B-4.2.3 Study of the effects of environmental factors on the forest dynamics in northern Siberia. (Final Report)

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Abstract To analyze the dynamics of forests in the northern Siberia, we investigated the age structure, spatial distribution pattern and growth pattern of larch trees growing in the northern part of taiga forests in the eastern Siberia region. The study sites were located in the lower reaches of the Lena and Kolyma rivers, and in the lower and middle reaches of the Enisei river. In some of the study sites, we found an obvious tendency for aggregation of the trees in a scale of a few meters, which suggests patchy distribution of favorable conditions for tree establishment. However, the condition needed for the seedling establishment is unknown. Spatial heterogeneity of a larger scale of tens to hundreds of meters were also observed in the forest structure. In each of the study sites, the distribution of the tree age was not uniform: there had been 'good periods' and 'bad periods' for new tree establishment. The 'good periods' did not coincide among sites as closes as less than 1 km from each other. In the middle reach of the Enisei river, synchronous pattern of shoot extension growth were found among the larch trees. The synchrony indicates environmental control of the extension growth. A preliminary analysis indicated that the extension growth of a year depends on the amount of photosynthetic production stored in the previous year.

Key Words Forest structure, Height growth, Larch forest, Tree age

1. Introduction

The forth-coming global climate change should affect the terrestrial vegetation and thus, the global carbon cycle. The vast forested area of high latitude regions of the northern hemisphere is considered to be one of the most susceptible regions to the climate change. In northern part of eastern Siberia, the main component trees of the forests are larch species. The forest is called taiga. The possible effects of the climate change on the taiga ecosystems and its feedback to the global carbon cycle are of great concern of human society.

To predict how the climate change would affect the distribution pattern of the northern forests, knowledge on the dynamics and maintenance mechanism of the forest is needed. In 1994, we tried to get a coarse view of the forest dynamics from the age and size structure and spatial distribution of the trees near the northern border of taiga in Siberian region. In addition, we made a belt transect of ca. 600 m in a larch forest in 1995 to get an image of the spatial heterogeneity of the forest structure.

Through the observations in 1994 and 1995, we found that processes in the taiga ecosystems take place at a spatial scale ranging from a meter up to hundreds of kilometers and at a temporal scale up to thousands of years. Direct observation and experiments cannot cover such wide range of scales. We need a help of models to predict the responses of the forest ecosystem to the climate change. Construction of a mechanistic growth model of larch trees should be a promising approach to the prediction of the possible effects of the climate change on the larch forests. In the summer of 1996, we measured the branching pattern of larch trees as a bases for the tree growth model. Further, we analyzed year-to-year variation of growth of larch trees which might be related to environmental factors.

2. Study Sites and Methods

1994

In the summer of 1994, we visited two locations in the forest tundra. One was on the west bank of Lena river ca. 100 km west of Tiksi. The location of the site was 71° 37' N and 125° 32' E. The site was a flat area near a small stream and some flat-top hills. The altitude was ca. 150 m a.s.l. The tree density of the forest diminished from south to north, toward the tundra with no trees. The canopy of the forest was solely composed of *Larix gmelinii*. Many trees had old cones, but new ones were rare. The forest floor was typical of the forest-tundra, dominated by sphagnums and herb and grass species with some shrubs of a few tens of cm high.

The other one was in Taymir peninsula, ca. 100 km north of Noril'sk, and was located at 70° 03' N and 87° 36' E. It was near a large lake called Pyasino. In this area with small lakes, marshes, and hills, patch-like stands of *Larix sibirica* trees were scattered in tundra. Dense shrub community composed of *Alnus*, *Betula* and *Salix* species was found abundant. Some of the patches of *L. sibirica* have the shrub layer and some do not. Like in Tiksi site, many trees had only old cones.

In each of the tow study sites, two plots of 10 m x 50 m were set. In the four plots, locations of all the larch trees were determined. After measuring the tree height, disk samples of the stem near the ground surface were collected for the determination of the age.

1995

in the summer of 1995, we visited the west bank of the Kolyma River. Numbers of lakes were spotted in this area. The location of the study site was 68°41 'N, 160°16' E. The forest line ran within a few kilometers north of the study site. The only component species of the forest canopy was *Larix gmelinii*. The canopy of the forest was sparse with less than 30% closure in most of the area. Height of canopy trees was around 10 m.

A belt transect of 4 m width was set starting from the edge of the hill dropping to the river. The belt transect was extended to inland for ca. 600 m. The transect included flat areas on hilltops, slopes on the hillside, and wet area between the hills. Topography along the belt transect was measured. The belt was dissected into 7 segments on the bases of topography and numbered S1 to S7.

All larch trees appeared in the belt were mapped and their height and diameter were measured. Stem diameter was measured at 50 cm height and at the ground level for trees $\geq$ 1 m in height and those $<$ 1 m, respectively. Nine tree samples of various sizes were chosen for the analysis of height growth. Disk samples were collected from the stem at various heights from the ground surface.

