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Landscape-level Forest Ecosystem Conservation on Changbai Mountain, China and North Korea (DPRK)

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Changbai Mountain, the highest mountain in the east of the Eurasian Continent, is covered with a wide range of distinct altitudinal vegetation types featuring the Earth's richest biodiversity in the cool temperate zone. However, some development trends on Changbai Mountain urgently require the launching of innovative policies and actions for sustainable forest conservation on Changbai Mountain. This paper provides an overview of forest conservation issues in the area: it summarizes the ecological significance of forest vegetation on Changbai Mountain, reviews historic forest utilization and protection in the region, and discusses forest conservation measures that exist on Changbai Mountain. The paper also describes specific civilization-based economic developments, including deforestation, logging, non-wood product collection, and tourism, which threaten forest sustainability inside and around protected areas on Changbai Mountain. We propose that forest ecosystem management should be implemented outside the designated protected areas and human pressure should be reduced inside nature reserves on Changbai Mountain. Landscape and ecosystem approaches should be used to promote forest conservation at the mountain level. In addition, China and North Korea (DPRK) need to engage in multiscale, multidisciplinary, and multistakeholder transboundary conservation efforts.

Keywords: Forest conservation; habitat protection; cool temperate forest; forest sustainability; landscape fragmentation.

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Introduction

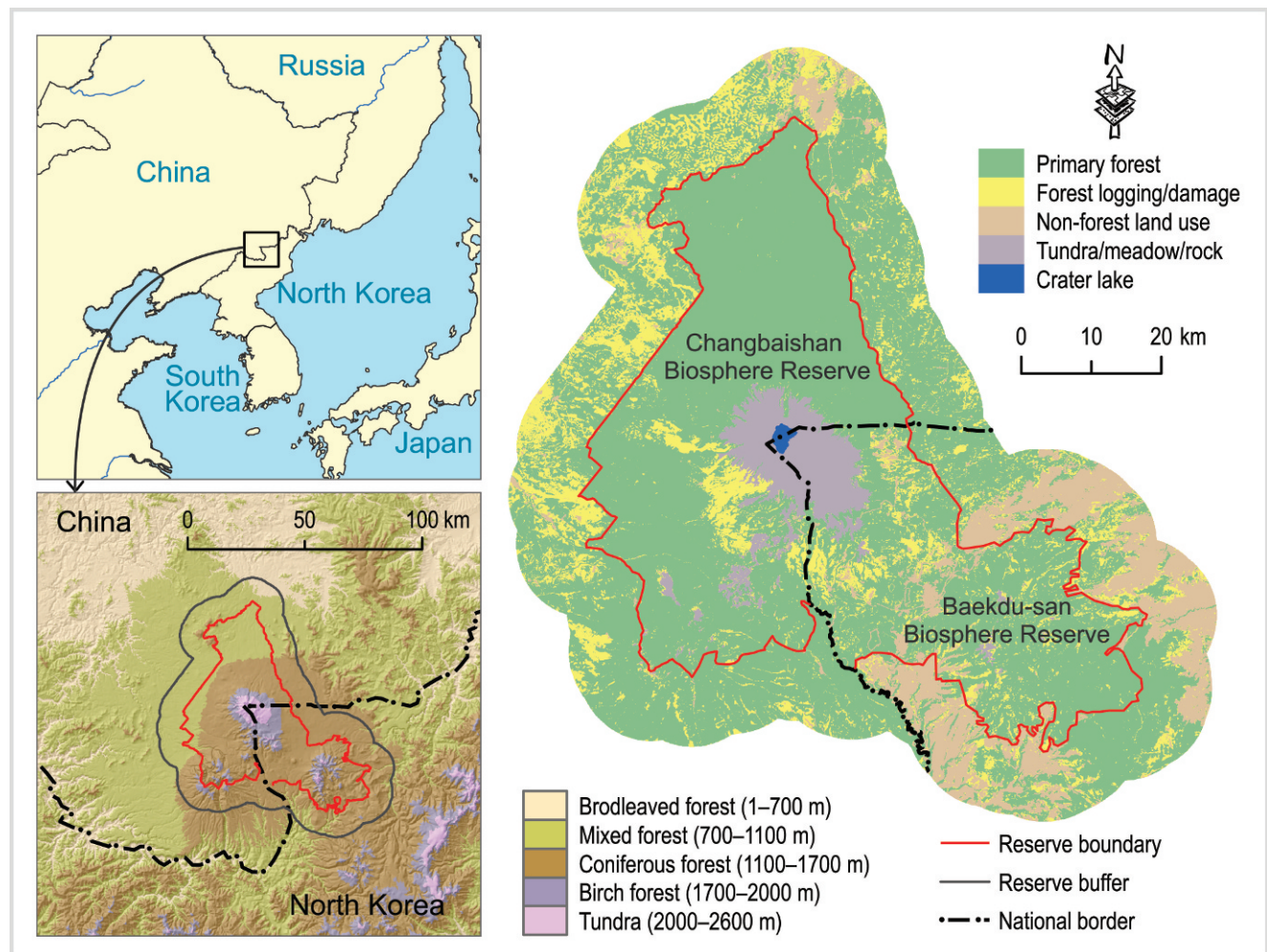
Only 12.9% of Earth's land surface is protected (Chape et al 2008), and, with a growing human population, it is highly unlikely that protected areas will ever cover more than a small fraction of Earth's land surface. This is particularly the case in the temperate zone (Potapov et al 2008). The temperate mixed forest has the second lowest level of protection among all 20 natural forest types on Earth (Schmitt et al 2009). Parviainen (2005) estimated that there are only 300,000 ha of old-growth forests (0.4% of the total forest area) left in strict forest reserves and other protection areas in the temperate zone of Europe. Although North America was not explored by colonists from Europe until the 17–18th centuries, most of its hardwood and mixed forests had been cleared for farming and other land-use purposes by the early 1900s (Sample and Anderson 2008). Hansen et al (2010) found that Asia has the second largest area of gross forest cover loss. As a proportion of the total forest area lost in all biomes, loss in the temperate biome is the second highest. Therefore, it is important to strengthen the protection of temperate forests on Earth, particularly in Asia.

