Structure of the montane taiga forests of West Khentii, Northern Mongolia

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ABSTRACT: Studies were undertaken to investigate the composition, structure and diversity of four different types of North Mongolian montane forest near the southern border of the taiga. These forest types, classified as willow-poplar, larch-birch, spruce-fir and Siberian-pine forests, were found to be significantly different with respect to the elevational gradient. In the study area, two fire regimes could be distinguished at lower and drier elevations, frequent surface fires resulted in less diverse forests comprising coniferous species, which in their adult form were found to be fire-resistant, burn-colonizing and light-demanding deciduous tree species. In contrast, the forests colonizing the moist, higher elevations and shaded slopes had a higher diversity of tree species with greater basal area, higher proportion of deadwood, and more regenerating trees; here the coniferous shade trees experienced infrequent but destructive treetop fires. Overall, our results showed that the four forest types differed in composition according to the tree species, diameter and height classes.

Keywords: montane taiga; elevation; deadwood; regeneration

Boreal forests ("taiga") make up 24% of the Earth's total forest cover with three fifths of their extension, which is more than 500 million ha being located in Eurasia (Mayer 1979, 1984; Wirth 2005). On account of their short growth periods, coniferous species have a productivity advantage over deciduous species and hence coniferous forests are known to dominate the Palaearctic zone. Deciduous trees occur predominantly as pioneer species only, colonizing after forest fires, insect outbreaks and windfalls, or at special sites such as river terraces (Grabherr 1997). In Eurasia, the taiga is classified into "dark taiga", consisting of shade-tolerant tree species, and "light taiga", consisting of light-demanding species. Light taiga occurs only where shade-tolerant species do not grow either due to climatic or edaphic reasons (Walter 1974, 1984; Grabherr 1997). Restricted to the Northern Hemisphere, boreal forests reach their southernmost extent in the Central Asian steppes of Northern Mongolia (Walter 1974).

Mongolia is a land-locked country in Central Asia, being biogeographically located in the Palaearctic zone and is an important region within the Eurasian steppe belt, with 17.5 million ha forest cover on the southernmost fringe of the Great Siberian forest and on some of the mountain ranges in the northern and north-western part of the territory. The closed forests occupy only 8.1% of the land area of Mongolia (Tsogtbaatar 2004). The forests of Mongolia consist of mainly coniferous and deciduous species and the area covered by these forest types is 10.7 million ha. The most common tree species in these forests is *Larix si-*

birica, commonly known as Siberian larch (ENKHSAIKHAN 1998). Mongolia's northern part is covered by approximately 11 million ha of boreal forest (UNDP, GEF 1998). Mongolia's forests grow under extreme conditions of the dry continental type of climate with low precipitation rates and high radiation rates prevailing almost throughout the year. From north to south, the forests can be classified into four different types based on their altitudinal gradient – subgoltsy, taiga, sub-taiga and pseudotaiga belt (TSEDENDASH 1995). The Mongolian taiga belt constitutes approximately 2% of the world's total taiga forest cover. Amongst all the natural disturbances, fires induced by lightening have the greatest impact on the boreal zone: they not only shape the landscape diversity and affect energy flows and biogeochemical cycles (e.g. carbon release), but also influence forest age, structure, species composition and physiognomy (GOLDAMMER, FURYAEV 1996; GRABHERR 1997; SCHULZE et al. 2005; WIRTH 2005).

The Khentii Mountains of Northern Mongolia where the Siberian forest belt borders the steppe represent a unique and pristine ecosystem. The Khentii Mountains are subdivided into two subprovinces: Western and Eastern Khentii. In the Khentii region, the western Siberian dark taiga forests with *Picea obovata, Abies sibirica, Pinus sibirica*, and *Larix sibirica* meet the eastern Siberian light taiga forests composed of the species such as *Betula platyphylla* and related species, *Larix* sp. and *Pinus sylvestris* (ERMAKOV et al. 2002). Therefore the vegetation structure in the Khentii region strongly depends on altitude and exposition. The lower montane belt at 900–1,200 m a.s.l. is distinguishable from the upper montane belt at 1,200 to 1,600 m a.s.l. (HILBIG, KNAPP 1983). Vegetation of the upper montane belt is dominated by dark taiga forests of *Pinus sibirica, Abies sibirica, Picea obovata*, and more rarely, *Larix sibirica* and *Betula platyphylla*. Dark taiga forests of *Pinus sibirica, Abies sibirica, Picea obovata*, and *Larix sibirica* grow at the most humid sites. In the lower montane belt, *Larix sibirica* and *Betula platyphylla* dominate in the light taiga. These forests of the lower montane belt in the forest-steppe transitional zone are often called sub-taiga forests (TSEDENDASH 1995). They occur on relatively dry northern slopes of the lower montane belt. Whereas the northern slopes of the lower montane belt are stocked with light forests, the southern slopes are covered with meadows or mountain steppe, or more rarely with *Ulmus pumila* open woodland (DULAMSUREN et al. 2004). The main factor for the steppe vegetation on southern slopes is the high radiation exceeding 400–500 kJ·cm^{-2}; here forests cannot grow because the precipitation is not sufficient to meet the moisture demand of the forests (TRETER 1996).

