TEMPORAL AND SPATIAL DYNAMICS OF HUMAN IMPACTS ON FOREST RESOURCES IN THE AMUR RIVER BASIN AFTER THE MID-TWENTIETH CENTURY

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SUMMARY

For a forthcoming qualitative study on the potential relationship between the eco-functions of the "giant" fish-breeding forest system (GFBF) and forest degradation in the Amur River basin, and to better understand how much past anthropogenic impacts have been damaging the function, the author carried out studies to clarify the temporal and spatial dynamics of human impacts on forest resources in this region. In particular, the studies examined the period after the mid-twentieth century, when forest degradation accelerated, and were based on available research resources plus field work, with a special focus on forest exploitation for log production and large-scale forest fires. Temporal changes in the structure of the timber trade since the mid-1980s were also studied in order to identify the dynamics and underlying causes. These studies were based on earlier works, databases developed by several institutes, and a series of interviews in both the Russian Far East and China. This study tried to reveal the big picture of dynamics of anthropogenic impacts in the basin. It included rapid forest degradation during the 1970s and early 1980s due to intensive timber production under state economic policies and frequent large-scale forest fires, along with strong domestic timber demand. A significant decrease in forest development from the late 1980s to early 1990s, mainly because of resource depletion on China's side of the basin and lower demand under socio-economic disorder during the transition period on Russia's side of the basin, was clarified. Also seen was a revitalization of forest development on Russia's side of the basin, mainly due to a rapid increase in timber exports to China after the late 1990s. Consequently, forest degradation in the basin has been amplified overall along the Amur River. Dramatic changes in the structure of the timber trade since the mid-1980s, brought about by China replacing Japan as the top importer of timber from the Russian Far East, were also clarified. The conclusion addresses future issues for gaining a more qualitative understanding of the socio-economic part of the GFBF system.

INTRODUCTION

The Amur is an international river running through Mongolia, China, and Russia, with a length of 4,444 kilometers (km), including its tributaries, and a watershed area encompassing 2,051,500 square kilometers (km^2). Forests are a key element of the landscape in the Amur River basin and play a very important role in maintaining the watershed's ecosystem and material flows, from the river's upper tributaries in China and Mongolia to the Okhotsk Sea in the Russian Federation (Shiraiwa 2005, Onishi et al. 2008, Simonov and Dahmer 2008).

Since the beginning of the twentieth century, however, the forests in the basin have been either destroyed or seriously degraded, mainly due to agricultural practices and forestry exploitation for timber production, as well as forest fires (Himiyama 2002, Simonov and Dahmer 2008). As a result, logged and burned forests in the basin encompassed around 6,000 km^2 and 12,000 km^2, respectively, and subsequently the forestland area has decreased by about 110,000 km^2 over the last 80 years (Ganzey et al. 2009).

Forestry activities in China's province of Heilongjiang, which accounted for a large portion of the activities on China's side of the basin, progressed until the end of the twentieth century, and resulted in serious depletion of its forest resources (Dai 2000). The forests on the Russian side of the basin remained relatively untouched until recently, but after the collapse of the Soviet Union in the early 1990s, export-oriented forest development expanded rapidly (Kakizawa and Yamane 2003, Sheingauz et al. 1996). After 2000, China emerged as a major importer of Russian timber, and forest products from the Amur River basin became a major source of timber supply (Yamane and Lu 2001, Kakizawa and Yamane 2003, Yamane 2003, Lankin 2004, Sheingauz et al. 2005, and Song et al. 2007). Export-oriented forest development in Russia, mainly driven by demand in China, however, is likely to bring about further environmental degradation and damage to the entire watershed's ecosystem and material flows.

A next step of the Amur-Okhotsk research project might be a qualitative study on the potential relationship between the eco-function of the "giant" fish-breeding forest (GFBF) system and forest degradation in the basin, and also understanding to what extent anthropogenic impact has damaged the function so far. Thus, it is very important to assess the temporal and spatial dynamics of approximate causes and their underlying causes on the basin.

Based on this background, the author carried out studies to clarify the temporal and spatial dynamics of human impacts on forest degradation, in particular after the mid-twentieth century when forest degradation began accelerating, based on available research resources plus field surveys, with a special focus on forest exploitation for log production and large-scale forest fires in the basin, where the timber trade has gotten a lot of attention as the driving force of forest degradation (e.g., Yamane 2003, Lankin 2004, Mishina 2008). Thus China–Russia timber transportation routes, timber flows, and infrastructure developments since the mid-1980s were also studied in order to identify dynamics and underlying causes. The paper analyzes timber-trade statistics from both state reports and related individual land or seaport gateways, and outlines recent changes in the timber-trade policies of both countries. Additionally, the impacts of the latest policy changes on the future of China–Russia timber-trade flows in the basin were discussed.

TARGET AREAS AND APPROACHES

1. Target areas

The Chinese province of Heilongjiang and major regions in the Russian Far East (RFE), such as Khabarovsk Krai, Primorsky Krai, Amur Oblast, and Zabaykalsky Krai (formerly Chita Oblast), were selected as target areas for the study. This province and these regions encompass the core watershed of the Amur River.

2. Approaches

(1) Assessing temporal and spatial changes of forest degradation in the basin

As for forest development on China's side of the basin, temporal changes after the mid-twentieth century were assessed based on various earlier studies (e.g., Tao 1987, Dai 2000, Yu and Shinohara 1999, Yu and Shinohara 2001). Chinese state forest resource statistics from 1987 to 2007 were also used for the temporal and spatial change analysis of logging activities on individual state forest management units in the province.

Information in reports on forest fires in the province is fragmentary, but Chinese state forest resource statistics were helpful in examining the temporal changes of forest fire frequency and burned areas in Heilongjiang. Several earlier studies, such as Dai (2000) and Jin and Hu (2002), also indicate the causes of forest fires and aided in discussion of the relationship between logging activities and forest fires in the province. The spatial distribution of large-scale forest fires in the province was analyzed only for the period from 1980 to 1999 and was based on Jin and Hu (2002).

As for forest development on Russia's side of the basin, temporal changes after the mid-twentieth century were analyzed based on a database developed by the International Institute for Applied Systems Analysis (IIASA) and the Far East Russia Economic Research Institute. The author could not acquire information concerning the spatial dynamics of logging activities in the basin, and thus an earlier study for Khabarovsk Krai conducted by Kakizawa (2004) was referred to for discussion. Underlying causes of the dynamics were also discussed based on earlier studies such as Sheingauz et al. (1996), Yamane (2003), and Sheingauz and Kakizawa (2003).