Changbai Mountain, known as Changbaishan or Changbai Shan in China, Mount Baekdu in North

Korea (DPRK), or Paektu-san in South Korea, stretches along the border between China and DPRK (Figure 1) and is covered by well-developed altitudinal vegetation zones, including mixed forest (700–1100 m), coniferous forest (1100–1700 m), Erman birch forest (1700–2000 m), and tundra (>2000 m) (Shao et al 1996). Contiguous intact forests with the richest biodiversity in the cool temperate zone on Earth are found within a 200,000-ha nature reserve, known as Changbai Mountain Reserve (CBR) on Changbai Mountain (Jeffers 1987; Barnes et al 1992). There are 9 species of amphibian, 12 reptiles, 24 fish, 56 mammals, 230 birds, and 1255 insects within CBR (<http://cbs.jl.gov.cn/>). CBR is home to 430 species of fungi, 200 lichens, 311 mosses and liverworts, 78 ferns, 11 gymnosperms, and at least 1325 angiosperms (Wang 2007). These figures are far higher than any comparable World Heritage Site in the United States or Europe (MacKinnon 2007).

Forest ecosystem protection on Changbai Mountain has received national and international attention for more than 3 decades. In 1986, an International Symposium on Temperate Forest Ecosystem Management and Environment Protection was held at CBR through joint sponsorship by the Chinese Academy of Sciences and the Institute of Terrestrial Ecology, UK. Since then, scientists from the Chinese Academy of Sciences have been actively involved in international collaborative research efforts on Changbai Mountain and

FIGURE 1 Location of Changbai Mountain across the border of China and DPRK (North Korea) and position of 2 biosphere reserves and their 10-km buffers on Changbai Mountain. Technical explanations for the land cover data can be found in Tang et al (2010). (Map by LN Tang)



have started to publish scientific articles in English.