In the Western Khentii, the tree line and the permafrost start at a lower altitude than in the East-Khentii (MELNIKOV 1974), thereby resulting in different mountain forest types with different typological structures. Khonin Nuga is a valley in the West Khentii region of Northern Mongolia and is located in the buffer zone of the Strictly Protected Area of Khan Khentey, which is drained by the Eroo River, which forms the upper part of the watershed region of the Lake Baikal. The floodplain vegetation of West-Khentii is heterogeneous with various types of forests, shrubs and meadows (DULAMSUREN et al. 2004).

The forest types investigated in this study are relatively unique types within the taiga belt since the area represents the southernmost distribution of the dark taiga in Central Asia. Only a few studies have been done on the forests of this area so far (MÜHLENBERG et al. 2004; DULAMSUREN et al. 2005). While reviewing the Mongolian forests, CRISP et al. (2004) distinguished between "disturbance-maintained forests" and "gap-driven forests" but they did not use any data from Mongolia. In the present study we could investigate the natural forest conditions of the southern taiga by documenting the forests in an area that is relatively inaccessible and located close to the strictly protected Khan Khentey area which was relatively free from human disturbance. A research station of the University of Göttingen, Germany, was established in this area in 1997 in cooperation with the National University of Mongolia and has been functional since then.

The main aim of our study was to investigate the composition, structure and diversity of four different forest types within a montane forest belt of the southernmost extent of the taiga, taking into account the growing stock, fallen deadwood and regenerating trees.

MATERIAL AND METHODS

Study area

The study area is a part of the West Khentey Mountain Range, which is located to the south of Lake Baikal, near the border between Mongolia and Russia (WALTER 1974; Fig. 1).

Covering an area of 400 km^2, it encompasses the region between 49°01' and 49°10'N and 107°11'

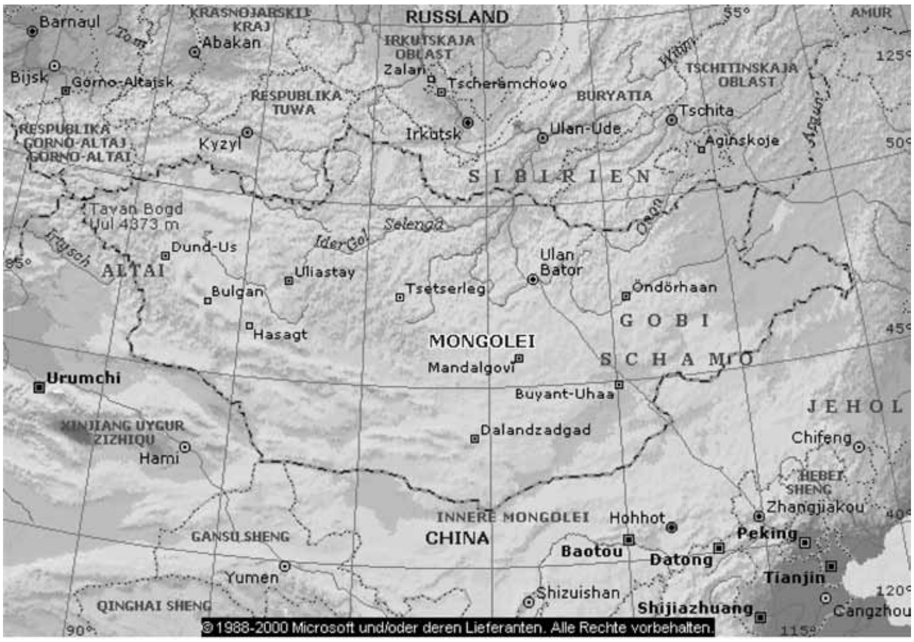

Fig. 1. Map of Mongolia showing the location of the research study area marked by green square

and 107°31'E, where 85% of the total area is forest (Solongo 2005). The study site is in the transition zone between the southern extension of the Siberian taiga and the forest steppe. Natural forests growing on permafrost soil are found on northern slopes, while southern slopes receiving greater amounts of solar radiation are naturally covered with steppe vegetation due to relatively dry conditions. In this transition zone the elements of boreal conifer forests meet the floristic elements of the Central-Asiatic steppe (Dulamsuren et al. 2005, Hauck et al. 2006, 2007). Meadow steppes on the drier southern slopes at lower elevations (up to 1,100 m) alternate with forests of varying composition on slopes less exposed to the sun at higher elevations, while moisture-tolerant forests and shrublands, in addition to wet grasslands, occupy the valleys (Dulamsuren 2004). There are four types of forests within the study area that differ in both ecology and fire adaptation (Walter 1974; Babintseva, Titova 1996; Larsson 2001; Wirth 2005). We investigated the forest structure in the following types of stands:

