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FIRE AND FOREST DEVELOPMENT IN THE DAXINGANLING MONTANE-BOREAL CONIFEROUS FOREST, HEILONGJIANG, NORTHEAST CHINA – A PRELIMINARY MODEL

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Abstract

In May 1987 a major wildfire swept through the Daxinganling Mountain Region, Heilongjiang Province, Northeast China. The fire affected a total land area of 1.14 million ha, thereof 870 000 ha was forest land. Worldwide attention was caused because of the high loss of human lives and property. Forest fires, however, are a natural phenomenon. During the past 20 years of forest exploitation and land exploration lightning still amounts to more than one third of all known wildfire causes. This implies that fire must have played an important role in the forest development of the region, especially during the pre-settlement period. In this preliminary study a model on the fire ecology and the role of fire regimes in forest dynamics in Daxinganling is presented. Based on fire history data and field observations natural fire return intervals range between 6 and 170 years. The composition of larch, pine, birch and spruce forests is determined by the fire frequency which mainly depends on the topography and site conditions. The boundary of the natural range of spruce is limited by fire.

1. Introduction

Between 6 May and 2 June 1987 a major wildfire swept through the Daxinganling Mountain Region of Northeast China. Three fires which had been started by forestry operations swept a total of 20 000 ha during the first day. After a cold front passed the area during the night of 7 May windspeed increased fire intensity and rate of fire spread (Zheng Huanneng *et al.* 1988).

High fire intensity, spot fires and the development of fire storms sent the fires out of control. Due to weather conditions the fires calmed down by the end of May and finally were extinguished in early June. More than 1.3 million ha of land were affected by the fires of which 870 000 ha was damaged forest land. Worldwide attention focussed on the fire scene because several towns and forest farms were lost at the wildland/residential interface. About 200 people were killed and more than 200 people were injured by the fire and a total of 614 000 square meters of houses were lost leaving more than 56 000 people homeless (Di and Ende, this volume).

While the 1987 wildfires were reported widely by the world media as a catastrophic event (Salisbury 1989), the available fire statistics show that forest fires are a common phenomenon in Northeast China. The Daxinganling Region (Heilongjiang Province) is covered by 5.26 million ha of forest land equalling to 62%

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of the land area (in 1985). The forest land is mainly covered by montane-boreal coniferous forest. Wildfires were recorded soon after forest exploration started in 1964. Between 1966 and 1987 fires burnt a total of 5.6 million ha of land of which 3.1 million ha was forest and 2.5 million ha brushland and other land; a great part of the land affected by fire was burnt repeatedly during the period. However, in 1966 a total of 10.4% of the forest land burnt (546 300 ha) and all reported fires of 1987 burnt 17.4% of the forest land (913 135 ha).[1]

Agricultural burning, forestry operations and carelessness are the major ignition sources after forest exploitation expanded by the mid-sixties. However, during the 1966 to 1986 period lightning still ignited more than one third of all known wildfires. In 1987 lightning accounted to 63% of all fire ignitions and during the 1988 spring fire season 63% of the fires were started by lightning.

If one looks to the neighbouring regions it is recognized that wildfires are a common phenomenon in the territory of the Soviet Union, especially in the southern taiga of Central Siberia (Popov 1982). During the 1987 fire season a considerable amount of forest land was burnt on the Soviet territory adjacent to the Daxinganling Region (north of the Heilong River). Even if reliable survey data are not available it can be estimated on the base of satellite imagery that a total of 1.5 million ha of forest land was burnt east of Lake Baikal.

Large-scale conflagrations in Northern Asia (Siberia) were repeatedly reported. One of the major wildfires early this century was reported by Shostakovitch (1925) who estimated that during the severe drought of 1915 a total of about 181 million ha of land were affected of which about 14 million ha was burnt forest.

The occurrence of lightning-caused fires is similar to the conditions in the northern boreal forests of North America. This implies that natural fires must have been present in the region during the pre-exploration and pre-settlement period. Thus, fire must have played an important role in forest development and forest dynamics (see also Popov 1982).