A review of the current state of the art

The work by Zhau and Zhau (1991) was the first publication that addressed issues in nature reserve management on Changbai Mountain. They suggested that forest conservation on CBR was threatened by poor administrative coordination, insufficient governmental budget, and use for recreation. Barnes et al (1992) studied the regeneration of the mixed forest ecosystems on Changbai Mountain and pointed out the ecosystems' uniqueness in species composition within the cool temperate zone on Earth. Shao et al (1996) provided the first remotely

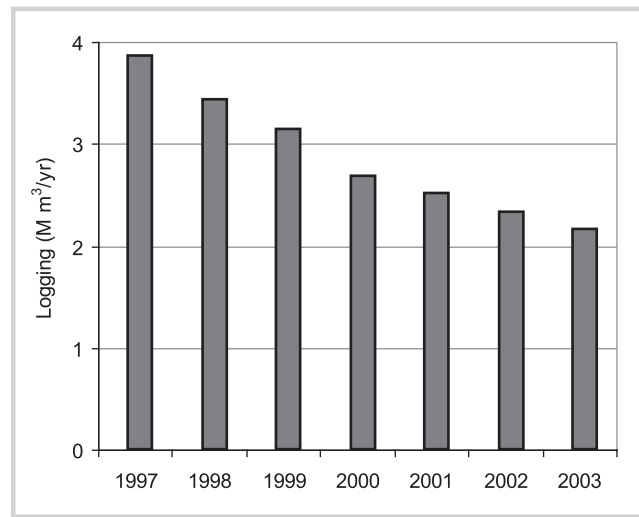
sensed map of forest distribution within CBR and its surrounding areas on Changbai Mountain with Landsat Thematic Mapper (TM) data. By using the same remote sensing data, Shao and Zhao (1998) analyzed spatial variations in forest cover and the isolation of CBR within a managed forest landscape on Changbai Mountain. Zhao (1999) suggested that illegal hunting and collecting commercial and medicinal plants were jeopardizing conservation efforts on Changbai Mountain. These pioneer works laid important foundations for increased efforts in forest research on Changbai Mountain in the past decade. Tang et al (2010) integrated ground data with remotely sensed data at different resolutions and found that

forest degradation is increasing on either side of reserve boundaries and national borders on Changbai Mountain.

The need for concerted, research-based action

Every trend in development on Changbai Mountain suggests that it is urgent to translate research findings into innovative policies and actions for sustainable conservation of forest ecosystems on Changbai Mountain. In this article, we ask: what are the conflicts between economic development and forest ecosystem conservation on Changbai Mountain? What should conservation policies address to improve forest protection on Changbai Mountain?

FIGURE 2 Forest logging in Jilin Province since the implementation of the Natural Forest Protection Program in China. Logging after 2003 stayed the same as the 2003 level. (Source: Yu et al 2011)



A brief history

During the interglacial period between the tertiary period and the quaternary period, the warmer climate made the plants of North China floristic region, such as Siebold's magnolia (*Magnolia sieboldii*), move to Changbai Mountain. In the early quaternary period, the continental glaciers southward movements made the plants that came from the Arctic and Siberia areas settle in Changbai Mountain, such as Changbai Scotch Pine (*Pinus sylvestrisformis*) and *Salix polyadenia* var. *tchangbaischanica* (Wang 2007). There are some tertiary period relic plants, such as Korean pine (*Pinus koraiensis*) and ginseng (*Panax ginseng*), on Changbai Mountain. The combination of all of these native relic species and alien species made Changbai Mountain a distinct and important gene pool of rich biodiversity (MacKinnon 2007).

Forests on Changbai Mountain were relatively intact until the early 1900s (Shaw 1914). Changbai Mountains were regarded as the birth place of the ancestors of the present-day Man people, who established the Jin Dynasty (1115–1234) and the Qing Dynasty (1644–1911). Fishing, hunting, and animal husbandry were the Man's main activities in using the forests. With the development of agriculture, the Man cut an increasing number of trees for building houses, making ships, and heating and cooking but without affecting the sustainability and regeneration of the forest ecosystems because of the low population at that time.

Changbai Mountain is one of the most important timber bases since the establishment of People's Republic of China in 1949, after centuries during which encroachment on old-growth forest through agriculture had remained minimal (Ye et al 2009), followed by a sudden growth of agriculture and forestry in the early 20th century (Yu et al 2011). More than 20 state-owned

forestry enterprises were established on Changbai Mountains. Their mission, from 1950 to 1980, was mainly timber harvesting. Forest stocking in Changbai Mountains was reduced from 600 million cubic meters in 1949 to 70 million cubic meters in 1985 (Yu et al 2011). Since the mid-1980s, most of the forestry enterprises have faced dwindling timber resources, but they had no choice but to continue to log whatever was available because of the rapid population growth in the forestry region. Researchers (eg Shao and Zhao 1998; Tang et al 2010) have pointed out that the CBR has become isolated within managed forest landscapes as extensive logging took place near the reserve boundary (Figure 1).

