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The trend of land-use sustainability around the Changbai Mountain Biosphere Reserve in northeastern China: 1977–2007

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Extensive land-use and land-cover change, triggered by rapid development of tourism and the expansion of townships, has occurred in the area surrounding the Changbai Mountain Biosphere Reserve (CMBR) in northeast China, a reservoir for distinctive ecosystems and biological diversity. The objective of this study was to examine the land-use changes surrounding the reserve in the context of forest and nature reserve management with the aid of maps from Landsat MSS imagery of 1977 and Landsat TM imagery of 1991 and 2007. The total land area and its change over time for each land-use class were calculated and cell-by-cell change data were used to detect, quantify, and determine the trends in land-use conversions. Results showed that there were large increases in land area for residential, commercial, industrial, and transportation land-use types, whereas the forest area decreased considerably. At the same time, the area under jurisdiction of townships has nearly doubled, with the largest increase in Manjiang. Land-use change was caused by regional population growth as a result of tourism development that triggered the expansion of township boundaries and contributed to shifts in forest management policy. Our study offers land and reserve managers within the CMBR and similar areas a basis for making more informed land-use and management decisions to potentially minimize detrimental ecological impacts of land-use change.

Keywords: land-use change; township; driving forces; tourism; Changbai Mountain Biosphere Reserve

Introduction

Along with climate change and biological invasions, land-use and land-cover change has been recognized as a key element contributing to global environmental change (Foley et al. 2005; Ellis et al. 2010). The need to provide food, fiber, water, and other services to humans accelerates land-use changes. Such processes are drawing increased attention from researchers focusing on environmental and socio-economic well-being, assessing and monitoring the status of natural resources, detecting changes in spatial and temporal scales, and understanding their resulting effects on ecosystems and predicting the changes for the future (Manandhar et al. 2010; Shao et al. 2011).

Biosphere reserves are sites established by national governments and recognized under UNESCO. Their purpose is to promote and demonstrate a balanced relationship between people and their global environment. As of 2010, there were 28 biosphere reserves in China. The Changbai Mountain Biosphere Reserve (CMBR) in Jilin province was first accepted by the World Biosphere Reserve Network in 1979 (Cui et al. 2006). The CMBR became the first in China to encourage tourism development in 1982. With the burgeoning tourism industry, both developers and the provincial government have actively engaged in building roads, bridges, cable car systems, and the like for the convenience of visitors and to attract more tourists.

According to the Regulations of the Central People’s Republic of China for Nature Reserves (1994), biosphere reserves are divided into three functional zones: core, buffer, and experiment zones. Only experiment zones serve as limited areas reserved exclusively for environmental observation and experimentation. The tourism infrastructure (hotels, restaurants, shops, etc.) has developed outside the reserves, with prime locations in terms of distance and cost, being immediately adjacent to a reserve. Not surprisingly, buildings have occupied considerable areas of land at the edges of reserves and in townships surrounding them. In the process, changes in land cover and land use have been accelerated and have affected the regional environment (Burak et al. 2004; Yepes and Medina 2005; Cengiz 2007; Don et al. 2008; Li et al. 2009; Schwaiger and Bird 2010).

As a result, townships surrounding the protected areas have sprawled (Foley et al. 2005; Wittemyer et al. 2008; Zhao et al. 2008; Joppa et al. 2009). It is well recognized that urbanization has significant effects on ecosystem structure, function, and the provision of ecosystem services (Almeida et al. 2007; Xu et al. 2009; Chen et al. 2010; Karaburun et al. 2010; Pollock-Ellwand 2011). More significantly, it can lead to irreversible effects on both the nature of protected areas and patterns of land use (Zhao et al. 2010; Bell et al. 2011).

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Although some studies in and around the CMBR have been carried out regarding such topics as forest degradation and conservation (Tang et al. 2010, 2011), landscape change (Zheng et al. 1997) and tourism-induced deforestation outside the CMBR (Zhao et al. 2011), a quantitative analysis of land-use changes surrounding biosphere reserves in China has not been conducted yet. At the same time, land-use change trends have attracted increasing attention from both local communities and policy decision makers alike (Cui et al. 2011; Lin et al. 2011; Opschoor and Tang 2011). Unfortunately, there is no accurate and timely information regarding the nature and pattern of land-use changes that might contribute to effective policy responses.