Concerning forest fires that occurred on Russia's side of the basin, it was not possible to acquire temporal fire statistics covering the four target regions after the mid-twentieth century, thus information on Khabarovsk Krai and Primorsky Krai derived from earlier studies such as Yefremov and Shvidenko (2004) and Sheingauz (2000) was analyzed. Underlying causes of large-scale forest fires were examined, also based on earlier studies conducted by Korovin (1996), Valendik (1996), and Sheingauz (2000), and additional interview investigations with local experts and related officials conducted in 2007, 2008, and 2009. The spatial distributions of large-scale forest fires were analyzed for three different periods: 1970 to 1983 (Valendik 1996), 1987 and 1989 (Korovin 1996), and from 2004 to 2006 (IIASA database 2004–2005).

(2) Clarifying the dynamics of timber trade structure in the basin

Aiming to grasp the structure of the timber trade from the 1980s to 1990s from the

RFE to Asia-Pacific countries, the author examined several earlier studies conducted by Waggener et al. (1996), Sheingauz et al. (1996), Yamane and Lu (2001), and Kakizawa and Yamane (2003). Then the author roughly determined major timber trade routes as well as quantitatively assessed timber flows from the basin to Japan, China, and South Korea.

In order to update information on the flow of timber from Russia to China and timber trade-related policies, the author visited Beijing, China, in August 2001, November 2002, July 2003, July and December 2004, June 2005, August 2006, July and November 2007, and March 2009, and the city of Khabarovsk in Khabarovsk Krai, Russia, in December 2004 and August 2008. The figures on volumes of timber transported from Russia to China through individual customs points were acquired from China's customs statistics from 1996 to 2005. As for statistics on timber trade with Japan, the author referred to information provided by Japanese timber industry journals and conducted interviews with local experts or related parties at the same time as conducting field work.

Regarding recent improvements of individual customs facilities and development of timber trade from the RFE in border areas of the basin, the author went through Chinese gateway cities and towns to inspect their conditions (Mudanjiang, Jixi, and Jiamusi in Heilongjiang province) in October 2003, May and July 2004, August 2006, July and November 2007, and August and October 2008. In addition to these field works, the author analyzed the latest condition of these three locations using information gathered from internal and external sources such as related websites, literature, and documents.

FINDINGS

1 Temporal and spatial changes of forest degradation in Heilongjiang, China

(1) Forest exploitation for log production

Forest exploitation for log production conducted in Heilongjiang progressively intensified during the last half of the twentieth century, and thus serious forest degradation occurred on China's side of the basin until the end of the century.

After Communist Party leader Mao Tse-Tung (Mao Zedong) founded the People's Republic of China, the forests on China's side of the basin were designated as state forest. Forestry development then progressed more intensely under the control of the central government. Initially, from 1945 to 1952, the area produced a massive amount of timber to support the liberation war and post-war reconstruction. Timber production during the period was estimated at 21 million cubic meters (m^3), representing half of the total timber production of the whole country (Figure 1). Heilongjiang's local government

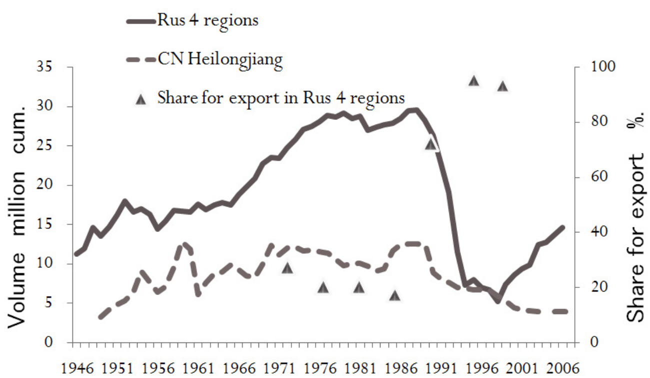

Figure 1. Log production in Heilongjiang and four major regions in the RFE after the mid-20th century, derived from Chinese state forest statistics and IIASA database.

decided to develop infrastructure with the aim of strengthening forestry development, resulting in various extensive projects such as railway recovery, new railway construction for logging, relocation of sawmills, and extension of logging rail lines from resource-depleted areas to the resource frontier. As a result, forestry development expanded again into pristine areas.

When modern China entered a strong phase of economic development after 1953, the country succeeded in establishing a centralized economic planning system modeled after the system in the former Soviet Union. The state forest in Heilongjiang was allocated an annual planned timber production volume by the central government, and thus forest management leaned even further towards unsustainable methods to achieve the imposed production target. Since Heilongjiang contained the most abundant natural resources such as coal, timber, and reclaimable barren lands, in addition to having suitable infrastructure for resource development and industrialization, the province was assigned to be a major natural resource-driven industry area. As for the state forests in the province, the "northeast state forest regional development master plan" was established, and more intensive forestry development was started based on the plan. Because of this situation, a very high target of timber production was set for the province, and unsustainable forestry activities accelerated rapidly as a result. Some areas began to employ intensive selective-cutting in timber production, and the rate of clear-cutting by logging operations also increased significantly. Consequently, the speed of forest loss in the province accelerated further.

This forest management style based on over-harvesting continued until 1962, when the Great Leap Forward ended. After that, the government tried to modify forest management policy to be more sustainable. Unfortunately, this attempt did not last long. The Great Proletarian Cultural Revolution started in 1966, which eliminated the state's forest management system, and unsustainable practices recommenced. The annual mean timber production volume in Heilongjiang's state forest during this period was more than 12 million m^3, and more than 50% of the area logged was being clear-cut and not replanted. As a result, forest loss in the province worsened.

The Cultural Revolution in China ended in 1976, and then the country rapidly evolved into a commodity-based economy under planned socialism. In the background of such a policy change, the state decided to switch its forest management policy from being destructive to being more sustainable under the forest law of the country, which was established in 1979 and finally entered into force in 1984. Unfortunately, over-exploitation continued due to the unabated pressure on the forests in Heilongjiang to achieve high production

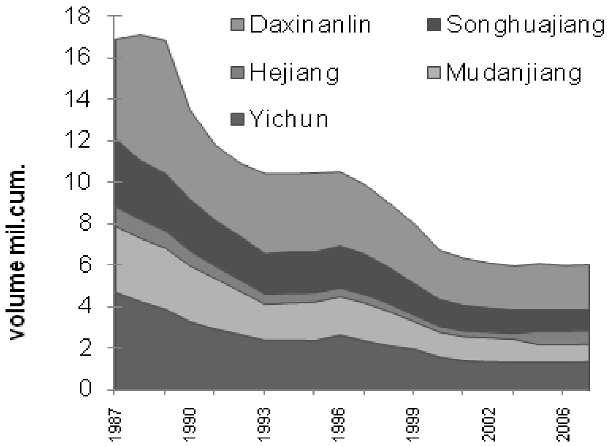

Figure 2. Log production from 1987 to 2007 in state forest management bureaus in Heilongjiang, China, derived from Chinese state forest statistics.

goals, and forest loss in the area continued. Annual mean resource depletion reached 38 million m^3, which was twice the annual growing stock in the area.