– Siberian pine forests: Siberian pine (*Pinus sibirica*), Siberian fir (*Abies sibirica*) and Siberian spruce (*Picea obovata*) are fire-intolerant coniferous shade tree species that have comparatively heavy seeds with initial slow growth rates. This forest type represents parts of the dark taiga within the montane zone (Fig. 2).
– Spruce-fir forests: the *Abies sibirica-Picea obovata* forests form a link from the dark taiga to the light sub-taiga forests. Within these forests, Siberian larch (*Larix sibirica*) and Scots pine (*Pinus sylvestris*) are light-demanding, pioneer coniferous tree species. They are well adapted to fire because of the dispersal ability of their lighter seeds and the fire-resistant characteristics of their bark (Fig. 3).

Fig. 2. Siberian pine represents the dark taiga within the montane belt with the highest basal area of trees and it is also a forest type with the highest density of trees

Fig. 3. Spruce-fir forest with high accumulation of deadwood

– Larch-birch forests: these forests are dominated by the species *Larix sibirica* and *Betula platyphylla*. They represent the light sub-taiga forests (Dulamsuren et al. 2005). The birch (*Betula platyphylla*), European aspen (*Populus tremula*) and Sallow willow (*Salix caprea*) are deciduous light-demanding tree species with a stronger ability to form a pioneer community. All these species exhibit combined qualities of strong light demand, very fast initial growth rates, low maximum age, limited competitive ability in the absence of disturbance and light seeds (Fig. 4).
– Willow-poplar riparian forests: deciduous, moisture-tolerant, fire-intolerant species such as poplar (*Populus laurifolia*) and several species of willow (*Salix rorida*, *S. chwerinii, S. rhamnifolia*) are mostly found in the riparian habitats and are adapted to ice, flooding, and temporary high groundwater levels. They also show the pioneer community forming characteristics of the light-demanding deciduous species (Fig. 5).

The percentage proportion by cover of each forest stand within the study area was 16%, 21%, 59% and 4%, respectively (Solongo 2005).

METHODS

In August and September 2002 and in June and July 2003, the growing stock and fallen deadwood were assessed in 388 randomly selected sample plots. A random sampling was chosen for both to cope with the small-scale heterogeneity of the virgin forest and to cover different phases of the forest development. The size of each plot was 100 m^2. Altitude, slope exposure, and slope gradient were determined for each plot using a Global Positioning System (GPS), a compass and a gradient meter, respectively. Each plot was topographically classified as valley floor, foothill, slope, upper slope or mountain ridge. The basal area of the growing stock was determined using angle count samples (basal area factor 1) (Zöhrer 1980; Kramer, Akca 1982; Gregoire, Valentine 2008). The species, diameter class (1.3 m from the ground, in 10 cm intervals), vitality (alive, dying, dead), and visible damage (fire, windfall, rot) were recorded for each tree. The length of fallen deadwood was determined from circular sample plots with a 15 m radius. Tree species and diameter class (in 10 cm intervals, for all trunks >10 cm diameter) and the number of individuals of each species in each height class (at 20 cm intervals) were also recorded. Using density data given in Mayer-Wegelin and Mammen (1959) and Dietz and Heckel (1975) for European tree species, weighted ratios were calculated for the basal areas and lengths of fallen deadwood to determine the ratios of dry wood weight between the

Fig. 4. Larch-birch forest representing the light sub-taiga forest type on the slopes

Fig. 5. Willow-poplar riparian forest

four forest types. As regional differences are relatively synchronous between tree species depending on longitude and altitude, mean European values can be used to weight basal areas and lengths.

The Kruskal-Wallis test was applied to assess the differences between the distinct parameters within the various forest types. All parameters were extrapolated to hectares (100 by 100 m). Spearman's rank correlation coefficient tests were used to determine whether the tree species occurred more or less frequently than expected along the range site factors. Mann-Whitney U-test were used to make pair-wise comparisons of the differences in the central tendency. The statistical analysis was conducted using Microsoft Excel 2000 (Microsoft Corp.), WinStat 3.1 (Kalmia Co. Inc.) and STATISTICA 1999 (StatSoft Inc.).

RESULTS

Forest types and sites

Except for the slope gradient, the four forest types differed significantly in all site factors (Kruskal-Wallis test, $P < 0.001$). Differences in elevation gradient were significant for all forest types (two-tailed Mann-Whitney U-test, $P < 0.01$; Table 1) except for larch-birch and spruce-fir forests, which occurred at the same altitude.