In this study, the land-use changes that have occurred in the CMBR area over the last 30 years are investigated using GIS. The purpose of the study is to provide quantitative data that may be useful in assessing land-use changes in the context of increases in population, urbanization, and tourism, in the process providing constructive input for formulating land-use policies. In particular, our objectives are to initiate the process of quantifying spatial and temporal land-use change and variability of change within the different townships surrounding the CMBR over the past three decades, and to consider the influence of tourism demand in contributing to the above results. The findings of this study are intended to contribute to effective and appropriate decision-making with respect to biosphere reserve management and sustainable development in the region.

### Methods

#### Study area

The CMBR (41°41’49”–42°25’18”N, 127°42’55”–128°16’48”E) in Jilin Province of northeastern China is situated on the China–North Korea border and covers an area of 196,456 ha (Figure 1). Elevation ranges from 720 to 2691 m above sea level. The region has a temperate, continental climate, with long, cold winters and warm summers. Annual average precipitation ranges from 700 to 1400 mm, most of which occurs from June to September.

The study area consists of all land in China within 30 km of the CMBR, which amounts to 729,000 ha surrounding the Reserve (Figure 1). There are 10 townships in this peripheral area. Three are located south of the reserve in an area where the natural terrain prohibits direct access to the reserve, thereby requiring travel over some distance to an entrance on the reserve’s west side. Given this less accessible location of these townships, and the fact that tourism infrastructure in them has been much more limited than in other townships surrounding the reserve, they were not included in the study area. Thus, the area under the jurisdiction of seven townships served as the focus for this study. Three of these townships are located within Antu County and four in Fusong County.

The seven towns vary in area from 64 to almost 1700 ha, with populations ranging from 3600 to more

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Figure 1. Location of study area.

Note: CMBR, Changbai Mountain Biosphere Reserve (China); B-SBR, Baekdu–San Biosphere Reserve (North Korea).
than 62,000. The town of Erdaobaihe, with a population of approximately 49,000 in 2007, is immediately adjacent to the northern boundary of the CMBR, while the others are situated at an average of 20 km from the edge of the Reserve. Most of the peasants in the region depend on crop farming, raising livestock, and forest products for their livelihood. At the same time, tourism in the CMBR area has climbed steadily over the past three decades, increasing from 29,000 in 1980 (Yuan et al. 2008) to 1.87 million in 2009 (Statistical Communiqué of the Changbai Mountain Protection and Development Zone of Jilin Province 2011).

**Data**

Satellite data used in this study include one MSS image taken on 26 September 1977 and Landsat TM images taken on 31 May 1991 and 2 October 2007. The MSS and TM images were re-sampled to 25 m resolution (Hossain et al. 2009; Manandhar et al. 2010). All images were classified using supervised classification based on forest maps obtained from Jilin Province and the China Jilin Forest Industry Group Co, Ltd. and finalized after classification using ancillary data. As the historical ground-truth data was not available, we were not able to verify the accuracy of the MSS image of 1977. The overall classification accuracy of the final land-use map is 90.2% for 1991 and 93.4% for 2007.

The study looked at five major land-use classes: forestland, farmland, developed land, water, and open land. For unchanging water areas, a water mask was constructed prior to classification in order to reduce potential error (Salvati and Sabbi 2011). In this classification scheme, forestland is defined as land with a tree canopy cover greater than 10%, as well as cutover land, and ginseng land. Developed land includes residential, industrial, commercial, and transportation land, while open land refers to bare land, gravel, and grassland, the latter including land with a canopy density of less than 10%. The water class includes areas of open water and wetlands, the latter being minimally found in the study area.

**Change detection and measurement**

The raster layers from 1977, 1991, and 2007 were utilized to detect land-use changes surrounding the CMBR. Total area and area change for land-use class were calculated for each of the two periods. We used cell-by-cell change data to detect, quantify, and determine the direction of land-use conversions.