China's Natural Forest Protection Program was launched in 1998 to ban logging from many natural forests in China (Zhao and Shao 2002). In Jilin Province, where forests are distributed mainly in the Changbai Mountain area, timber harvesting was rapidly reduced (Figure 2). To stimulate motivation for forest protection efforts, the central government has started to pay ecological subsidies to the local foresters whose forests were classified as ecological welfare forests under complete protection since 2003 (Dai et al 2009). The ecological welfare

forests in Changbai Mountain account for one third of the total forests in area. Despite these long-term forest protection efforts, it will take decades to expect the recovery of old-growth forest landscapes on Changbai Mountain (Shao et al 1994). Nevertheless, the existing forest protection efforts contribute positively to forest restoration on Changbai Mountain. Changbai Mountain landscape as a whole is a carbon sink (Zhang et al 2007; Bao et al 2010).

Current state

Opportunities

Among the earliest nature reserves in China, the initial goal of CBR was (1) to preserve ecologically and economically valuable ecosystems, such as the temperate Korean pine-hardwood mixed forests; (2) to protect habitats for wildlife species, such as Siberian tigers (*Panthera tigris altaica*); and (3) to preserve various endangered, rare, and endemic species in the region, including *Mergus squamatus* and *Panthera tigris lingipilis* that are found in the IUCN Red List (<http://www.iucnredlist.org/>). On the Korean side, a 132,000-ha protected area, Mount Baekdu Nature Reserve, became a Man and biosphere reserve in 1986 (MacKinnon 2007). The expansion of

nature reserve areas on Changbai Mountain is significant to protect the biodiversity and ecosystem at the mountain scale (Jeffers 1987; Tang et al 2010).

Because forest landscape on Changbai Mountain is connected to the wider forests of northeast Asia, the East Asian Steering Committee of the World Commission on Protected Areas has developed a conception plan for the establishment of a Baekdu–Daegan ecological corridor for promoting species movement, under which protected areas on Changbai Mountain between China and DPRK are connected (MacKinnon 2007).

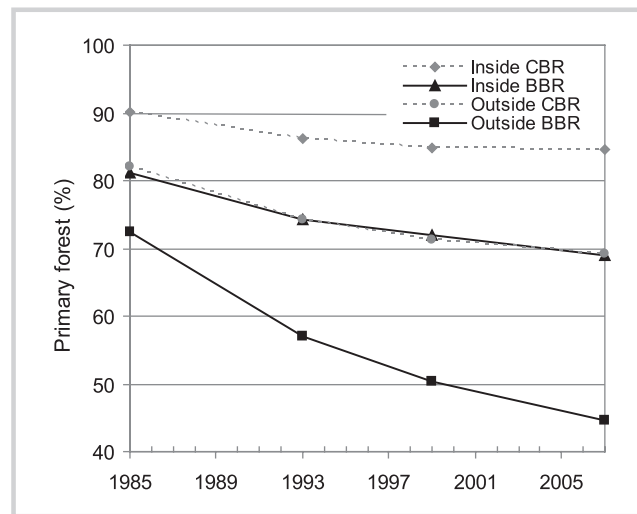
Recommendations also have been made to develop cross-border conservation zones for protecting Siberian tigers between the Russian Far East and Changbai Mountains (Marcot et al 1997). Although none of these plans has been implemented, there are improved common understandings on the landscape-level forest protection on Changbai Mountain among conservation experts and organizations.

Challenges

Because of strict forest laws in China, forests within nature reserves are protected from logging. However, major challenges still exist in forest protection on Changbai Mountain.