1996

Measurements of various features of size of long shoots and branching patterns were carried out from 26 July to 7 August of 1996 in an experimental field of Sukachef Institute of Forestry located near Tura (ca 66°N, 100°E) in Ebenki region, Russia. Five saplings at an open site where the larch trees were clearly cut ca. 40 years ago and another five saplings on the forest floor of a nearby larch forest were selected as samples. Height of the samples ranged from 1.3 to 3.2 m. The age was from 17 to 32 years in the samples at the open site and from 43 to 120 years in those under the forest canopy. Branching pattern and extension growth in the last several years were measured on the main axis and some lateral branches. Yearly growth was determined from the bud scars. In addition, disk samples were collected from the sample trees near the ground surface to determine age and annual diameter growth.

3. Results and Discussion

1994

In the plots near Tiksi, trees younger than 100 years were relatively abundant, but older trees up to 400 years were also found (Fig 1). There were many seedlings younger than 10 years in one of the two plots, but none in the other. There two plots were only 1 km apart. It indicates that the factors controlling the seedling establishment are not climatic.

In the plots near Noril'sk, the age distribution pattern was symmetric and unimodal. They were centered around 60 - 80 years in one of the plot, and 80-120 in the other. Young seedlings were hardly found in both of the plots.

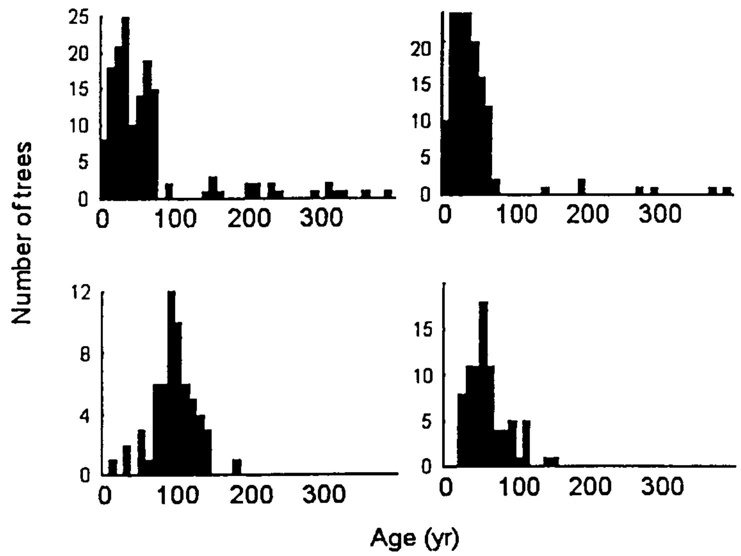

Figure 1. Histograms of the age of the larch trees in the study plots near Tiksi (top) and Noril'sk(bottom).

The height of the forest canopy was around 5 or 6 m in Tiksi site, and a little taller in Noril'sk site. High abundance of short trees was observed in Tiksi site. It suggests vigorous regeneration of the forest. Whether the forest is expanding into the tundra area was not obvious. Some, but not many, of larch seedlings and saplings were found in the tundra outside of the forest tundra area.

In three of the four study plots, there was an obvious tendency for spatial clumping of the larch trees. Some of the neighboring trunks were from one stump, but most of the clumps were not due to such sprouting. This spatial pattern of the larch trees suggests patchy distribution of the habitat suitable for the tree establishment, even though factors controlling the recruitment success of larches is not clear.

Figure 2 shows the spatial distribution of the trees in a plot of the site near Noril'sk. Ages of the trees were also indicated. There are several clumps of the trees as stated earlier, but the ages of the trees were not clumped within each clump. There are a few tens or more years difference in the ages of the trees in each clump. There seems no distinct difference of tree age among the clumps. If the clumping of trees is a result of heterogeneity in suitability for tree establishment, the spatial pattern of the tree ages suggests that many suitable sites were created simultaneously and the condition remained suitable for several decades. Further observation is needed for determining the critical process and requirements of seedling establishment of larch trees in forest tundra regions.

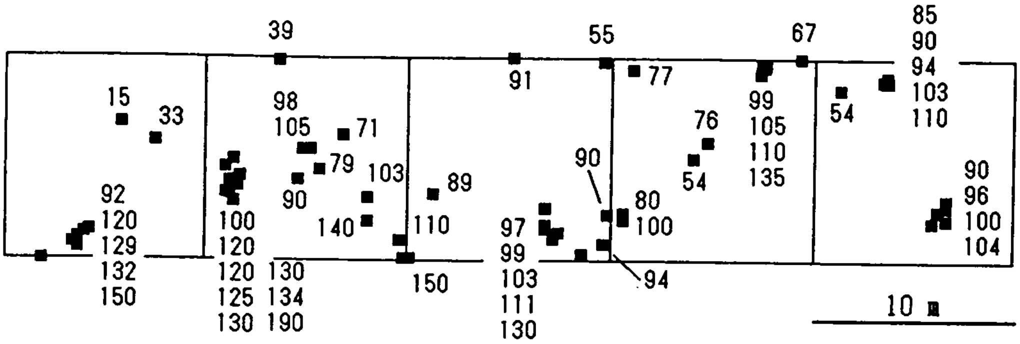

Figure 2. Map of larch trees in a plot of the site near Noril'sk. Each circle indicates the location of a tree. Numbers indicate the age of the trees.