**Gross gain, gross loss, net change, and swap change**

A cross tabulation matrix for 1977 and 2007 was utilized to derive the gross gains, gross losses, net changes, and swap changes for land-use categories. Net change represents the difference between the gross gain and gross loss. The swap change for a category – which measures the extent to which losses (gains) in one land-use category during a given time period are replaced by gains (losses) from other categories, thus exerting a cancelling effect not detected in figures for net change – is the total change minus the net change (Pontius et al. 2004; Manandhar et al. 2010). Here, the total change for a given land-use category is expressed as the absolute value of the sum of gains and losses.

**Land-use changes in townships**

We examined the township sprawl and quantified the increase of developed land on the basis of the land-use map derived from the aforementioned satellite images. Although developed land is only a small part of the total area, it imposes a substantial ecological footprint, and thus the increase in developed areas needs to be considered in terms of environmental monitoring and sustainability (Manandhar et al. 2010). Differences in the magnitude of developed land among towns were calculated and compared to better assess potential impacts on the nature reserve.

**Results**

**Gross gain, gross loss, net change, and swap change**

In 2007, the study area was still predominantly forested (93%), with farmland (2.8%), developed land (2.5%), water (0.7%), and open land (0.9%) comprising the remaining area (Table 1). From an aggregate perspective, the major land-use changes during the 30-year study period (1977–2007) included the net loss of 14,000 ha of forestland, accompanied by a net increase of almost 11,000 ha of developed land and 2756 ha of farmland. The bulk of the net loss of forestland occurred during the first period (1977–1991); only 0.2% of net forest loss occurred during the second period. The net gain of developed land was relatively evenly distributed across both periods, with the trend slightly increasing in the second. Farmland gained overall in the first period only to experience a net loss from 1991 to 2007.

Table 2 incorporates gains and losses for each land-use category as components of total change and swap change, depicted in terms of percentage of the entire study area landscape. This reveals more of the dynamics underlying the aggregate results depicted in Table 1. Here we find that in both periods, forestland underwent the largest amount of total change. This is not entirely unexpected, however, given that the landscape in the study area is overwhelmingly forested. From 1977 to 1991, however, losses dwarfed gains in forestland, yielding a small swap and a dominant net change of −1.67% of the landscape. From 1991 to 2007, most of total forestland losses were counterbalanced as part of swap changes with farmland, yielding an overall net loss of only 0.18% of the total landscape, one-ninth of that percentage in the previous period.

Farmland followed a different trajectory through the two time periods, ultimately resulting in an overall net increase of 0.36% in the overall landscape over the focal
Table 1. Area of land-use classes in 1977, 1991, and 2007.

<table>
<thead>
<tr>
<th>Land-use class</th>
<th>1977</th>
<th>1991</th>
<th>2007</th>
<th>Net change (ha)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (ha)</td>
<td>%</td>
<td>Area (ha)</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forestland</td>
<td>729,263</td>
<td>94.92</td>
<td>716,539</td>
<td>93.27</td>
<td>−14,133</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmland</td>
<td>18,872</td>
<td>2.46</td>
<td>26,744</td>
<td>3.48</td>
<td>21,629</td>
</tr>
<tr>
<td>Developed land</td>
<td>8253</td>
<td>1.07</td>
<td>13,295</td>
<td>1.73</td>
<td>19,172</td>
</tr>
<tr>
<td>Open land</td>
<td>6493</td>
<td>0.85</td>
<td>6302</td>
<td>0.82</td>
<td>6950</td>
</tr>
<tr>
<td>Water</td>
<td>5373</td>
<td>0.70</td>
<td>5374</td>
<td>0.70</td>
<td>5374</td>
</tr>
<tr>
<td>Total</td>
<td>768,254</td>
<td>100</td>
<td>768,254</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Components of land-use change from 1977 to 2007 in terms of percentage of the study area.