Inadequate ecosystem boundary: The old-growth Korean pine–hardwood mixed forest is the climax forest type in northeastern China. Originally, CBR was designed to protect large-area, typical mixed forest stands (Yang 1984). Such an intention of reserve design made the reserve particularly meaningful, because the mixed forest is the target of logging outside the nature reserves. However, geospatial data revealed that the majority of the nature reserve boundary on the western slope was just below the upper limit of the mixed forest, and it turned out that the total area of the mixed forests are not big enough, and few of them are

FIGURE 3 Changes in land use and land cover derived from Landsat TM data in 1985, 1993, 1999, and 2007, for an area that includes 2 nature reserves and their 10-km buffers on Changbai Mountain. Technical explanations can be found in Tang et al (2010). CBR stands for Changbai Mountain Biosphere Reserve (on the Chinese side) and BBR stands for Mount Baekdu Nature Reserve (on the North Korean side).



biogeographically represented (Shao et al 1996). Because the reserve boundary is so high in elevation, the shape of CBR is relatively narrow and makes it difficult to protect wildlife species that require broad forest conditions on Changbai Mountain (Shao and Zhao 1998).

Size of protected area is too small:

Although every single living tree is protected from cutting within CBR under China's forest laws, forests in its surrounding areas have been extensively logged (Shao and Zhao 1998). On the North Korean side, the forests were cleared for farming and other land use in addition to timber harvesting. As a result, primary forest decline outside the nature reserves was much faster than that inside the nature reserves (Figure 3). Forest-cutting activities outside the reserves resulted in high contrasts in forest distribution patterns between the reserves and their surrounding areas, which is clearly visible with remotely sensed data (Tang et al 2010).

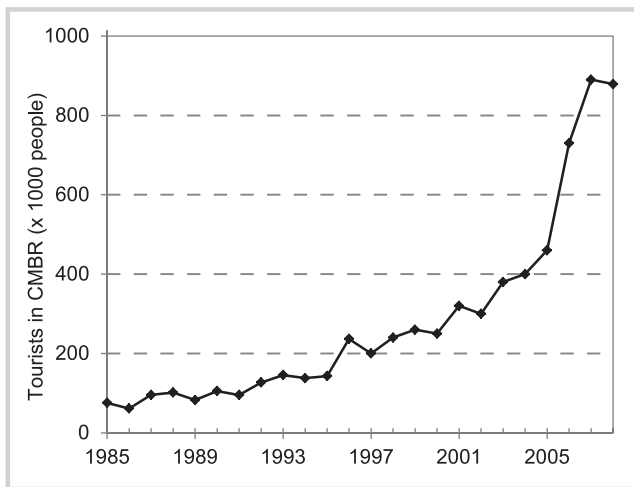
Poaching: Poaching is responsible for most of the losses of wildlife in Changbai Mountain, which made some animal species reach a status close to extinction. For example, the Chinese tree frog (*Rana temporaria chensinensis*) is an economic species because its oil is in high demand in

both domestic and international markets. This animal species used to be widely distributed and very productive in the mixed forest but now is listed as a rare and endangered species in China because of poaching (Yang and Xu 2003). Some large animals, such as the Siberian tiger, have become even more endangered. In the early 1900s, the Siberian tiger lived throughout northeastern China, the Korean Peninsula, northeastern Mongolia, and southeastern Russia (Marcot et al 1997). Poaching and free hunting in the 20th century sharply reduced its wild population. According to the 2005 statistics, the wild population descended to about 450–550, with the majority of the population (431–529) confined to a limited area in the southeast of the Russian Far East. The population of Siberian tiger in China is estimated at only 20 (Zhou 2008).

Herb and medicinal plant collection:

The exploitation of natural resources within CBR also includes the collections of potherbs, wild mushrooms, medicinal plants, and pine nuts. Bai et al (2008) have suggested that, between 1963 and 2006, there were obvious human-induced changes in shrub and herb layers of the mixed forests. Extensive collection of Korean pine nuts also is destructive (Tang et al 2010). Korean

FIGURE 4 Changes in the number of visitors over time in Changbai Mountain Biosphere Reserve. Data were obtained from the Administration Committee of Changbai Mountain Nature Reserve.



pine is an ecologically important species for the cold temperate mixed forest zone in eastern Eurasia because its seeds are food sources for wildlife. The pine seeds have been used as nuts for decades in northeastern China but now are sold in the global market. Driven by market demand, increasingly more people enter the nature reserve to harvest pine seeds every year (Shao and Zhao 1998). Some harvests have been granted by the reserve administration, but most harvests were illegal before 2000. The legalized pine seed harvest inside CBR in 2000 caused sharp declines in pine seed yield in 2002 because of physical damage to the pine trees (Tang et al 2010). Pine seed quality, pine tree regeneration, and the populations of Eurasian red squirrel (*Sciurus vulgaris*), spotted nutcracker (*Nucifraga caryocatactes*), wild boar (*Sus scrofa*), and marten (*Martes flavigula*) were all harshly reduced (Piao et al 2011).