In this study the effects of the 1987 fire as well as preliminary fire history data were integrated into static forest descriptions. A model the fire ecology and the role of fire regimes in forest dynamics in Daxinganling is presented.

2. General description of the Daxinganling montane-boreal coniferous forest

According to the forest classification by Wang (1961) the Daxinganling Region belongs to the montane-boreal coniferous forest formation. This forest formation occurs on an extensive geographical and altitudinal range from the Siberian border (Heilong River) to the high mountain areas of the grassland-desert regions and the tropics. In the North of Daxinganling this forest type occurs in elevations of less than 500 m. The soils developed under this forest type are highly podsolized and acidic. This reflects not only the granite and sandstone bedrock but also the prevailing moist and cold climate. Snow covers the forest floor in Daxinganling at least six months between end of October and early May. The rainfall in the region is lower than in the southern range of this forest type and amounts to about 350 to 500 mm, 70% of which falls during May to August. The average relative humidity is 70–75%.

1. Statistical data were made available by the Jiagedaqi Fire Control Center, Daxinganling Region.

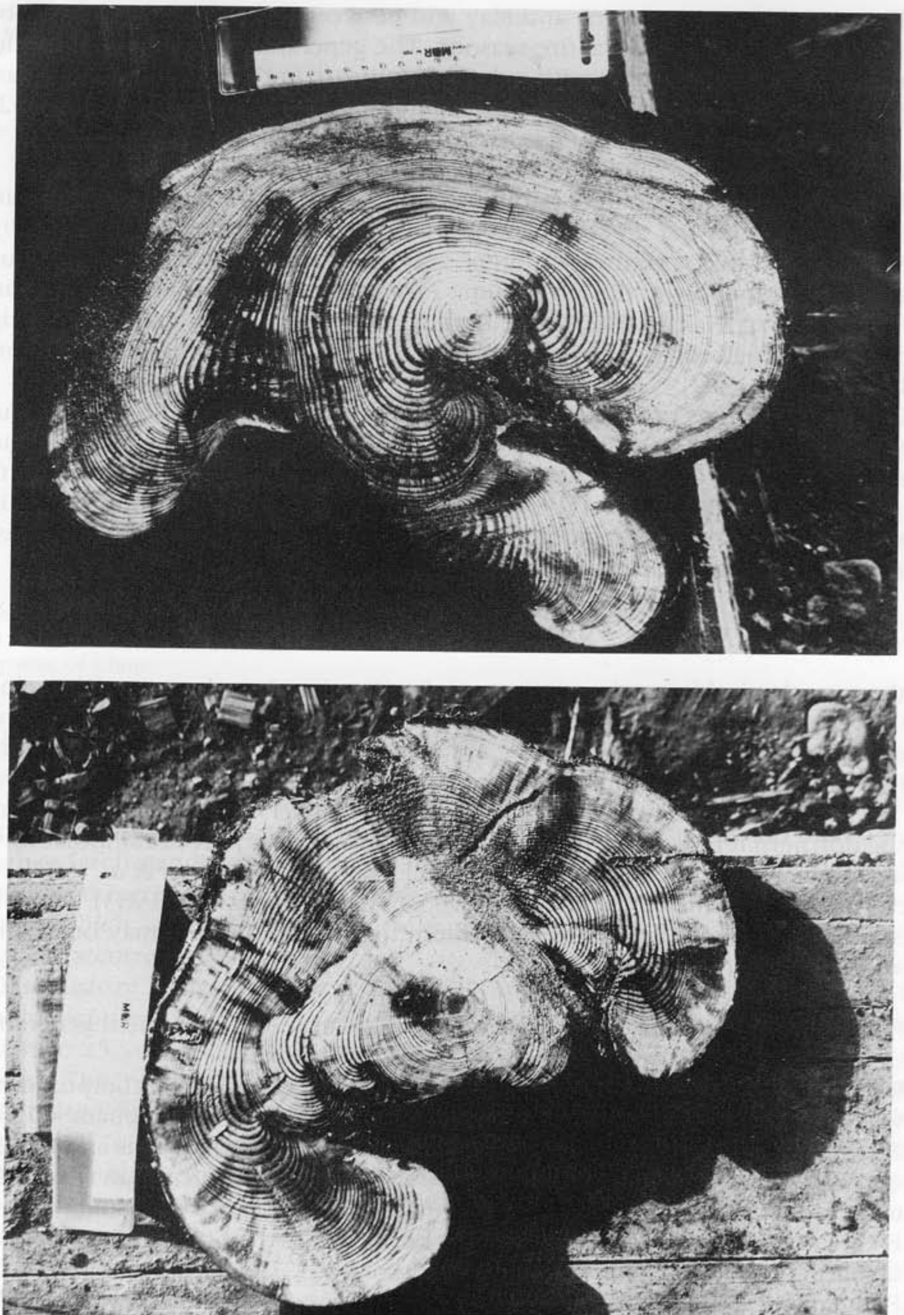

Fig. 1. Samples of cross sections used for dating historical fires in Northern Daxinganling. The series of fire history sites has not yet been completely analyzed. *Above*: *Larix gmelinii* from Malin Forest Farm (Road No. 13), recovered after the 1987 fire. – *Below*: *Pinus silvestris* var. *mongolica* from Panzhong Forest Farm (Road No. 19), recovered from a site severely burnt in 1987.
Photo's by Xueying Di.

The periods between March and May and between September and November are therefore the most critical fire seasons. The general decrease in precipitation toward the North is coupled with a definite increase in the annual, monthly and daily temperature range. The lowest temperature recorded in China was −52.3 °C at Mohe. The average temperature throughout the whole year is −2 to −4 °C (January −20 to −30 °C, July 17 to 20 °C) (Ji and Hu 1987).