After 1992, when China's transition to a market economy accelerated, a decrease in timber production due to forest resource depletion in the area became a serious issue, and consequently deficits in income from state forests became more acute. The cumulative deficit of state forests reached one billion yuan, and half of all state forests stayed in the red for more than two consecutive years until 1995.

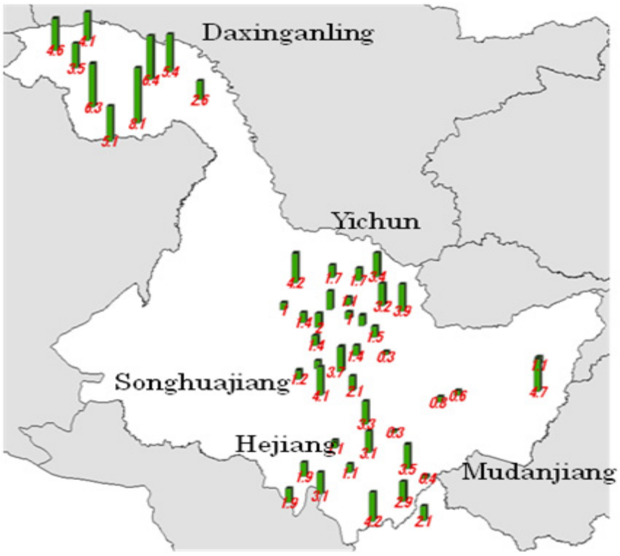

Figure 3. Total log production from 1991 to 2007 in individual state forest management units in Heilongjiang, derived from Chinese state forest statistics.

The cumulative impacts of forestry development on the land led to devastating floods downstream of logged areas after the 1980s. Large-scale floods continue to occur frequently and the damage they cause has become more extensive. A catastrophic flood in 1998 in the watersheds of the Songhua, Yellow, and Yantze rivers, which killed 3,000 and affected 240 million people, is still fresh in the people's memory. Finally, the Natural Forest Protection Program (NFPP) was launched in 1998, leading to significant cuts in timber production from state forests. Structural over-exploitation of natural forests in the area, which had continued throughout the twentieth century, finally ended.

Log production volumes of individual forest management bureaus in Heilongjiang during 1987 and 2007 are shown in Figure 2. Total logging volume decreased significantly even before the start of the NFPP and further decreased progressively after that. Major forest management bureaus such as Yichun and Mudanjiang reduced their production significantly. In contrast, log production in management units under the Da Xing'anling forestry management bureau, located in the upper river basin, were still active (Figure 3). As a result, forest degradation has progressed all around the province, particularly in the Greater and Lesser Xing'anling Mountains.

(2) Large-scale forest fires

In the 40 years between 1950 and 1990, around 620,000 fires were recorded in China, burning 36 million hectares (ha) of forest. Most fires were observed in state forests in the three northeastern provinces, and frequent fires have accelerated the degradation of forest resources, mainly in natural forests. Forest fires occurred most frequently until the middle of the 1960s. More than 20,000 fires per year were recorded in seven of the years between 1950 and 1965. The number of forest fires then decreased slightly until 1968, but during the 1970s it increased again, with more than 10,000 fires recorded per year. In the 1990s the number of fires dropped significantly to 5,000, due to the strengthening of fire control and diminished forestry activities.

Changes in the frequency of forest fires in Heilongjiang vary slightly compared to the rest of China. Forest fires in the province occurred most frequently in the 1970s, with the number being from 500 to 1,500 per year, but it dropped dramatically thereafter (Figure 4). The sizes of affected forest areas followed similar trends to the number of forest fires. Until the middle of the 1960s, during years with many recorded forest fires, more than one million ha were affected annually in Heilongjiang, indicating that forest fires, along with forestry development, were a major proximate cause of forest loss here.

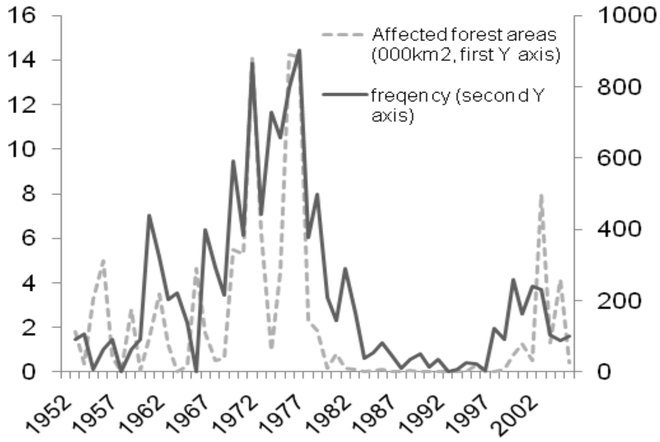

Figure 4. Affected forest areas and frequency of forest fires from 1952 to 2007 in Heilongjiang, China, derived from Chinese state forest statistics.

From 1970 to 1990, forests suffered four years of extremely large fires, which affected a forest area of more than one million ha, and thus forest fires remained a major proximate cause of forest loss in the country. The forest areas affected in the whole country from the middle of the 1960s to 1978 showed closely similar dynamics as in Heilongjiang (r = 0.95), and the share in Heilongjiang exceeded 50% for most years during this period. Thus the facts indicate that forest fires in China during the period were predominantly in Heilongjiang.

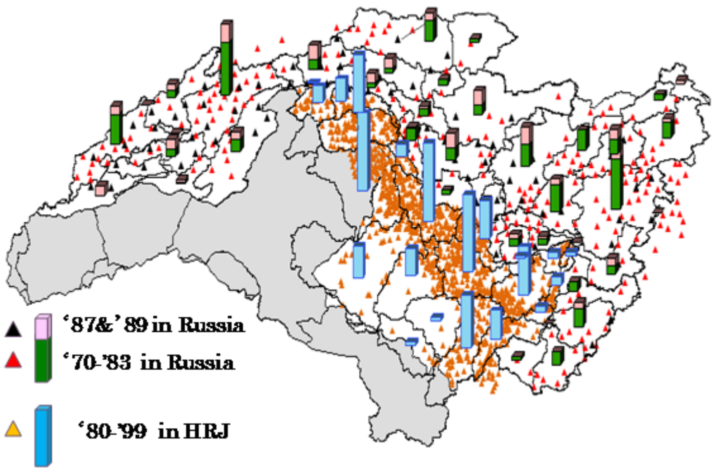

Figure 5. Spatial characteristics of large-scale forest fires in the Amur River basin before 2000.