<table>
<thead>
<tr>
<th>Period</th>
<th>Land-use class</th>
<th>Gain</th>
<th>Loss</th>
<th>Total change</th>
<th>Swap</th>
<th>Net change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977–2007</td>
<td>Forestland</td>
<td>1.97</td>
<td>3.83</td>
<td>5.80</td>
<td>3.94</td>
<td>−1.86</td>
</tr>
<tr>
<td></td>
<td>Farmland</td>
<td>2.73</td>
<td>2.37</td>
<td>5.10</td>
<td>4.74</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>Developed land</td>
<td>1.43</td>
<td>0.00</td>
<td>1.43</td>
<td>0.00</td>
<td>1.43</td>
</tr>
<tr>
<td></td>
<td>Open land</td>
<td>0.13</td>
<td>0.07</td>
<td>0.20</td>
<td>0.14</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>6.26</td>
<td>6.27</td>
<td>12.53</td>
<td>8.82</td>
<td>−0.01</td>
</tr>
<tr>
<td>1977–1991</td>
<td>Forestland</td>
<td>0.07</td>
<td>1.74</td>
<td>1.81</td>
<td>0.14</td>
<td>−1.67</td>
</tr>
<tr>
<td></td>
<td>Farmland</td>
<td>1.26</td>
<td>0.23</td>
<td>1.49</td>
<td>0.46</td>
<td>1.03</td>
</tr>
<tr>
<td></td>
<td>Developed land</td>
<td>0.66</td>
<td>0.00</td>
<td>0.66</td>
<td>0</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>Open land</td>
<td>0.04</td>
<td>0.07</td>
<td>0.11</td>
<td>0.08</td>
<td>−0.03</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2.03</td>
<td>2.04</td>
<td>4.07</td>
<td>0.68</td>
<td>−0.01</td>
</tr>
<tr>
<td>1991–2007</td>
<td>Forestland</td>
<td>1.91</td>
<td>2.09</td>
<td>4.00</td>
<td>3.82</td>
<td>−0.18</td>
</tr>
<tr>
<td></td>
<td>Farmland</td>
<td>1.48</td>
<td>2.15</td>
<td>3.63</td>
<td>2.96</td>
<td>−0.67</td>
</tr>
<tr>
<td></td>
<td>Developed land</td>
<td>0.77</td>
<td>0.00</td>
<td>0.77</td>
<td>0.00</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>Open land</td>
<td>0.08</td>
<td>0.00</td>
<td>0.08</td>
<td>0.00</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>4.24</td>
<td>4.24</td>
<td>8.48</td>
<td>6.78</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Land-use change in townships

Attention now turns to the seven towns surrounding the CMBR in terms of land-use changes that occurred over the three decades comprising the study period. The focus here is on trends in the status of developed land within the township boundaries, since to this point in time that is where the major land-use changes have occurred. As we shall see in the future, the situation may evolve into the more traditional picture of ‘urban sprawl’ as development pushing out from town boundaries into the immediately adjacent countryside. Changes in developed land from 1977 to 2007, along with development gains from forestland and farmland over that period, may be found in Table 3.

In 1977, about one-third of all land within the seven towns had been developed. This included three-fifths of the area in the town of Songjiang, and 13–43% of lands in the other six towns. This picture changed radically over the following three decades. In 2007, three-fourths of all lands in the seven towns surrounding the reserve had been developed. The largest increase occurred in the smallest town, Manjiang, where the developed area increased fourfold. In four other towns, the area of developed land doubled from that in 1977, while in Lushuihe and Songjianghe it increased by 150%. While the town of Songjiang displayed the least extent of sprawl, with developed land increasing by about 20%, three-fifths of land within the town boundary had already been developed in 1977, and this had risen to above 80% in 2007.

On an overall basis, about three-fifths of land that was developed within the seven towns from 1977 to 2007 was previously agricultural land, while slightly more than two-fifths had been forestland (Table 3). In five of the seven towns, the contribution of farmland to development exceeded that of forestland by more than 30%. Clearly the largest relative contribution of forestland to development occurred in Erdaobaihe, the town contiguous with the boundary of the CMBR. There almost four-fifths of the increase in developed land came at the expense of forests,
Table 3. Change in developed land as percent of town area from 1977 to 2007 for towns surrounding the CMBR, with contributions from forestland and farmland to development.