The forest of Daxinganling is dominated by larch (*Larix gmelinii* Rupr.) and mixed with pine (*Pinus silvestris* var. *mongolica*). White birch (*Betula platyphylla* Suk.) is associated with these conifers. Less important in Daxinganling is spruce (*Picea abies* var. *obovata* (Ledeb.) Fellm., *Picea jezoensis* (Sieb et Zucc.) Carr. and *Picea koraiensis* Nakai). The forest flora is relatively simple containing a high proportion of paleoarctic and circumpolar species (detailed information is provided by Chen 1987).

Larch rarely grows on south facing slopes where it is replaced by almost pure pine stands. Birch and aspen occupy disturbed sites. Birch is also found in pure stands on slopes and also as understory species under larch and pine. On the flat plateaus, in low valleys and at the base of hills swamp forests are found in which *Larix gmelini* var. *olgensis* dominates. In these swamps sedges and grasses (*Calamagrostis* spp.) are abundant. Spruce is found on these organic soils.

3. The role of fire in forest dynamics

In the past, classical forest descriptions or classifications have been tending to look at the vegetation as a 'static' or climax stage of development. Disturbances such as fire were rather regarded as single 'catastrophic' event than as frequent feature.

Recent approaches in ecosystem analyses, however, have recognized the role of fire as a dynamic factor in forest development. This includes the fire regimes in the northern temperate forests and the boreal and northern circumpolar forest associations of North America and northern Eurasia (see Slaughter *et al.* 1971; Viereck and Schandelmeier 1980; Foote 1983; Wein and MacLean 1983).

Several main functions of fire in northern forest communities may be generalized as follows:

- High intensity stand replacement fires in all age classes trigger the regeneration of stands and the successional forest development.
- Irregular burning patterns lead to a mosaic of forest landscape composed of a variety of successional development stages (seral stages) and induced edges.
- Site conditions created by climatic effects such as permafrost soils and raw humus accumulations may be neutralized periodically by fire through removal of temperature insulating layers and nutrient recycling.
- Frequent (short to medium return interval) fires act as a selective force by favouring fire adapted or fire tolerant species.
- Frequent fires have a thinning effect thus influencing stand structure, understory and shrub-herb layer composition.