After catastrophic forest fires occurred in the northeast region in 1987, the central government strengthened the fire control system. The frequency of fires and the area damaged by forest fires decreased dramatically in the 1990s. However, large-scale fires seemed to increase in the 2000s due to undetermined causes.

A positive correlation ($r^2 = 0.2382$, n = 32) was observed between log production and the frequency of fires between 1954 and 1984. Additionally, large-scale forest fires occurred frequently (around 70%) mainly in state forests in the Greater and Lesser Xing'anling Mountains between the 1960s and mid-1980s (Figure 5a). These facts suggest that the frequency of forest fires has increased in line with the progress of forest development in the region, and the careless handling of fire by forest workers has caused many forest fires.

Although the causes of forest fires vary, there are only two main categories of cause: human or natural. Relatively few forest fires have natural origins, mainly lightning. Forest fires caused by lightning are relatively more common in unexploited forested areas in the northeast, where most forest fires are of non-production origin, livelihood origin, or accidental origin. Smoking in the forest, using fire for heating or cooking, burning paper for devotional purposes in tombs, etc., are customary uses of fire in day-to-day life as people follow their cultural traditions. It is likely that most forest fires in Heilongjiang are closely related to human activities, since both the number and area of forest fires increased in sync with the over-exploitation of forest resources.

2. Temporal and spatial changes of forest degradation and the underlying causes on Russia's side of the basin

(1) Forest exploitation for log production

Total log production in the four major regions of Khabarovsk Krai, Primorsky Krai, former Chita Oblast, and Amur Oblast was the most active during the 1970s and 1980s, and dropped to a lower level in the 1990s (Figure6). Then the activities became revitalized since the end of the 1990s.

Logging operations progressed mainly in Primorsky at the beginning. After the 1960s, full-scale logging also started in Khabarovsk, and the speed of forest development accelerated. From 1980 to 1990 the total logging area and volume in both krais were around one million hectares and 20 million m3, respectively. Logging activities in former Chita Oblast were relatively stable from the 1960s to 1980s, at around five million m^3 in production, but log production dropped to less than one million m^3 in the last half of the 1990s. Log production in Amur Oblast increased gradually from 2.5 million m^3 in 1946 to 7.1 million m^3 in 1988, and then decreased drastically to 0.4 million m^3 in 1998. After 1998, log production recovered, most obviously in places like Khabarovsk and Primorsky krais.

Logging operations in Russia paid little attention to sustainability and used a "cut-and-move" strategy—moving to new logging frontiers when timber resources were exhausted in one area. It was said that such logging methods originated in legal and institutional arrangements aiming to achieve production quotas under the planned economy, where achieving the volume of harvest assigned by Moscow was recognized as the most critical goal; thus neither profitability nor efficiency were paid attention. Timber products were sold at very low prices and the forest industry was sustained by generous federal subsidies. Most timber produced in the region was loaded to European Russia and exported mainly to Japan. The profits from forest development were not redistributed for forest

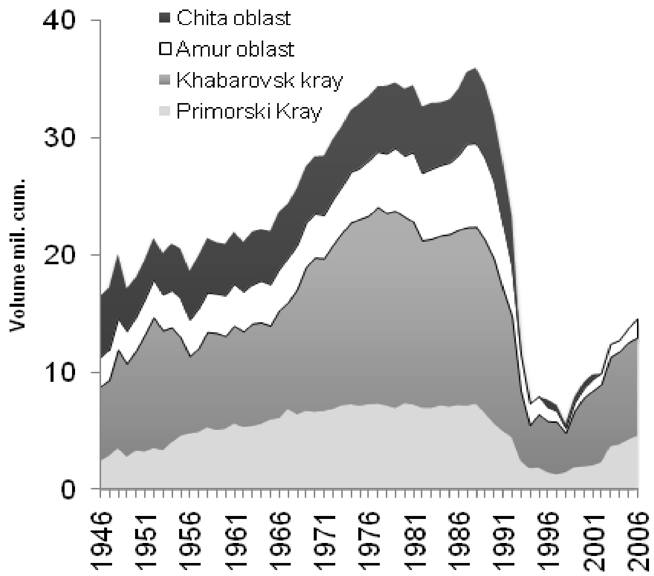

Figure 6. Log production of four regions in the RFE from 1946 to 2006, developed from IIASA database.

production such as forest management and technology modernization or improvements to bring more efficient resource use.

After the collapse of the Soviet Union, on top of the shortcomings of the legal and institutional base, weakened forestry governance caused by political disorder and economic crisis increased extensive logging even more than before. Log production for export has gone up especially due to the rapid increase of domestic transportation costs and sharply lowered domestic demand.

Until recently, logging operations in the region were still quite extensive and wasteful, with the main aim of harvesting high-quality logs. It is said that logging timber wasted amounts of around 25% to 30% of the harvested wood stock (Sheingauz 2000a). In selective cutting only 35% to 50% of usable stock is felled, and in clear cutting only 65% to 80%. Only thick and high-quality timber is carried out from logging sites; utilization of the rest is very low. This is why very few facilities for processing thin- and low-quality timber are found in the territory. Usually only 30% to 35% of harvested timber was processed in the southern part of the Russian Far East (S-RFE); as a result of the economic crisis these figures have dropped to 10% to 15%.

Such logging operations were common in the Soviet period, but unreasonable pricing of timber and a shortage of wood-processing facilities for valuable wood amplified the extensive and wasteful logging practices. In addition, insufficient control on the violation of rules was also an underlying factor. The devaluation of ruble since 1998 created favorable conditions for export, because logging is now the easiest way to acquire foreign currency.

In Khabarovsk Krai, logging operation hotspots moved from forests near the city of Khabarovsk to untouched forests farther north along the Baikal–Amur Railway, and finally reached the forests along the Tatarskiy Strait (Kakizawa 2004). In Primorsky Krai, logging operation hotspots reached the upper stream of Bolshaya Ussurka River (known until 1972 as the Iman River, a branch of the Ussuri River) in the 2000s. In Amur Oblast and former Chita Oblast, logging activities progressed into easily accessible forests mainly along the Trans-Siberian Railway until the mid-1990s, but since the end of the 1990s the China–Russia border area has been added as a major arena for log production in particular for export to China. In sum, the fronts of logging activities on the Russian side of the basin have moved to the until-recently untouched forests along the Amur River.

(2) Large-scale forest fires

The number of fires and area burnt manifest very wide fluctuations from year to year. In the S-RFE, after World War II, Primorsky Krai and Khabarovsk Krai experienced six and nine large-scale forest fires, respectively. Catastrophic fires seem to occur once every 10 to 12 years. However, the forest fires of 1998, which occurred mainly in Khabarovsk Krai and Sakhalin Oblast and burned an area of 2.2 million ha, were the worst since the forest fires of 1954 and 1976. Yefremov and Shvidenko (2004) pointed out that the history of trends prior to and after the 1980s clearly shows an increased level of natural fire incidence, which might be viewed as an increase in the share of forest fires caused by anthropogenic factors.