Rapid increase in use for recreation:

The conservation mission of CBR is under increasing pressure from recreation on the mountain. Tourism on the Chinese side has accelerated from less than 100,000 visitors a year in the early 1980s to nearly a million a year in 2007–2008 (Figure 4). The area above 1500 m on Changbai Mountain has been assigned to promote tourism industry by the Jilin provincial government. To provide good service

to the visitors, the reserve management bureau has invested many resources in constructing roads, building hotels, and bringing more labor to the reserve to provide various services (Yang and Xu 2003). The booming tourist industry in the reserve not only threatens the natural virgin state of forests within CBR but also has accelerated deforestation outside CBR (Zhao et al 2011).

Recommendations

The first 2 challenges mentioned above are unique problems for forest conservation in CBR, whereas the last 3 challenges represent worldwide commonly observed conflicts between conservation enhancement and poverty reduction (Adams et al 2004). These challenges are even more severe on the North Korean side of Changbai Mountain (Tang et al 2010). The forest ecosystems on Changbai Mountain will be degraded further if no actions are taken to tackle these conservation problems.

Applying the landscape approach

The sustainability of the remaining old-growth forests on Changbai Mountain requires a landscape approach that integrates forest protection inside the nature reserves and forest management outside the nature reserves. The landscape approach aims to maximize

conservation and development values by applying the science of landscape ecology to better understand interactions across sectors and landowners over a large area (Sayer 2009). To develop and implement landscape-level forest sustainability, plans that take into consideration both protected and managed areas should facilitate sustainable forest conservation (Franklin and Lindenmayer 2009). Forest sustainability outside CBR needs to be strengthened by implementing forest ecosystem management. From this point of view, China's forestry policies need to include mechanisms that facilitate forest sustainability across landscape and administrative boundaries. To date, such landscape-level cooperation has not yet been developed because the local administrative units are struggling for economic income rather than for forest sustainability. It is important for the top government to provide the locals with sufficient economic support by using economic incentives for sustainable forest management. Moreover, a government-operated tourism industry on Changbai Mountain should pay for forest protection within CBR and forest restoration around CBR (Farley and Costanza 2010).

Applying the ecosystem approach

It is important to effectively protect both the visible form (trees) and invisible functionality of the forest ecosystems on Changbai Mountain. This can be achieved by applying the ecosystem approach that tends to conserve all the species in an ecosystem (Walker 1995). Poaching, herb collection, and intensified recreation represent the major threats to the ecosystem approach to forest conservation on Changbai Mountain. China's forest policies cover forestry activities that range from afforestation to forest protection (Wang et al 2007). The implementation of the forest policies under the top-down forestry administrative structure (Tang et al

2009) has been demonstrated by an iron fence (Shao and Zhao 1998) and an armed patrol (Wang et al 2007). However, such forest policies have failed to control human activities such as seed harvesting and forest recreation. China's forest policies need to be improved to target not only the trees but also the processes of forest ecosystems. Ecologically sound conservation effects can be achieved if local people see an economic or political benefit through participating in ecosystem protection (Galvin and Haller 2008).

Promoting transboundary cooperation

Any forest or wildlife habitat across national borders should be treated as a single functional entity. Forest conservation on the Chinese side alone is incomplete given the location and size of CBR. It is necessary to promote broader cooperation between the 2 nature reserves across national borders between China and DPRK. Although the 2 biosphere reserves on Changbai Mountain are next to each other, there exist different degradation processes in forests and different strategies for ecological conservation between them (Tang et al 2010). Multiscale, multidisciplinary, and multistakeholder transboundary conservation efforts need to be made between China and DPRK (Chettri et al 2007). The Chinese and international funding agencies should support cooperation projects to study the relationship between chronic human-induced environmental threats and resulting consequences at the landscape level, as well as to create opportunities for cross-border conservation actions, such as exchange visits and organizing meetings, on Changbai Mountain. The landscape and ecosystem approaches should serve as fundamental principles of transboundary conservation initiatives, and specific measures can refer to the guidelines from the International Union for Conservation of Nature (eg Sandwith et al. 2001).

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