In Daxinganling several forest types can be distinguished which obviously have been developed under the long-term influence of natural fires. The forest stand descriptions are based on preliminary field observations and fire history data.

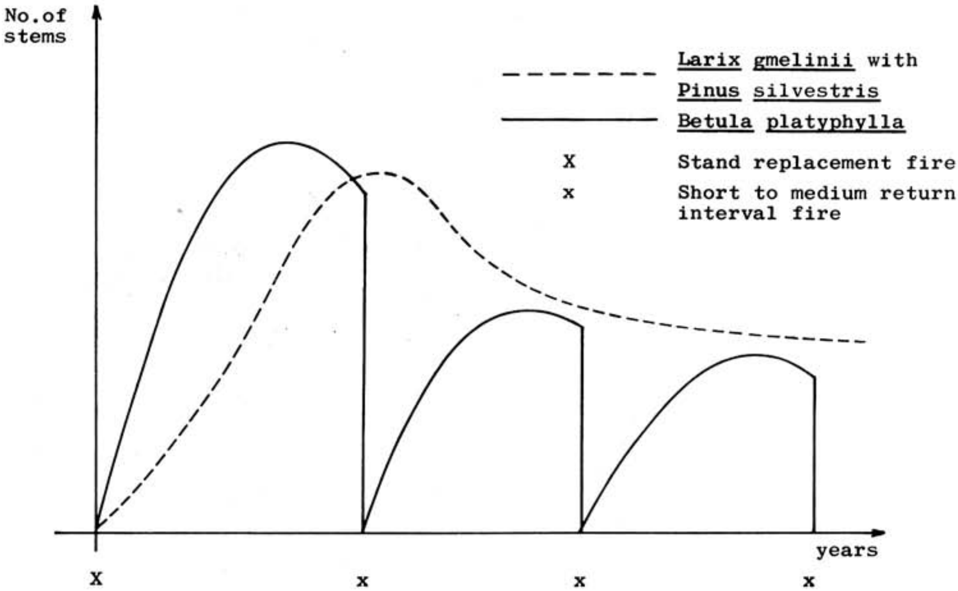

Fig. 2. Generalized dynamic model of larch (-pine) – birch stand development on northern slopes and flat terrain in the Daxinganling montane-boreal coniferous forest. Heilongjiang Province, People's Republic of China.

3.1. Pure pine stands on south facing slopes

In many hills and mountains, especially in the northern part of the Daxinganling Mountain Region, a distinct boundary between pure pine stands and mixed pine-larch or larch stands can be found. The structure of pure pine stands on south facing aspects is commonly related to the more drier and warmer conditions on those slopes which, according to our observations, are additionally influenced by the regular occurrence of fires.

Fire history analyses (fire scar analyses) on pines have shown that the fire frequency of pre-settlement fires (lightning fires) may vary between 6 and 54 years (average 25 years). The fire scars are usually found on the upslope part of the trunks. The frequent upslope running fires periodically remove the litter layer and other dead fuels as well as the shrub layer and understory. The relatively low amount of fuel load on southern slopes becomes easily flammable and may carry low to medium intensity surface fires. The frequent burning of those sites prevents the accumulation of debris/ground vegetation and therefore the site conditions as a whole tend to be more xeric and less favourable to larch.