As for the spatial distribution of large-scale forest fires on Russia's side of the basin during the former Soviet-era, large-scale forest fires occurred the most frequently overall particularly in former Chita Oblast and Khabarovsk Krai, and it seems that these occurred more frequently during the closing years (Figure 5). In the 1990s and 2000s, large-scale forest fires occurred more frequently than before. In recent years, large-scale forest fires occurred frequently in Chita, Amur, and Jewish Autonomous Oblast (JAO), or near the Russia–China border area (Figure 7).

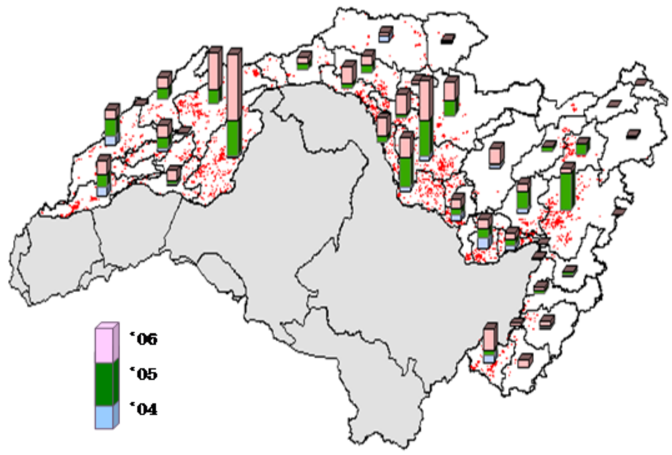

Figure 7. Spatial characteristics of large-scale forest fires in Russia's side of the Amur River basin from before 2004 to 2006.

Recent official studies indicated that more than 70% of the forest fires were caused by human activities. It has also been pointed out that intensive selective logging has made forest conditions drier and such changes amplify the risk of fires caused by spontaneous combustion (Sheingauz 2000b). In this sense, commercial-logging activities have a close linkage with forest fires.

The frequency and spread of fires are also very different in Primorsky Krai and Khabarovsk Krai because of differences in the type of forest vegetation and the intensity of forest management. It is said that there is no close correlation between forest fires and logging operations, but the areas where forest fires occurred in both krais are along the Sea of Japan and main transportation corridors, such as the Trans-Siberian Railroad and BAM railroads or main roads leading to loading points. This observation suggests the connection of forest fires and human activities, including logging operations. In fact, the frequency of forest fires has increased in line with the progress of forest development in the region, and the careless handling of fire by forest workers has caused many forest fires. Large amounts of slash left at logging sites can be very good fuel for fires. In addition, new road construction for logging operations has opened new access routes for local people, leading to small fires in the forests. There is a possibility that these tendencies mentioned above are the same even in other regions in the basin. The recent increase in the frequency of large-scale forest fires near the China–Russia border area might have some connection with the significant increase of logging activities.

As Valendik (1996) pointed out, for a fire to achieve a large size, fire control is closely connected and thus a weakened fire control system can be a key underlying cause for frequent large-scale fires. The system for forest fire control in Russia had a strong structure and was designed systematically. The expenses were basically financed from the state budget: fire control, construction of forest roads, water reservoirs and fire barriers, laying of mineral strips on the ground, purchasing of equipment, salaries for staff, and rent of aircraft. The legislative base for forest fire control is also well prepared, including the Forest Code of the federation and federal or local acts. After the collapse of the Soviet Union, however, the fire control system became considerably weakened. This change was caused by a substantial decrease in the budget from the federal government for the fire control system, due to the unfavorable economic condition during the 1990s in Russia. The budget for air-based and ground-based systems for fire control during 1991 and 1996 were relatively stable, at 129 to 168 million rubles, and 5 to 15 million rubles, respectively. However, the consumer price index reached 248,733 points in 1996 and consequently the financial base became seriously inadequate for maintaining the fire control system. A combination of inadequate resource allocation of regional authorities by the central government, inability of regional authorities to clear year-end debts resulting from this situation, and the release of annual budgets too late for effective fire control measures to be put in place prior to the fire season were fundamental causes of the fires (UNDAC 1998). This financial situation at the end of the 1990s led to a serious shortage of capacity for fire control systems and a significant deterioration of their original functions: effective fire monitoring and quick-response fire-fighting. The biggest effect was a cutback of air-based monitoring. This curtailment was caused by steep rises of costs for aircraft and fuel prices. The capacities for ground monitoring also declined. The costs for equipment for fire-fighting as well as fuel for large-sized machinery, such as bulldozers and trucks loaded for staff, became prohibitively high, and shortages of living essentials and delayed wage payments for staff also became critical.

There is a high possibility that the frequency of large-scale forest fires, such as the fires of 1998, will increase noticeably, because the situation is not likely to improve for some time. In fact, the situation has not improved even in 2009, and the reinforcement of the fire control system has seen little progress. Rather, the forest management function of local bodies has been severely weakened further, since the new forest code legislates that such functions are entrusted to the private sector (Kakizawa et al. 2009, Kakizawa 2009).

3. Temporal changes of timber trade structure in the basin

(1) General trend of timber trade from the Russian Far East to Asia Pacific countries after the mid-1980s

Timber exports from the RFE fluctuated between five million m^3 and six million m^3 from the 1980s to the end of the 1990s, but thereafter trade volume increased rapidly to 15 million m^3 in 2006 (Figure 8). Raw logs has been a major export item consistently during the period, but the structure has changed drastically in the last few years, including a significant increase of lumber exports, a switch in the top import country from Japan to China after the year of 2000, a shift from sea routes to inland routes for timber transportation, etc.

Most of the timber from the RFE until the mid-1990s was headed for Japan; China and allied countries such as the Republic of Cuba and South Korea (a new partner since the 1990s) imported timber from the RFE, but their shares were relatively small. According to one expert’s estimation, about 50 to 60% of timber products in the S-RFE were exported to Asia-Pacific countries, mainly Japan, until the mid-1990s. Japan has imported Russian timber constantly since the 1960s. In the middle of the 1970s, for example, around nine million m3 of timber, mostly raw logs, were shipped to Japan. Even after the collapse of the Soviet Union, imports of Russian logs to Japan steadily increased after 1991 (around four million m^3), reaching a high in 1999 (around six million m^3).

Timber exports to China after 1998 increased at a rapid pace. The volume of timber flowing from the RFE to China increased significantly from 1996 to 2005, growing from about 0.5 million m^3 to 15 million m^3, in tandem with the trend of China's total timber imports. In contrast, timber exports to Japan in the period decreased by around five million m^3 with some extent of variation.