Spruce-fir forests were found to occur less frequently as the exposition increased (one-tailed Spearman's rank correlation, $P < 0.001$) and were restricted to the cool, moist northern and eastern slopes. Species that are more resistant to dry conditions (Siberian pine, Scots pine and larch) were found to occur more frequently and close to the mountain ridges ($P < 0.001$). Shade tree species such as Siberian pine and fir occurred more frequently with increasing altitude ($P < 0.001$), but the former species occupied cooler moist areas on upper slopes at higher altitudes with significantly greater exposure to the sun than the latter (two-tailed Mann-Whitney U-test, $P < 0.01$). On the other hand, the frequency of occurrence of light-demanding tree species decreased with altitude ($P < 0.001$). Willow-poplar forests occurred in wet riparian sites at lower altitudes, mostly in valleys and on the lower slopes.

Composition, structure, and diversity of different forest types

All forest types differed from each other in terms of the mean values of basal area composition, deadwood characteristics and stem frequency, average

Table 1. Mean values of three site factors within the various forest types and in the study area as a whole

Forest type	Mean altitude (m)	Exposure*	Position on the slope**
Larch-birch forests	1,149	6	3
Willow-poplar forests	1,028	6	4
Spruce-fir forests	1,183	2	3
Siberian pine forests	1,423	5	2
Study area	1,195	5	3

*median of a scale of eight intervals of increasing sun exposure, **median of a scale of five of decreasing relative slope level

Table 2. Mean values of four basal area parameters for the growing stock within the various forest types and in the study area as a whole ($m^2 \cdot ha^{-1}$)

Forest type	Basal area of the stand	Basal area of light-demanding tree species	Basal area of deciduous tree species	Basal area of trees of > 50 cm diameter
Larch-birch forests	19.1	17.9	10.8	2.6
Willow-poplar forests	22.5	22.1	18.4	2.0
Spruce-fir forests	26.5	10.6	3.3	3.1
Siberian pine forests	39.1	3.9	0.4	10.6
Study area	24.0	14.3	7.9	4.0

Table 3. Mean values of four deadwood parameters within the various forest types and in the study area as a whole ($m^2 \cdot ha^{-1}$)

Forest type	Basal area of dead trees	Basal area of dead trees of > 50 cm diameter	Length of fallen deadwood of > 10 cm diameter	Length of fallen deadwood of > 50 cm diameter
Larch-birch forests	2.5	0.5	439	44
Willow-poplar forests	2.0	0.2	204	22
Spruce-fir forests	2.7	0.4	703	40
Siberian pine forests	5.4	0.7	1,011	114
Study area	3.0	0.5	577	53

Table 4. Mean stem frequency in the stand and among regenerating trees for the various forest types and in the study area as a whole ($n \cdot ha^{-1}$)

Forest type	Entire stand	Stand up to 10 cm diameter	Regenerating trees over 1.4 m high	Regeneration overall
Larch-birch forests	378	123	147	318
Willow-poplar forests	486	192	174	277
Spruce-fir forests	636	275	499	1,035
Cembran pine forests	524	158	401	980
Study area	460	163	263	573

tree species richness and average diameter class diversity for both established and regenerating trees (Kruskal-Wallis test, $P < 0.001$; Tables 1–6).

The total basal area of the stand ($P < 0.05$) and the basal areas of both the light demanding trees ($P < 0.01$) and the deciduous species ($P < 0.001$) were significantly different in all forest types (two-tailed Mann-Whitney *U*-test; Table 2).

The basal area of trees > 50 cm in diameter was larger in Siberian pine forests than in all other forest types ($P < 0.001$) and in spruce fir forests as compared to willow-poplar forests ($P < 0.05$). The total basal area of dead trees ($P < 0.05$) and the total length of fallen deadwood ($P < 0.001$) were significantly different for all pairings (two-tailed Mann-Whitney *U*-test; Table 3), except for larch-birch/spruce-fir forests.

The basal area of dead trees > 50 cm in diameter and the length of fallen deadwood > 50 cm in diameter were significantly larger in willow-poplar forests ($P < 0.05$) and in Siberian pine forests ($P < 0.01$), respectively, as compared to the other forests types.

The Siberian pine forests had a higher number of species as standing deadwood than all other forest types (two tailed Mann-Whitney *U*-test, $P < 0.001$; Table 3), and except when compared with spruce-fir forests, they also had more tree species as fallen deadwood ($P < 0.05$). In contrast, spruce-fir forests had more species amongst the regenerating trees ($P < 0.001$) than all other forest types, and Siberian pine forests had more regenerating species than larch-birch forests ($P < 0.05$).