<table>
<thead>
<tr>
<th>Town</th>
<th>Area (ha)</th>
<th>1977</th>
<th>2007</th>
<th>Gain</th>
<th>Forestland (%)</th>
<th>Farmland (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erdaobaihe</td>
<td>1675.5</td>
<td>29.10</td>
<td>67.90</td>
<td>38.80</td>
<td>79.06</td>
<td>20.94</td>
</tr>
<tr>
<td>Lushuihe</td>
<td>709.8</td>
<td>34.38</td>
<td>85.96</td>
<td>51.58</td>
<td>40.36</td>
<td>59.64</td>
</tr>
<tr>
<td>Songjiang</td>
<td>323.9</td>
<td>60.60</td>
<td>80.55</td>
<td>19.95</td>
<td>34.82</td>
<td>65.18</td>
</tr>
<tr>
<td>Quanyang</td>
<td>756.5</td>
<td>37.53</td>
<td>72.31</td>
<td>34.78</td>
<td>11.80</td>
<td>88.20</td>
</tr>
<tr>
<td>Songjianghe</td>
<td>1011.2</td>
<td>27.64</td>
<td>78.69</td>
<td>51.05</td>
<td>17.02</td>
<td>82.98</td>
</tr>
<tr>
<td>Liangjiang</td>
<td>370.1</td>
<td>42.92</td>
<td>74.10</td>
<td>31.18</td>
<td>16.38</td>
<td>83.62</td>
</tr>
<tr>
<td>Manjiang</td>
<td>63.7</td>
<td>13.84</td>
<td>73.73</td>
<td>59.89</td>
<td>23.82</td>
<td>76.18</td>
</tr>
<tr>
<td>All towns</td>
<td>4910.7</td>
<td>33.78</td>
<td>74.79</td>
<td>41.01</td>
<td>41.27</td>
<td>58.73</td>
</tr>
</tbody>
</table>

while this proportion was 40.4% in Lushuihe and just over 33% in Songjiang. On the other hand, from 76% to 88% of lands developed in the remaining towns replaced forestland.

Discussion

The foregoing account has painted a picture of a relatively remote area in the northeast China that is experiencing the early stages of development. The area remains overwhelmingly forested. Although the land-use changes are far from drastic, that does not reduce their importance in their setting the pace for future development, sustainable or otherwise.

Land-use changes

Our particular focus has been the status and trajectory of the forest resource. We have seen that over the focal three-decade study period, net forest loss in the CMBR area slowed from 12,7000 ha (1977–1991) to 1409 ha (1991–2007), only 11% of that of the earlier period. In the first period, almost all net change was loss, since little swap occurred; in the second period, much more losses were counterbalanced by being part of swaps, leaving a much smaller negative net change. Thus the initial net loss trend was mitigated by additions as components of swaps in the second period.

At the same time, recalling from Table 2 that both gains and losses reflect actual changes on the landscape, regardless of whether or not they are components of swaps, the total change of the forest landscape increased from 1.8% in 1977–1991 to 4% from 1991 to 2007. Thus an increase in actual forest landscape change was happening concurrently with a decrease in net loss to the forest landscape.

During the three-decade study period, land-use changes involving farmland have charted a decidedly different trajectory than for forestland, ultimately resulting in a relatively small net change (in this case, positive) only one-fifth the size of forestland net change. After increasing from 2.5% to 3.5% of the total landscape from 1977 to 1991, farmland declined to 2.8% in 2007. Again it must be recalled, however, that in 1977 the area of farmland was only 2% that of forestland in the study area. This pattern of change may have occurred for two reasons. First, it is usually easier and cheaper to develop farmland than forestland; and second, land immediately adjacent to towns could already more likely have been farmland than forest.

The area of developed land surrounding the CMBR more than doubled over the course of the study period, increasing from 8253 ha in 1977 to 19,172 in 2007. At that time it occupied 2.5% of the total landscape, slightly less than the 2.8% occupied by farmland. We have seen, as in other studies (e.g., Pontius et al. 2004; Manandhar et al. 2010) that once land is developed it stays developed, so that unlike forestland and farmland dynamics, swapping played no role in land-use changes associated with this category. Moreover, the pattern of development was quite similar over both periods as the developed area increased from just over 1% to 2.5% of the study area landscape over the focal three decades. We also saw that open land has played a relatively minor role in the land-use change picture for the Changbai area thus far.

With respect to the seven towns surrounding the reserve, for the largest town (i.e., Erdaobaihe), almost all developed land gains came from forests. The other towns gained developed land primarily from farmland, with the exception of Lushuihe, where sources of gains were split evenly between farmland and forestland. For all towns in the study area, development continues to occur and lands on the edges of towns, whether forestland or farmland, will provide the source for development.