Log exports in the region, which had been increasing at a rapid pace, ended up decreasing after 2008. Such a change has been brought about mainly because of the step-by-step hike of Russian log export tax issued in 2007,

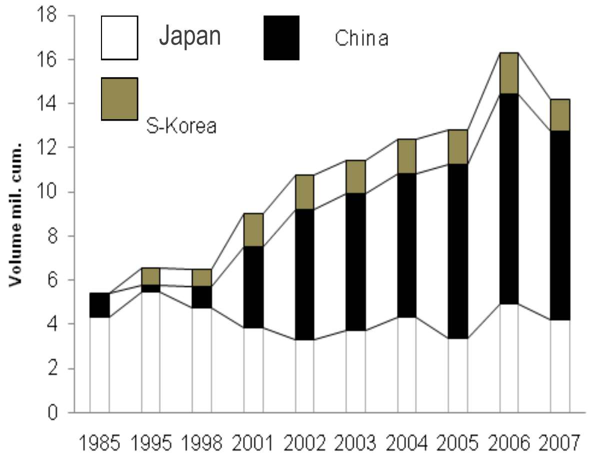

Figure 8. Temporal change of timber exports from the RFE to Northeast Asia Countries, derived from several sources.

(2) Transportation routes and their development

Timber is transported from the RFE to such major countries as Japan, China, and South Korea by rail, ship, ferry, and truck through the following three major routes.

The first is the seaport routes. Timber produced in the basin are transported by rail on the main line of the Trans-Siberian Railway, exported from seaports such as Nakhodka and Vladivostok in Primorsky Krai, and then shipped to major seaports in Japan, China, and South Korea. From Eastern Siberia or the RFE, timber is moved by rail along the Baikal–Amur Railway and then to Russian seaports such as Vanino and Sovgavan. A common variation of this route is to export logs from Nikolayevsk-na-Amurla at the river's mouth

The second is the land port routes. Timber is transported by rail on branch lines of the Trans-Siberian Railway to the border, and then by rail or truck to several gateways in China. Timber produced from nearby border areas is transported across to China by truck or ferry.

In the main channel of the Amur River watershed of the Amur basin, the Manzhouli gateway in the Inner Mongolia autonomous region is the only route connecting directly by railroad to Russia's Zabaykalsk, Chita Oblast. There are also two small routes used in the province and eight small or medium-sized gateways in China's Heilongjiang province, where Russian timber is transported by truck or ferry from Amur Oblast, Jewish Autonomous Oblast, and Khabarovsk Krai. Among them, Manzhouli is the major gateway in the main Amur River watershed. In 1992 this once-small border city was one of the first inland border cities opened up by the People's Republic of China. After 2000 the city developed dramatically, with construction of a new domestic airport connecting to Beijing and Harbin, as well as highways leading to Harbin, the capital of Heilongjiang province, through Hailar. Manzhouli started establishing a processing zone for import materials in 2003, and the project has progressed steadily since then. A wood-processing area was established in the zone in 2004, and now more than 40 Russian wood-processing enterprises are in operation there. As log imports from Russia increased, freight yards were enlarged in 2004 to expand capacity, and construction of a new yard also has been progressing. In the Ussuri River watershed of the Amur River basin, the Suifenhe gateway in Heilongjiang province is the only corridor connecting directly by rail to Russia's Grodekovo station (in Pogranichnyy) in Primorsky Krai. The distance to Ussuriysk and Vladivostok is 123 km and 230 km, respectively. Suifenhe was opened up as one of the first border cities, like Manzhouli and Heihe, in 1992, and is a core gateway of the China–Russia timber trade, especially for timber from the southern part of the RFE. The railroad gateway is a 24-hour operation with an annual handling capacity of more than six million m^3, having expanded in stages since 2000, and now the improvement of its cargo terminal station (Suifenhe North Station) has been completed. The gateway has a road connection with Russia, constructed in 1990, and it connects with a highway leading to China's city of Harbin through Mudanjiang. An already approved highway project will connect to Manzhouli. Other small routes include the Bikin–Raohe (or Jao-ho) river corridor (Khabarovsk Krai to Heilongjiang province), the Markovo–Hulin river bridge corridor (Primorsky Krai to Heilongjiang province), the Turiy Rog–Mishan land corridor (Primorsky Krai to Heilongjiang province), and the Poltavka–Dongning road corridor (Primorsky Krai to Heilongjiang province). Trucks can cross the border along the Bikin–Raohe river corridor during the winter when the rivers freeze and Markovo–Hulin corridors by border-bridge.

The third is the river port routes. Recently, as river transportation on the Amur River was opened up for trade, routes leading to China's river ports have also gradually been opened up. Among such sea-to-river routes, there is a new one that starts at a seaport, such as De-kastri and Sizuman, and then up the Amur River to river ports in China. In this case, logs are re-shipped from Nikolayevsk-na-Amurla or Khabarovsk. The Tongjiang gateway in Heilongjiang province is a recent major river port for the route. The river port was upgraded to increase capacity after 2004. Timber imported at the river port is transported in log booms from the lower reaches of the Amur, and is made up mostly of coniferous tree species such as larch and spruce. The city also has highway construction projects leading to Harbin through Jiamusi.

(3) Temporal changes of timber-trade flows and their driving forces

It is easy to guess the significance of changes of structure for timber trade on the basin by considering the development of the China–Russia timber trade after the mid-1990s, as described above. However, there have not been comprehensive studies conducted on temporal changes of timber flows and driving forces since the mid-1980s until now, partly because there are many difficulties in acquiring enough information. The author tried to estimate those through synthesizing various information derived from resource research, interviews, field work, etc.

The structure of timber-trade flows prior to and after the mid-1990s clearly shows a very different shape. Prior to the mid-1990s a major exit was seaports and the leading importer was Japan, but after the mid-1990s the major exits shifted to inland ports, and China became a top importer from the region.

The timber transported from the basin to Japan and South Korea passed 100% through seaport routes, and the most timber (around 90%) to China was also exported through these routes until the 1980s. Total timber export in 1985 from the RFE was around 5.7 million m^3 and the most timber was exported from seaports bound for Japan (Figure 9). As described above, these were small export volumes for China and other allied countries compared to these days. It is worth noting that Primorsky Krai, which is a relatively narrow region but located adjacent to Japan, shared a half of total timber exports from the RFE.