With respect to stem frequency (Table 4), the spruce-fir forests had up to twice the total number of stems present than any other forest type (two-tailed Mann-Whitney *U*-test, $P < 0.05$). However, if only a stem > 10 cm in diameter was considered, the frequency was relatively uniform, with 250 to 350 trees·ha^{-1} within all forest types. The stem frequency of regenerating trees was three times higher in forest types not disturbed by fire or riparian dynamics, such as spruce-fir ($P < 0.001$) or Siberian pine forests ($P < 0.05$), than in larch-birch and willow-poplar forests. Specifically, the number of regenerating coniferous shade trees increased as did their basal area ($P < 0.001$), but declined when the basal area of fire damaged trees ($P < 0.001$) and the number of deciduous light-demanding tree species ($P < 0.001$) increased. In contrast, the number of

Table 5. Average number of tree species within the various forest types and in the study area as a whole

Forest type	Growing stock	Standing deadwood	Fallen deadwood	Regenerating trees
Larch-birch forests	2.4	1.1	1.4	2.0
Willow-poplar forests	3.1	0.9	1.1	1.3
Spruce-fir forests	4.0	1.3	2.1	4.1
Cembran pine forests	3.4	1.9	2.1	2.7
Study area	2.9	1.3	1.6	2.5

Table 6. Average diameter and height classes within the various forest types and in the study area as a whole

Forest type	Growing stock	Standing deadwood	Fallen deadwood	Regenerating trees (height classes)
	(diameter classes)			
Larch-birch forests	4.7	1.7	2.1	4.9
Willow-poplar forests	4.8	1.3	1.2	4.7
Spruce-fir forests	5.5	1.8	2.4	10.9
Cembran pine forests	7.1	2.8	3.3	9.1
Study area	5.3	1.9	2.3	6.8

light-demanding conifers increased along with an increase in these two parameters ($P < 0.01$ and $P < 0.05$, respectively). The regeneration of the latter species decreased as the basal area of coniferous shade trees in the stand increased ($P < 0.001$). Similarly, the regeneration of deciduous light-demanding species decreased when the basal area of competing light-demanding trees increased ($P < 0.001$).

Our results showed that with the increase in the basal area of coniferous shade trees, the mean number of tree species and the number of diameter classes in the growing stock, standing deadwood, fallen deadwood and regenerating trees also increased (all: one tailed Spearman's rank correlations, $P < 0.001$ and $P < 0.001$, respectively). In the case of structural diversity (Table 6), the dif-

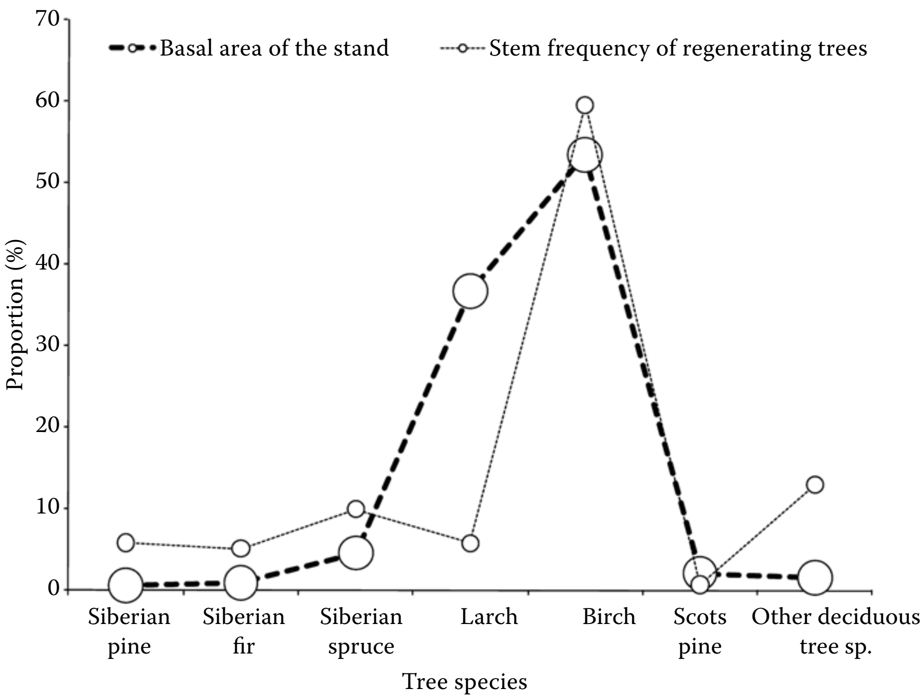

Fig. 6. Comparison of the proportion of tree species in the stand and amongst regenerating trees for larch-birch forests (mean % of basal area or stem frequency)