3.2. Larch-pine stands with birch on north facing slopes and gentle to flat terrain

On northern and gently slopes as well as on flat (non swamp) terrain the dominating larch is usually associated with pine and birch. After a stand replacement fire succession usually starts with pioneers such as birch and aspen. Under the canopy of the pioneers larch regenerates and becomes co-dominant or dominant in the

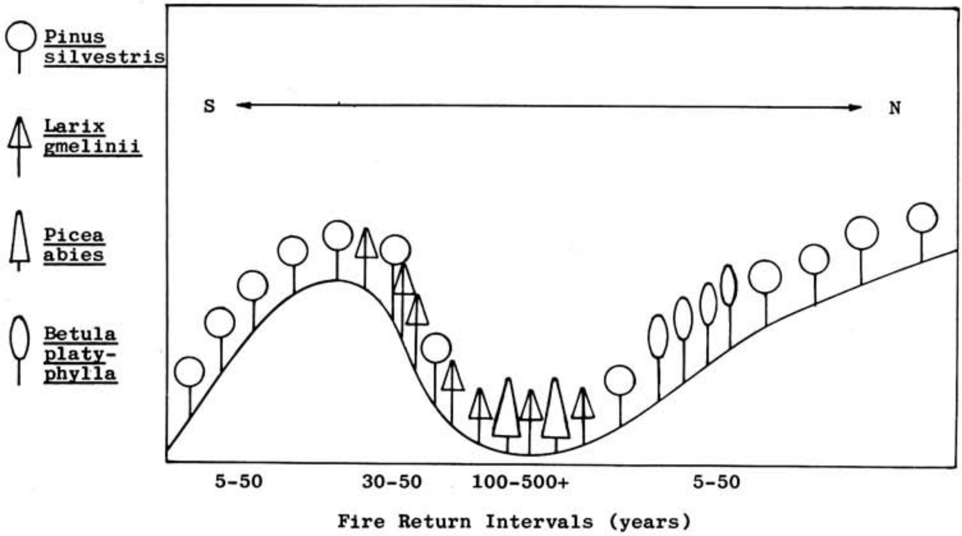

Fig. 3. Generalized scheme of forest patterns and fire regimes in the northern Daxinganling montane-boreal coniferous forest. Heilongjiang Province, People's Republic of China.

overstory. Birch and aspen are usually not completely replaced by competition with larch. The main selective agent is the periodic low to medium intensity surface fire of a medium return interval. These fires kill the birches which profusely resprout from stumps or reseed under the remaining fire tolerant larch overstory.

This process may be repeated several times until a high intensity stand replacement fire, followed by bark beetle attack, finally kills the whole stand thus initiating the succession from the beginning.[1] A dynamic stand model as developed in Fig. 2 shows the repeated removal of birch in these stands.

3.3. Larch swamp forests

In the depressions of flat plateaus and in wet valleys *Larix gmelinii* var. *olgensis* occupies swampy habitats. *Picea abies* var. *obovata*, *P. jezoensis* and *P. koraiensis* are scattered on these wet sites. Fires occur only during extreme drought periods in which the swamp/peat layers become flammable. High intensity fires or fires with long residence time therefore develop only after long intervals presumably between 100 and several hundreds of years. During the 'average' fire years the wildfires usually stop at the edge of the swamps.

The long intervals without fire represent an 'ecological niche' for spruce. The extreme fire intolerance of *P. abies* and *P. jezoensis* is probably the main reason why they are not found on those sites where shorter fire frequency does not allow its establishment (see also Man'Ko 1987; Wu 1988). A similar phenomenon in the taiga of southern Siberia is described by Popov (1982).

1. The 1987 fires have shown that bark beetles are highly attracted by fire damaged stands. In 1988 *Ips cembrae* Heer was found in both larch and pine.

Table 1. Fire regimes and fire impact in different forest types of the Daxinganling montane-boreal coniferous forest. Heilongjiang Province, People's Republic of China.