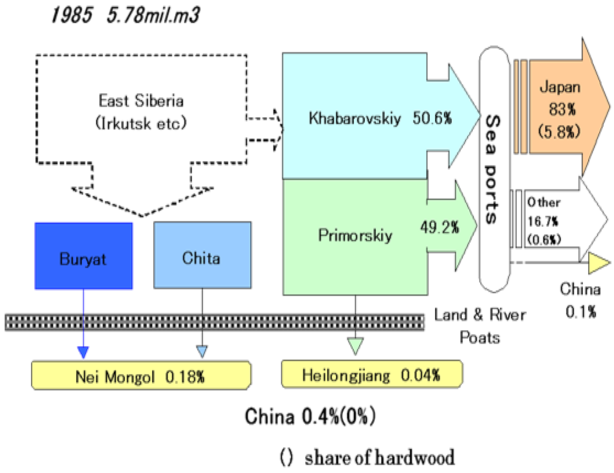

Figure 9. Estimated timber flows from the RFE to northeast Asia countries in 1985, based on several timber trade statistics.

In the 1990s the export volume increased to around 7.2 million m^3 but there was no notable change to the structure, except South Korea started to import logs from the RFE. The period during the collapse of the Soviet Union brought social and economic disorder throughout the country, and domestic demand dropped remarkably, thus most logs produced in the region were exported to Asia-Pacific countries. Since the 1990s, most of the timber transported from Russia to China shifted to pass through inland border corridors.

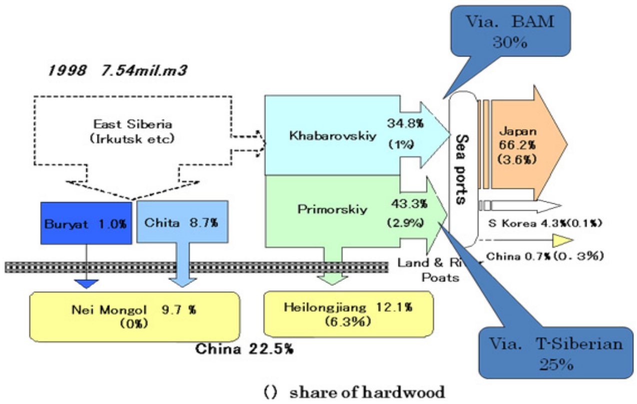

Figure 10. Estimated timber flows from the RFE to northeast Asia countries in 1998, based on several timber trade statistics.

The supply of RFE timber products to Asia-Pacific countries was equal to 8.39 million m^3 in 1998. Most timber products (78%) were exported by sea, while 22% was exported by rail. From the RFE provinces, 43% was shipped from ports in Primorsky Krai and 35% from ports in Khabarovsk Krai (Figure 10). From Buryat Republic most timber was transported by rail. Logs produced in the provinces adjacent to the Russia–China border, including Buryat, Chita, and a part of Primorsky, were transported to nearby gateways via rail and then loaded to China. This share of total export volume was around 20% in 1998. Logs produced inland or in the areas along railroads in Primorsky and Khabarovsk krais were transported to the coastal ports in these two provinces via two main railroads and then shipped out mainly to Japan and South Korea. This has been a principle route in both the Soviet and post-Soviet eras. On the coastal area of the Pacific Ocean in Primorsky and Khabarovsk krais, logs are transported directly to the nearest coastal ports by truck and then loaded mainly to Japan and South Korea. The share of this route was around 20% and has been increasing recently. In comparing the two watersheds of the Ussuri River and the Amur River, the volume of timber flow from the Ussuri watershed was more than 60% in 1996 compared to the basin's total, and was larger than that from the main Amur River basin. In 1997, however, the flow from there reached a 50% share and then increased to around 60%.

In the 2000s the structure changed drastically mainly due to a rapid increase of timber exports to China. More than 80% of the timber trade between the two countries in 2004 crossed via inland border points. In 2005 around 40% of timber products for export were exported by sea and 52% by rail (Figure 11). From the RFE provinces, 43% was shipped from ports in Primorsky Krai and 35% from ports in Khabarovsk Krai. Logs produced in the provinces adjacent to the Russia–China border, including, Chita, and a part of Primorsky, were transported to nearby gateways via rail and then loaded to China. This share of total export volume was around 20% in 1998. Logs produced inland or in the areas along railroads in Primorsky and Khabarovsk krais were transported to the coastal ports in these two provinces via two main railroads and then shipped out mainly to Japan and South Korea. This has been a principle route in both the Soviet and post-Soviet eras. On the coastal area of the Pacific Ocean in Primorsky and Khabarovsk krais, logs were transported directly to the nearest coastal ports by truck and then loaded mainly to Japan and South Korea. The share of this route is around 20% and has been increasing recently.

These changes were accelerated not only by global trade liberalization becoming associated with the World Trade Organization (WTO) but also improvement in China–Russia border trade conditions, including several preferential trade systems for border trade, favorable trade regulations for log imports, and infrastructure improvements at land ports, as described above, and so on.

As for the most recent dynamics, it is notable that China's river ports in the main Amur watershed have been developing rapidly, such as Tongjiang, Luobei, and Fujin, which showed more than 100,000 m^3 of timber imports annually after 2000. Among them, the import volume transported through the Tongjiang gateway has increased annually, reaching around 500,000 m^3 in 2005. Based on field surveys, the origin of timber imported to the port was a lower reach of the Amur River in Khabarovsk Krai. The origins of timber imported to small river ports in the main Amur watershed such as Jiayin and Minshan were thought to be Amur Oblast or the Jewish Autonomous Oblast on the other side of the river. Increasing timber imports at these gateways implies that there are active logging operations in forests in these two oblasts.

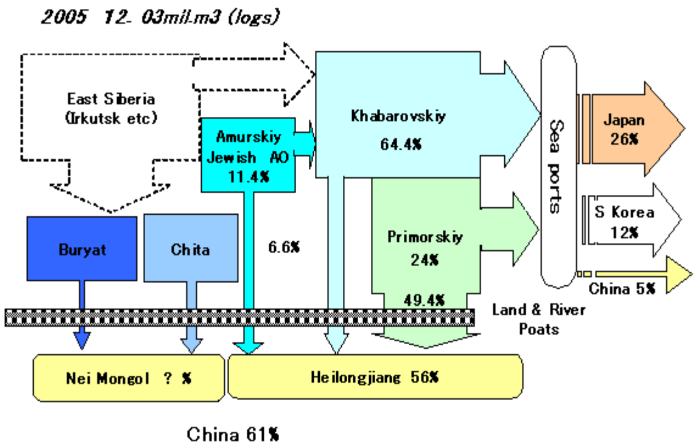

Figure 11. Estimated timber flows from the RFE to northeast Asia countries in 2005, developed based on various timber trade statistics.

It is possible to summarize the trends in timber flows over time into table 1. From this table we can see major changes in the timber trade from the RFE since the 1980s. First, the importance of land ports routes has grown significantly, because China has replaced Japan as the top importer from the RFE. Second, timber exports from Primorsky decreased gradually to 24% of total RFE exports in 2007, while Khabarovsk's share has increased to 66%.