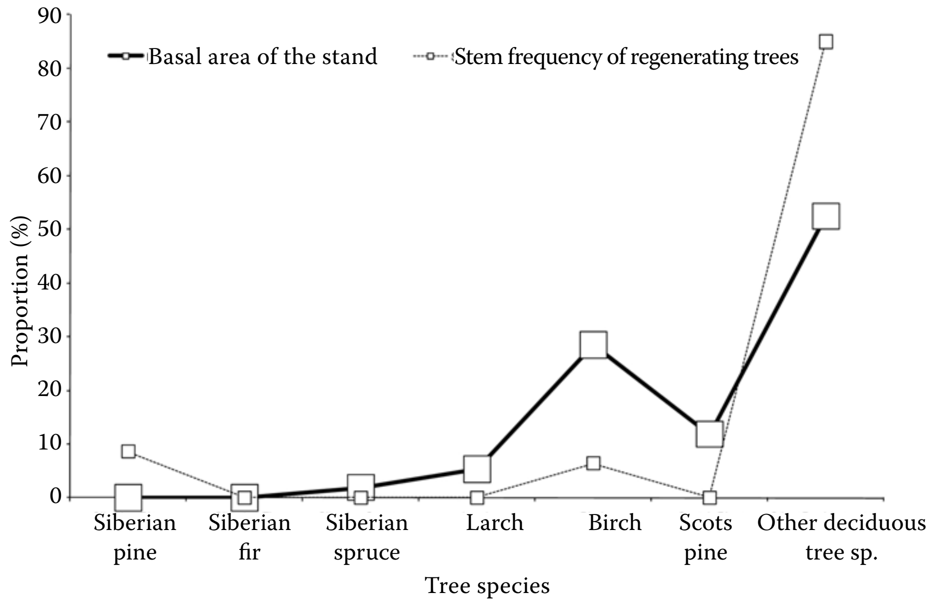

Fig. 7. Comparison of the proportion of tree species in the stand and amongst regenerating trees for willow-poplar forests (mean % of basal area or stem frequency)

ferences were significant for all pairings (two-tailed Mann-Whitney *U*-test, $P < 0.05$), except for larch-birch/willow-poplar forests (growing stock, standing deadwood and regenerating trees) and for larch-birch/spruce-fir forests (standing and fallen deadwood).

The four forest types were found to differ in composition according to tree species, diameter and height classes: amongst the mature trees, larch-birch forests comprised 37% of larch, 55% of burn-colonizing deciduous species including birch, and 6% of coniferous shade tree species (Fig. 6).

In contrast, larch was clearly less common amongst the regenerating trees (6%), in comparison with deciduous trees (73%) and coniferous shade trees (21%).

The willow-poplar forests (Fig. 7) contained the highest proportion of deciduous trees (upper storey 81%; regenerating trees 91%).

While birch was common in the upper storey (28%), the regenerating trees were mainly flood and moisture-tolerant alluvial species (85%), indicating the selective pressure exerted by floods and high groundwater table on the vegetation.

The canopy of spruce-fir forests consisted of 39% of spruce (Fig. 8).

Overall, 61% of the upper storey was made up of coniferous shade trees, 25% of coniferous light-demanding trees and 14% of deciduous trees. Amongst the regenerating trees, the proportion of coniferous shade trees was similar; but Siberian pine and Siberian fir were more abundant than

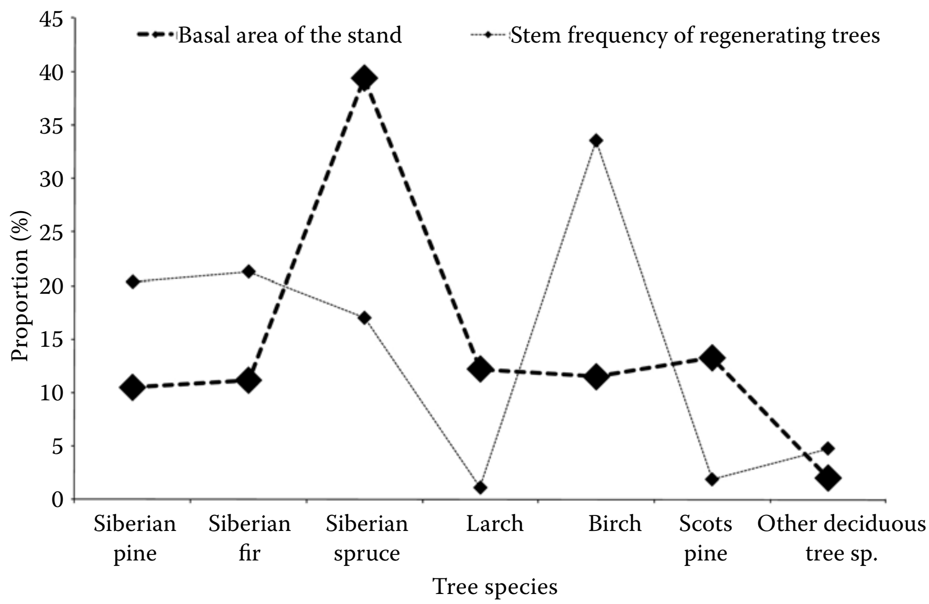

Fig. 8. Comparison of the proportion of tree species in the stand and amongst regenerating trees for spruce-fir forests (mean % of basal area or stem frequency)