Forest type	*Fire regime*	*Burning conditions*	*Fire impact*
Pure pine stands on south facing slopes	Short to medium return interval (5–50 years). Medium to high intensity surface fires (uphill) with long return interval stand replacement fires.	Rapidly drying ground fuels. Little fuel accumulation due to frequent burning. Little shrub-herb layer.	Formation of highly fire tolerant, open pine stands. Long-term elimination of larch. No birch.
Larch-pine forests with birch on north facing slopes and that terrain	Medium return interval fires (30–50 years). Low to medium intensity surface fires. Long return interval stand replacement fires.	Medium fuel accumulation. Shrub-herb layer. Drying of fuels slower than on south facing slopes.	Maintaining mixed pine-larch stands. Periodic removal of birch.
Larch-swamp forests with spruce	Long return interval fires (100–500 + years). High intensity stand replacement fires.	High fuel accumulation (raw humus layers). Generally wet and not flammable. Drying out only during extreme droughts.	Complete elimination of spruce. Regeneration and growing conditions growing improved after fire.
Pure birch forests	Short return interval fires (5–50 years). Medium intensity fires.	Understory of larch and highly flammable grass layer.	Periodic elimination of birch and conifers. Long-term establishment of birch due to fire-adapted regeneration.

3.4. Pure birch (-aspen) forests

Pure birch stands or birch-dominated stands in various sizes can be found in the intermix with larch-pine associations. The pioneering birch (mainly *B. platyphylla*) and aspen (*Populus davidiana*) usually establish after stand replacement fires by reseeding or coppicing.

If large short return interval fires occur early in succession, larch and pine may be eliminated from those sites. Conversely, the resprouting ability of birch as well as the long-distance transport of birch seeds ensure the reoccupation of these frequently burnt sites. As a consequence pure birch stands are maintained until a long period without fire allows the successional development of the coniferous component.

4. Daxinganling fire regimes: conclusions

The preliminary findings on the interactions between fire and forest development are summarized in Table 1. A general scheme of the forest distribution pattern as related to topography and fire regimes is shown in Fig. 3.

It must be noted that probably not only the fire return interval of fire intensity

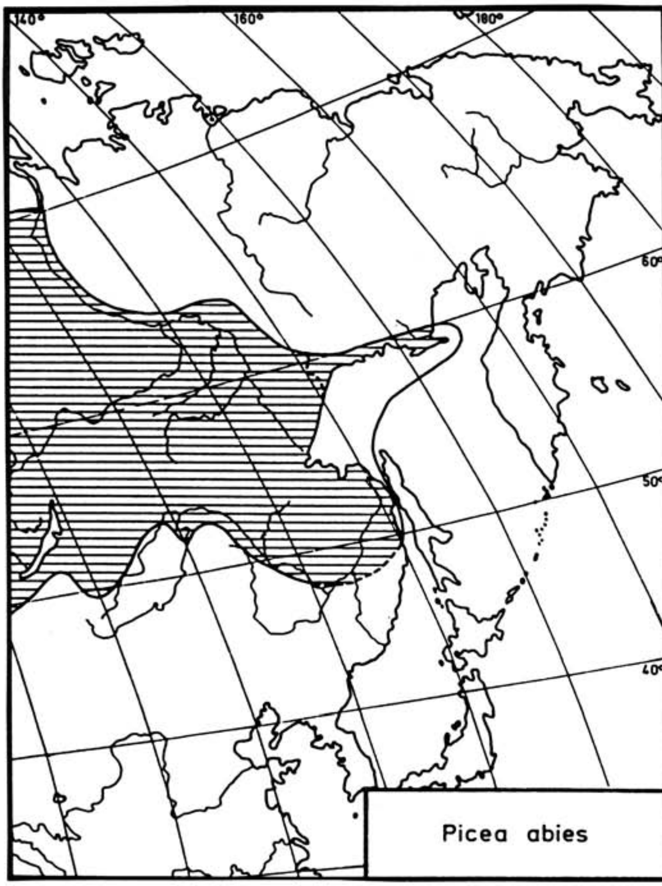

Fig. 4. Eastern geographic distribution of *Picea abies*. Source: Schmidt-Vogt (1977).

have an influence on the vegetation composition. As described in section 3.4 it is most crucial whether a stand is reburnt frequently during an early successional stage or during the later stages of forest development. Repeated early fires lead to patchy or large-sized pure birch stands.

