (Tables 1, 3). Baihe gained much more cultivated land than Lushuihe, and the gains in developed land were similar (Table 2). The increase in *I* value for Baihe was greater than that for Lushuihe, suggesting that land use in Baihe Forestry Bureau was more intense than that in Lushuihe Forestry Bureau (Table 4). From 1991 to 1999, Baihe Forestry Bureau continued to have had a higher deforestation rate and larger gains in cultivated land and developed land than Lushuihe Forestry Bureau, and also had a greater increase in *I* value (Table 4), indicating that the Baihe Forestry Bureau became more developed than the Lushuihe Forestry Bureau.

From 1999 to 2007, the contrast in land-use change between the two forestry bureaus became even more obvious than in the early period. The dynamic rate of developed land was 10.74% for Baihe but only 1.87% for Lushuihe (Table 2); the percentage of forestland or cultivated land converted into developed land in Baihe was higher than that in Lushuihe (Table 3); the dynamic rate of cultivated land (16.6%) for Lushuihe was greater than that (5.37%) for Baihe Forestry Bureau (Table 2). Both forestry bureaus experienced increase in *I* values were but Baihe's *I* value increased much more than Lushuihe's (Table 4).

Overall, Baihe's decline in forestland and increase in *I* values were more obvious than Lushuihe's. Baihe Forestry Bureau experienced larger increases in both cultivated land and developed land than Lushuihe (Tables 1, 2, 4). Forestland was converted into cultivated land and developed land, and even cultivated land was converted into developed land in Baihe Forestry Bureau, while forestland was converted mainly into cultivated land and cultivated land was rarely converted into developed land in Lushuihe Forestry Bureau.

4 Discussion

4.1 Effect of population growth on land-use change

Several comparative studies offer statistical evidence supporting the claim that population growth drives or strongly contributes to forest clearance (Allen and Barnes 1985). Not surprisingly, the human population density increased sharply in the study areas in parallel to the loss of forestland from 1977 to 2007 (Table 1). In the course of 30 years, Baihe's population increased by 5.3 times and Lushuihe's by 2.7 times.

The curves of population increase differed between the two forestry bureaus: Baihe's population increased steadily and showed a steeper increase in the latter period; Lushuihe's population increased sharply in the first period but later declined (Fig. 2). This difference in population growth patterns between the two forestry bureaus could be rooted in their different socioeconomic structures (Wittemyer et al. 2008): Baihe relies on both forestry and tourism whereas Lushuihe depends solely on forestry. Tourism on the Chinese side has increased from around 30,000 visitors a year in early 1980s to nearly a million a year in 2007/2008 (Fig. 3). The industrial

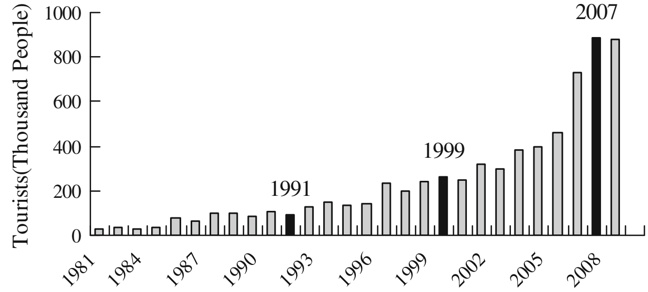

Fig. 3 Numbers of tourists in Changbai Mountain Biosphere Reserve from 1981 to 2008

structure was 30:29:41 in 2007 but 26:21:53 in 2008, indicating that tertiary industry (mainly tourism) is a major sector in Baihe. Tertiary industry has been a pillar industry in Baihe for nearly a decade. The development of the tourism industry on Changbai Mountain helped provide job opportunities in Baihe Forestry Bureau, and the steady population growth in Baihe Forestry Bureau coincided with a continuous increase in its developed land area (Fig. 2). Interestingly, both forestland and cultivated land were converted into developed land in Baihe Forestry Bureau, but forestland was converted mainly into cultivated land in Lushuihe Forestry Bureau. Managing cultivated land is rarely able to attract migrants due to the low economic benefits in Lushuihe, explaining why the human population density in the forestry bureau has been relatively stable since 1991. The cultivated land in state-owned forestry enterprises is used for growing economic crops such as ginseng and orchards. Conversion to cultivated land normally does not trigger as much habitat damage and biodiversity loss as conversion to developed land (Franklin and Lindenmayer 2009; Jim 2002).