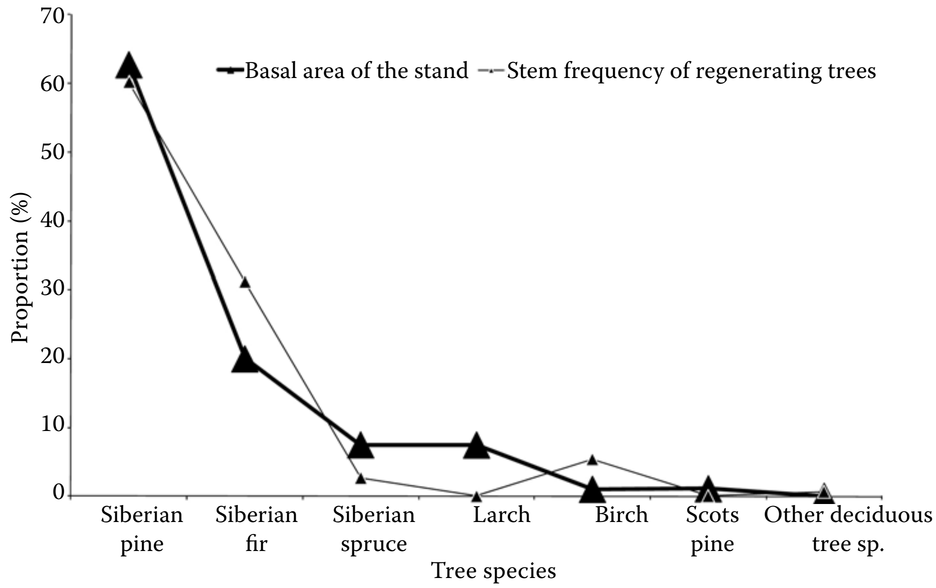

Fig. 9. Comparison of the proportion of tree species in the stand and amongst regenerating trees for Siberian pine forests (mean % of basal area or stem frequency)

spruce. Each of these three species made up approximately 20% of the regenerating trees.

In the Siberian pine forests (Fig. 9), both the upper storey and the regenerating layer were dominated by coniferous shade species (90%).

Although the coniferous light-demanding tree species constituted 9% of the upper storey, yet they were found to be absent in the regenerating layers, whereas the proportion of deciduous light-demanding tree species increased from 1 to 6%.

The proportion of live trees > 30 cm in diameter as well as the size of dead trees in the Siberian pine forests were larger than in the other forest types. The spruce-fir forests had a larger basal area within the small diameter class and trees with basal area > 30 cm in diameter were found to be 40% lower than in the Siberian pine forest (Figs. 10 and 11).

Altitude was an important site factor influencing the forest structure and composition as our studies showed that with increasing altitude (920 to 1,550 m a.s.l.) the stand basal area increased by 30%, the standing deadwood basal area by 25%, and the length of fallen deadwood by 14%. Overall, the living trees > 50 cm in diameter were found to be more numerous (156%), standing deadwood > 50 cm in diameter increased by 38%, and fallen deadwood by 76%.

DISCUSSION

Site parameters, particularly climatic differences caused by altitude and exposure seemed to have clearly influenced the forest structure within the

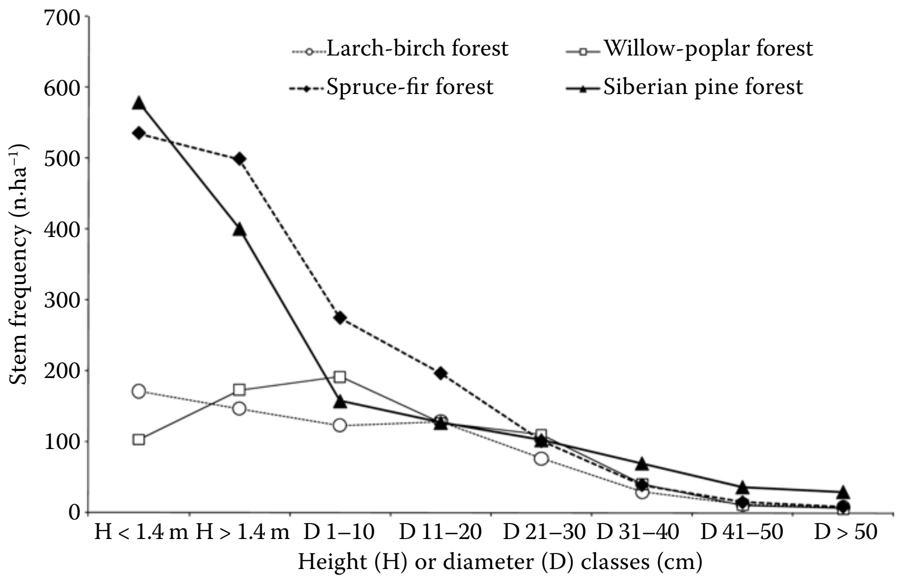

Fig. 10. Stem frequency between height classes of regenerating trees and diameter classes of the stand for the various forest types (mean in n·ha^{-1})