Potential driving forces

Utilizing the previous analysis for land-use changes in the study area and focusing on the seven towns surrounding the CMBR, we now consider three hypothesized interrelated driving forces for land-use changes in the study area. These include regional population gains, the increased demand for tourism services, and recent changes in forest and land management policies.

Population

It is often difficult to obtain accurate data at the township level, given that some towns in this area were mere villages in the 1970s and 1980s and did not develop to a size where such data was collected; or, in other cases,
more recent data for the year 2000 and following are ‘classified’ – that is, not made public – by some of the towns. Data is available, however, for Antu County, within which three of the seven towns in this study – Erdaobaihe, Liangjiang, and Songjiang – are located. We obtained population data for Antu County covering the period from 1977 to 2007 (Figure 2). The data reveal a steady increase in population from approximately 163,000 to a peak of 220,000 in 1999, after which population rates remained steady or declined slightly over the next 5 years and then began to rise again slowly.

Perhaps the most striking correspondence with the data discussed earlier may be noted when comparing the population trajectory in Figure 2 with the trajectories of forestland and farmland for the study area as seen in the two periods depicted in Table 1. As described earlier, during the second time period of this study (1991–2007), the net loss of forestland was greatly reduced from the preceding period (1977–1991) and the trend of increasing farmland that characterized the first period was reversed. As evident in Figure 2, 1991 is almost exactly the point at which the steady population increase that was characteristic of the first time period began to level off and remain steady thereafter. At the same time, both forestland and farmland experienced sharp increases in

### Tourism
Tourism in the CMBR area has experienced steady growth since 1980, when the number of visitors was a mere 29,000 (Yuan et al. 2008). By the turn of the century the number of tourists had increased to 200,000 (Cui et al. 2006); and in 2007, the final year of the three-decade study period, 900,000 tourists visited the reserve. Three years later in 2010 the number of visitors to the reserve climbed to 2.44 million and total income accrued to governments and private sector businesses over the preceding 5 years had reached 2.03 billion RMB (Statistical Communiqué of the Changbai Mountain Protection and Development Zone of Jilin Province 2011).

In order to increase supporting facilities and rapidly improve tourism services, many hotels, restaurants, travel agencies, and stores have been built in Erdaobaihe and Songjianghe, the two towns displaying the greatest increase in developed lands. Liangjiang and Songjiang are farther

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### Table 4. Change in population and developed lands in the seven towns surrounding the CMBR from 1999 to 2007.

<table>
<thead>
<tr>
<th>Town</th>
<th>Area (ha)</th>
<th>Population (person)</th>
<th>Developed land (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1999</td>
<td>2007</td>
<td>Change (%)</td>
</tr>
<tr>
<td>Erdaobaihe</td>
<td>1675.5</td>
<td>41,237</td>
<td>48,908</td>
</tr>
<tr>
<td>Lushuihe</td>
<td>709.8</td>
<td>34,048</td>
<td>42,228</td>
</tr>
<tr>
<td>Songjiang</td>
<td>323.9</td>
<td>11,688</td>
<td>32,764</td>
</tr>
<tr>
<td>Quanyang</td>
<td>756.5</td>
<td>31,900</td>
<td>40,637</td>
</tr>
<tr>
<td>Songjianghe</td>
<td>1011.2</td>
<td>67,358</td>
<td>62,574</td>
</tr>
<tr>
<td>Liangjiang</td>
<td>370.1</td>
<td>16,633</td>
<td>16,325</td>
</tr>
<tr>
<td>Manjiang</td>
<td>63.7</td>
<td>3695</td>
<td>3641</td>
</tr>
<tr>
<td>Total</td>
<td>4910.7</td>
<td>206,559</td>
<td>247,077</td>
</tr>
</tbody>
</table>

Notes: aDuring this period, the town of Songjiang incorporated two neighboring towns under its jurisdiction. This merger accounts for the exceptionally high percentage change in population from 1999 to 2007.
from the reserve than the above towns and thus have experienced the benefits of increased tourism to a somewhat lesser degree.

A new governmental tourism branch of Jilin Province with total control of human activities on Changbai Mountain has opened up three tourism routes from three directions leading to the CMBR. An airport has been constructed outside the biosphere reserve (Zhao et al. 2011) and the plan of the Changbai Mountain Protection and Development Zone of Jilin Province calls for a road to be built around the reserve.