The restriction of *Picea* spp. to the swampy topographical depressions is obviously related to the fire regimes on the different site types. The southern boundary of the range of *Picea abies* var. *obovata* fades out in the northern Daxinganling region (see Schmidt-Vogt 1977); the same refers to the western boundary of the range of *P. jezoensis* and *P. koraiensis* in the East of Daxinganling (see Schmidt-Vogt 1977; Man'Ko 1987) (Figs 4 and 5).

It is possible that the boundaries of the natural range of *Picea* spp. in Daxinganling are related to the lightning-fire bioclimatic conditions and the historic fire regimes.

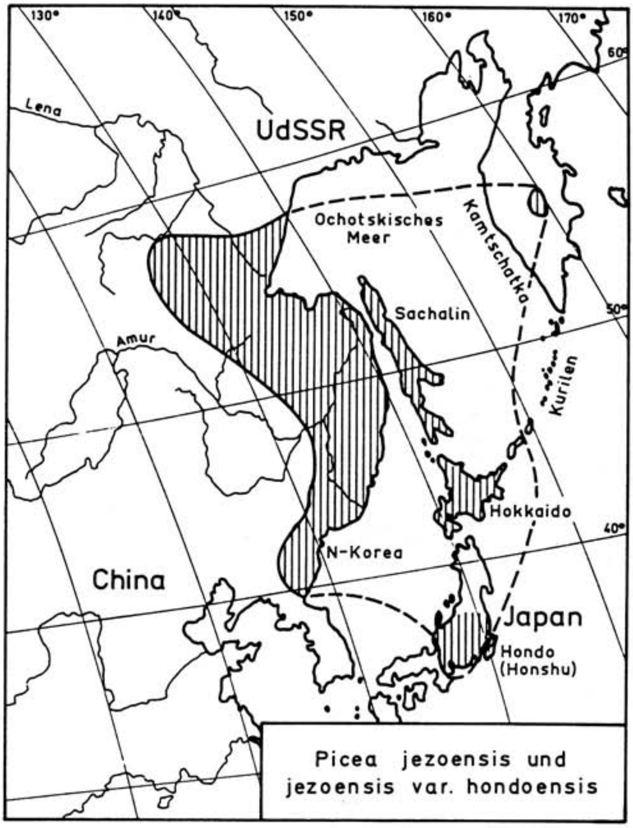

Fig. 5. Geographic distribution of *Picea jezoensis* and *Picea jezoensis* var. *hondoensis*. Source: Schmidt-Vogt (1977).

5. Forest management and research implications

The first phase of forest exploration of the Daxinganling region took place between 1955 and 1964. An increasing number of man-caused wildfires have occurred on the forest land since then. Forest utilization and forest management as well as road and railroad construction have dramatically changed the forest environment.

The natural fire regimes and the natural forest dynamics which have created the most valuable forests of northeastern China are more and more replaced by man-made fire regimes. This has resulted in

- increase of fire frequency and wildfire risk,
- repeated wildfires on young plantations and naturally regenerated stands,
- loss of seed sources due to overcutting and negative selection,
- increased risk of stand replacement fires and overall loss of productive forest land.

Strengthened fire prevention and suppression programs will not change the situation if forest management and silviculture do not consider the specific basics of fire and forest dynamics of the region. This has clearly been shown by the wildfires of 1987. The development of fuel management concepts and prescribed burning strategies therefore are imperative.

The preliminary model of the fire ecology of the Daxinganling montane-boreal coniferous forest as presented in this paper is based on field studies between 1987 and 1989 which were the first phase of a cooperative research program between the Universtiy of Harbin and the University of Freiburg. The model does not have an overall validity and is subject of amendments in the course of the research work which is sponsored by the Volkswagen Foundation.

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