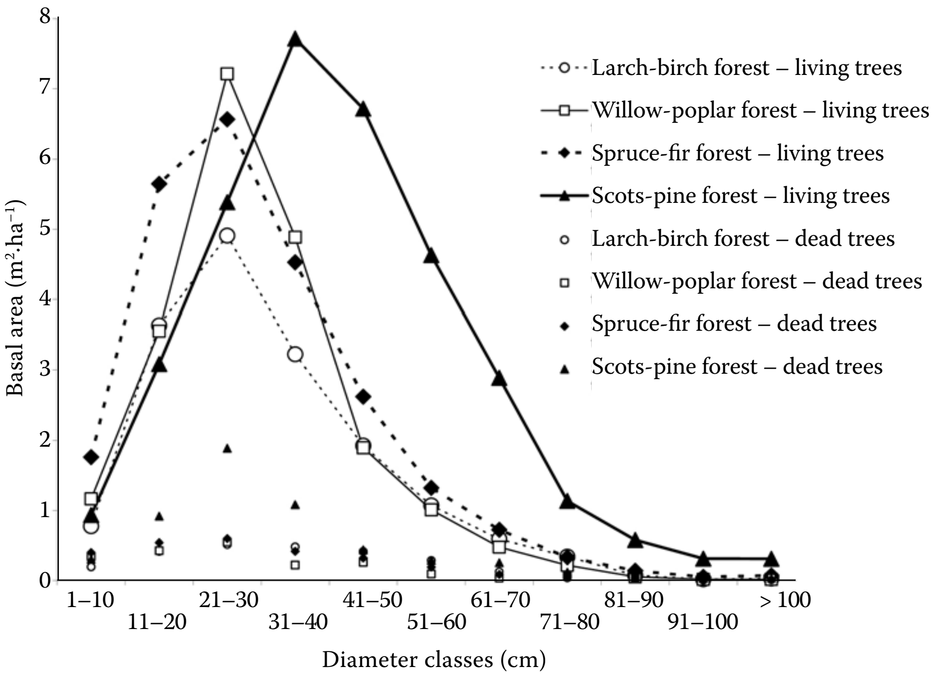

Fig. 11. Basal area of living and dead trees within the four forest types according to the diameter classes (mean values in $m^2 \cdot ha^{-1}$)

study area. Previous research studies in the study site have also reported the effects of wildfires in the sub-taiga and taiga to be altitude-dependent and thereby influencing the forest structure and dynamics (Chulunbaatar 2002). The greater volume of dead organic material, the fire-intolerant condition of coniferous shade trees and their higher density seemed to explain how fire was likely to spread into the treetops at higher altitudes. This seemed to clearly indicate that within the study area, due to the occurrence of frequent fires, the tree population in larch-birch forests tended to be uniform in age and size; while due to the longer periods for regeneration between fires, spruce-fir and Siberian pine forests had a higher diversity, both in terms of tree species and in the range of diameter classes. In recent times, a lower fire occurrence in Scandinavia (Goldammer, Furyaev 1996) has been known to lead to a loss of the fire-related generation of deadwood (Horson, Schieck 1999; Conner et al. 2001; Siitonen 2001). When compared with these forests, the proportion of deadwood in our study area was found to be clearly above the 10% reported for the wider Scandinavian region (Rylkov 1996), and within the range of values given for natural Scandinavian forests (absolute deadwood volume: 20–90 $m^3 \cdot ha^{-1}$; Larsson 2001; Siitonen 2001).

Although the density of regenerating trees recorded within all forest types was lower than the values given by Schulze et al. (2005), the yield table values of poor quality classes and the maximum ages given (Schober 1987) indicate that the stands in our study were fully stocked up to two-thirds. Therefore the expected minimum number of plants would be 650 according to Heurich and Rall (2006) or 400 according to Ott et al. (1997). Spruce-fir and Siberian pine forests clearly exceeded these numbers whereas larch-birch and willow-poplar forests were below 400 $trees \cdot ha^{-1}$. However, there is no reason to expect this level of regeneration to be too small so as to ensure the survival of these forest types.

This study was primarily aimed at investigating the forest structure and diversity within an undisturbed landscape except for the history of fire occurrences. This is a pioneer study on the forest structure in Khonin Nuga, a protected area with the high nature conservation value, due to a large area of less modified forests whose dynamics has not yet been altered by fire management. Due to the relatively southern location and gradual transition to steppes, these forests are assumed to be particularly rich in species, while at the same time being more sensitive to disturbance than the taiga forests located further northwards. In spite of the past history of selective logging and human interventions in the form of harvesting of cedar nuts, hunting and collection of antlers, the study results on the tree species composition, diameter distribution and proportion of deadwood indicate the high degree of naturalness retained by these forests. The protection of the area should therefore be accorded a high priority, and in particular efforts should be made to counteract an increase in the frequency of anthropogenic fires. The low human population density is another important factor which could have an implication for the future conservation and management strategy.

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