The above suggests that population increase as a driving force underlying land-use change may itself be driven by the increasing demand for tourism in the CMBR area. Moreover, it is apparent that provincial government policies regarding economic development in the area will very likely accelerate the role of these driving forces towards land-use change in the region.

National forest and land-use policies

Another important impetus affecting land-use change in the CMBR area emanates from the changing pathways of national policies regarding forest and land use over the course of the three-decade study period. In the decade prior to 1977, national forest policy in the People’s Republic of China was one of the ‘unrestricted harvesting’ to contribute to economic development. It was not until the Third Plenary Session of the 11th Central Committee of the Chinese Communist Party in 1978 that the tide began to shift and forest management was identified as an important focus of public policy. Forestry was now to be guided by universal forest protection, extensive reforestation and afforestation efforts, a combination of harvesting and planting, and sustainable utilization (Yu et al. 2011). Unfortunately, these new policies proved extremely difficult to translate into practice, and for another two decades they failed to sustain the nation’s forest resources (Zhao and Shao 2002). This undoubtedly contributed to the decrease in forestland in the study area from 1977 to 1991 being almost exclusively in the form of net loss (Table 2). At the same time, logging operations provided the major source of income for local residents.

In 1998 – midway through the second period of this study – China adopted a set of programs designed to broaden the focus of forest management in the country from wood production to include ecological sustainability. Two key elements of this package were the Natural Forest Protection Program (NFPP) to restore and protect natural forests in state-owned forest regions and ecologically sensitive areas; and the Conversion of Cropland to Forest Program (CCFP) in which the central government provided funds to encourage the transformation of marginal cropland to forest and grass cover. As described earlier, the net loss of forestland in the study area was drastically reduced in the second period (1991–2007). It is reasonable to infer that such a policy shift was a significant factor in the shift in the nature of forestland change from net loss in the first period to swap change (with greatly reduced net loss) in the second period (Table 2).

The area of developed land surrounding the CMBR more than doubled in 30 years, from 8253 ha in 1977 to 19,172 ha in 2007. Such an increase reflected both regional population gains and accompanying urbanization, likely stimulated by the increased demand for tourism services. At the same time, the direct conversion of natural cover to varying intensities of developed lands translates into decreased biological integrity of floral and faunal communities, while landscape fragmentation brings changes in biotic composition. The effects are revealed not only in the land-use changes displayed via multi-temporal images, but also in the ecological impacts on species, water, air, and other natural resources (Kiss 2004; He et al. 2008; Tang et al. 2010). These latter effects have not yet been evaluated for the Changbai Mountain region and will be the focus of future research.

At the same time, national forest policies have shifted in recent years towards the recognition of ecological integrity as a key ingredient of sustainable forest management. Although many challenges remain in achieving such a goal, the pathway of forestland-use change in the study area from 1991 to 2007 suggests that such a redirection of policy may have had beneficial effects. It certainly implies that enhanced communication and cooperation between those charged with implementing national policy in the management of the CMBR and provincial government agencies who direct land-use policies surrounding the reserve should be strongly encouraged. In terms of the driving forces underlying land-use change, strengthening the effective implementation of ecologically-informed national forest policies may help counterbalance and direct forces emanating from population change and tourism demand as mutual components of effective policies for sustainable development in the Changbai Mountain region of northeast China.

Conclusion

The CMBR is a vital reservoir for biodiversity and ecological services. Our study, based on the data gathered over three decades, revealed a net loss of 14,000 ha of forestland and a net increase of almost 11,000 ha of developed land in the area immediately surrounding the reserve. It is critical that the reserve’s ecological integrity be protected as a central ingredient of sustainable development in this region. At present, the forces for development driven by tourism demand and population growth, have yet to exert a transformative impact on the overwhelmingly forested landscape in the region. However, such forces will both continue and accelerate. Our study has outlined a baseline perspective to rely on in making better land-use and management decisions to potentially minimize detrimental ecological impacts of land-use change for the future. The goal is to temper and guide the increase in developed land area so that a balanced structure of sustainable development may
evolve, economic well-being will be enhanced and the ecological integrity of the CMBR and its surrounding areas will be better ensured.

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References