4.2 Challenges for forest conservation on Changbai Mountain

Forest ecosystems on Changbai Mountain have been degraded continuously by excessive logging and other human activities due to pressures from human population growth and socioeconomic development during the past decades (Tang et al. 2010). Previously, it was thought that a well-planned tourism industry would help increase job opportunities for the local population so that they did not have to rely on harvesting forest resources in a sustainable fashion. The results of this research revealed a different theory: promoting the tourism industry on Changbai Mountain brings tourists who need services and consume local goods. Under this model, developed land is needed to provide visitors with hotels, restaurants and other services while cultivated land is managed to grow forest by-products such as ginseng, edible tree fungus, mushrooms, and Schisandra that visitors can take away; in both cases deforestation becomes inevitable outside protected areas. This finding suggests that the development of tourism has had negative effects on forest conservation on Changbai Mountain.

Preserving forest cover outside protected areas is critically important because the existing protected areas are not large enough to be self sustaining, and matrix landscapes around protected areas can provide habitat that is unavailable within adjacent protected areas (Franklin and Lindenmayer 2009; Zhao and Jia 2008). Deforestation around protected areas not only reduces and damages important habitat, but also creates barriers between protected areas and their surrounding landscapes even if the deforested area is relatively small (only 4.50% of the total area). Such isolating processes have been going on around Changbai Mountain for decades and have intensified since a new governmental tourism branch of Jilin Province was founded in 2005. This new authority has total control of human activities on Changbai Mountain and has opened up three tourism routes from three directions on Changbai Mountain. An airport was even constructed outside the biosphere reserve, the center line of the runway of which is 9.4 km from the reserve boundary. As a result, forest ecosystems within the biosphere reserve face further isolation.

The uncontrolled growth of the tourism industry on Changbai Mountain seems to be following Hardin's 1968 *Tragedy of the commons* theory (Hardin 1968). The tourism authority seeks to maximize economic gain with the same mindset as the herdsman decades ago: how to maximize private gain from a public-owned nature reserve? The increase in biosphere reserve visitations without limitation will eventually contribute to the ruin of the integrity of forest ecosystems on Changbai Mountain.

5 Conclusions

Forestland is the dominant land-use type in the study area but has decreased continuously in area from 1977 to 2007. A total of 14,008 ha of forestland has been lost in the past 30 years. In contrast, cultivated land and developed land have both increased steadily in the area.

The difference in geographic locations between Baihe and Lushuihe Forestry Bureaus contributes to their different socioeconomic structures, which in turn triggers different land-use-change processes. During the period of 1977–2007, Baihe Forestry Bureau experienced more extensive deforestation and more gains in cultivated land and developed land than Lushuihe. As a result, forest landscapes in Baihe Forestry Bureau became more fragmented through cultivation and urbanization than in Lushuihe.

The booming tourism industry that has contributed to the dramatic deforestation and the expansion of developed land and cultivated land around Changbai Mountain Biosphere Reserve now threatens the integrity of forest landscapes on Changbai Mountain. Forests adjacent to the biosphere reserve visited by tourists facing a greater threat than those at a greater distance from the biosphere reserve. It is important to control local tourism development to lessen pressure on the biosphere reserve. New management and conservation measures, such as the creation of large-area, multi-use forest buffers and corridors around the biosphere reserve (Wittemyer et al. 2008), should be considered to help offset potentially heavy human settlement and mitigate the negative effects of population increase and economic development on forest conservation on Changbai Mountain.

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