Additionally it is worth noting that timber exports from regions along the upper reaches of the Amur River (i.e., Amur Oblast and Chita Oblast), which neighbor on China, have increased to around 10% of the total.

The year 2007 was a turning point for timber trade in the basin. In February 2007, Russia's central government announced a graduated but sharp rise in log export taxes to take effect after July 2007, and then carried out the first step as planned. The new system of export taxes on Russian timber has been in operation since then. The previous export tax on soft logs was 6.5%, or four euros / m^3 (around U.S.$5.2), but in July 2007 it was increased to 20%, or 10 euros /m^3. Finally, after January 2009, the tax was set to increase to 80%, or 50 euro/m^3. The export tax rate on hardwood logs, such as oak, beech, and ash, and even on semi-finished products is also set to rise sharply. This drastic and far-reaching policy change is, in essence, a log export ban, and it resulted in a significant drop of log exports from Russia to China and expansion of imports of Russian sawn wood in 2008 (Tai 2008). China, being the top importer of logs from Russia, has suffered serious impacts by this action. The Russian government, however, abruptly decided to postpone a further hike of its coniferous log export tax in November 2008, but the log export tax on hardwood was increased again as planned. Experts estimated that this new situation would bring about a recovery of Russian coniferous log imports and a sharp increase of sawn wood imports to China, and hardwood log imports from Russia would decrease significantly. In fact, after the announcement of Russia's decision, the major gateways for importing Russian coniferous logs, such as Manzhouli and Erlenhot, began to recover their coniferous log import volumes, but not to former levels. Along the land border area, even on Russia's side of the basin, there is a move to establish or strengthen wood-processing infrastructure.

In addition, recent deteriorating economic conditions, evident especially with a decrease in demand for wood products in countries that consume Russian timber, will also bring about serious impacts on the China-Russia timber trade. The global financial crisis at the end of 2008 led to a much greater decrease in demand for wood, and the timber trade from Russia to China, as well as China's own timber industry, began to exhibit entirely different characteristics.

In sum, the major underlying causes that brought about these changes are the supply-demand relationship between Russia and China, still-remaining rich forest resources and underdeveloped wood-processing industries on Russia's side of the watershed, and the rapid increase in the China's timber supply-demand gap, mainly due to the NFPP, under steadily increasing domestic timber consumption and net timber exports. Other major underlying causes include recent trade-related policies such as the log export tax hike in Russia, and preferential conditions for border trade created by improvements in the related infrastructure in China.

Table 1. Timber flow trends in Amur River Basin.
Figures for 2005 and 2007 are based on log trade volume and do not include Zabaikarie region.

	Export volume mil.m^3	Share of destination (%)			Share of origin (%)			Share of transport mode (%)	
		JPN	CHN	SKR	KHV	PRM	Other	Land	Sea
'85	5.78	83	0.4	—	51	49	0.2	0.2	99.8
'94	7.23	94	1	4	48	51	1	1	99
'98	7.54	66	23	11	35	55	10	22	78
'03	11.45	32	55	13	41	51	8	52	48
'05*	12.03	26	61	12	64	24	>11	>56	<43
'07*	14.03	30	61	10	66	24	>11	>58	<42

CONCLUSIONS

Based on the findings described above, the big picture of anthropogenic impacts after the mid-twentieth century on forest resources in the Amur River basin is summarized as follows:

1) Forest degradation in the basin progressed most intensively during the 1970s and early 1980s due to intensive timber production and frequent large-scale forest fires under state economic policies coupled with strong domestic demand for timber.

2) The pace of resource degradation decreased significantly from the late 1980s to the early 1990s, mainly because resource depletion worsened considerably on China's side of the watershed and less demand occurred under the socio-economic chaos during the transition period on Russia's side of the watershed.

3) A rapid increase occurred in timber exports to China and forest policies again boosted forest degradation on Russia's side of the watershed after the late 1990s.

4) As a result the timber trade structure in the basin has drastically changed, such that China, which imports more than 50% of log production from Russia's side of the watershed, became a key player in leading anthropogenic impacts on forest resources in the basin.

The underlying causes of these temporal and spatial dynamics are diverse, as described earlier. The increase of forest exploitation for logging in the basin was mainly due to internal and external market forces, such as domestic demand during a period of planned economies both in Russia and China and the increase of timber exports to Asia-Pacific countries after the mid-1990s. In particular, China's supply-demand gap, created mainly by the NFPP, under steadily increasing domestic consumption and net exports, revitalized forest exploitation on Russia's side of the watershed. Various underlying causes of widespread unsustainable logging operations, which brought about frequent forest fires—originating in such ultimate causes as "economic and political instability" and an "insufficient legal and administrative base"—are closely and mutually connected particularly in Russia.

It is possible to conclude that various anthropogenic factors functioned as driving forces for full-scale forest degradation in the basin after the mid-twentieth century. On China's side of the basin, forest development was drastically reduced, and forest conservation has emerged since 1998 after more than a century of forest exploitation. In contrast, on Russia's side of the basin this study revealed that the pressure for forest development has been growing again, particularly in untouched forests inland and along the China–Russia border area, with the aim of producing logs for export to China. There is no denying that such trends may bring about forest resource depletion on Russia's side of the basin, as happened to forests on China's side of the basin because of the cumulative effects of forest exploitation. Under these circumstances, full-scale degradation of the GFBF system may occur in the not-so-distant future. Thus, there is an urgent need for a strategic approach and environmental monitoring, conducted in cooperation with various related bodies, towards sustainable forest resource use and nature conservation.

As described above, this study was conducted with limited access to information, and thus for better understanding of the spatial dynamics of human impacts on forest resources in the Amur River basin, further data collection and analysis covering the whole basin are necessary. The situation of the China–Russia timber trade has been very dynamic, and the underlying causes of recent changes in this trade are closely linked to economic, policy, and infrastructural changes. Continued observation and further studies are needed to carefully examine the underlying causes of these dynamics. For a qualitative understanding of the socio-economic aspects of the GFBF system, the temporal and spatial changes of key anthropogenic impacts and underlying causes need to be analyzed in detail under the collaboration of related international and local research institutes. A geographic information system (GIS) database of forest fires and logging operations would also help to improve understanding. Additionally, changes in the timber trade structure in the basin and their effects on forest management and the industry should be completed through further interviews, field work, and research into information resources, since forest-related policies in the region are changing rapidly and under an air of uncertainty. Further research should also focus on the impacts of Russia's log export tax hike, and the prolongation or expansion of the Natural Forest Protection Program in China. Methods should include the continuous collection of timber-trade statistics, including customs-level statistics; monitoring of changes in wood-processing industries in China, Russia, and Japan; and interviews with key players, including high-level officials, businesspersons, NGOs, etc.

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