1995

The larch trees showed clumped distribution pattern along the belt. The clumped pattern was most obvious for plants less than 50 cm height. The distribution of seedlings was confined mainly to the border of hillside and wet land . On the other hand, trees taller than 3 m showed less clumped distribution. Hardly any correlation was found between the distribution of tall larch trees and seedlings.

The height of the larch trees showed L-shaped distribution (Fig. 3, all plants). Individuals less than 1 m in height were abundant, and taller ones distributed over the range from 1 m to around 10 m almost uniformly. Among the segments of the belt transect, S3 was lacking trees taller than 5 m. This segment included wet area and the feet of adjacent slopes, where larches lower than 50 cm were clumped. In the segments on the flat area on top of hills, the height distribution was far from L-shape with low abundance of small ones.

L-shaped distribution of the height of the larch trees suggests continuous recruitment of new individuals. However, recent establishment of new individuals were confined mainly to the border between the wet area and the feet of slopes. The disagreement of the distribution patterns of small ($\leq$ 50 cm) and tall (> 3 m) individuals indicates that the recruitment of larch trees is a process heterogeneous both in time and space: spatially heterogeneous pattern of regeneration is variable with time. An area with tall individuals but lack small ones must have been suitable for seedling establishment sometime in the past.

High density of seedlings at the edge of wet area suggests involvement of water regime in the establishment of larch seedlings. The wet area might be now on its way of drying providing good conditions of seedling establishment. Lack of trees taller than 6 m in and near the wet area can be due to their recent establishment. Apparently vigorous growth of established saplings supports the hypothesis that limited height in this area is not due to growth limitation, but short time period after changes in condition in favor of seedling establishment.

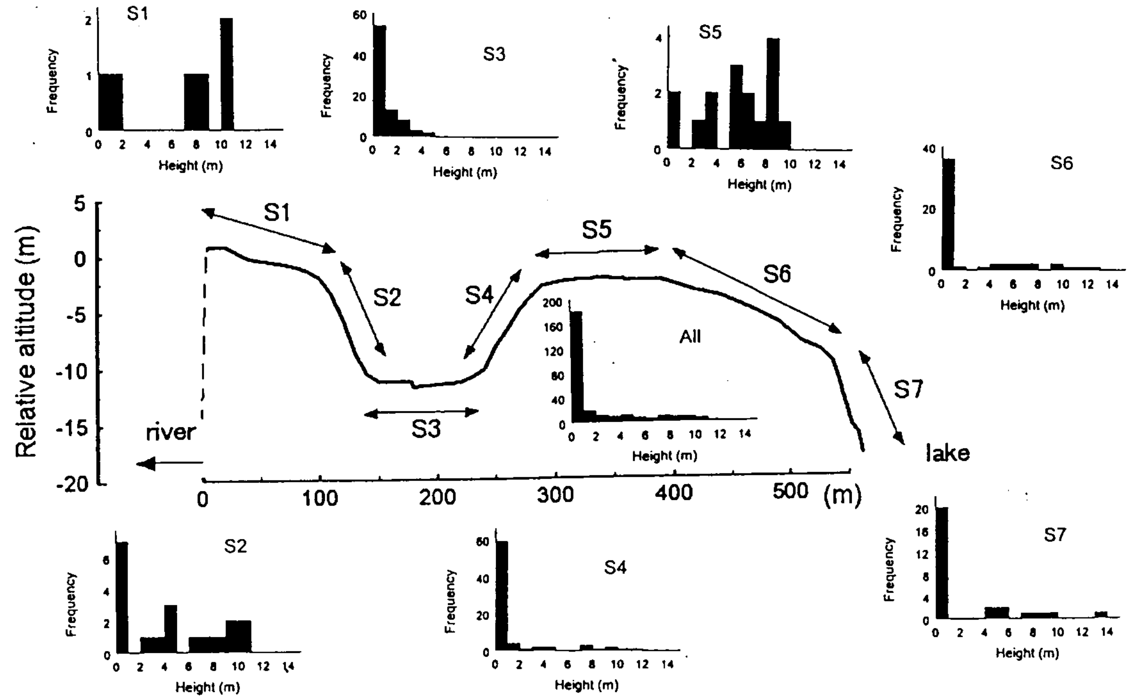

Figure 3 Histograms of the height of larch trees in the belt transect and in each segment of the transect.

1996

A large year-to-year variation in the length of long shoots was observed (Fig. 4). The patterns for main axes were quite similar among five samples at the open site. In all samples, growth in 1994 was the largest, and that in 1993 and 1995 was poor. The pattern was not clear in samples under forest canopy, but relatively poor growth in 1995 compared to 1994 and 1996 was observed in four out of five samples. Similar pattern was shared also among lateral branches, even though the amplitude was smaller.

The length of long shoots on main axes correlated with annual ring widths of corresponding years but the length:width ratio differed among the samples (Fig 5). The correlation was less clear in samples under forest canopy.

Correlation of year-to-year variation of current shoot length among different samples strongly suggests that the variation is due to climate conditions. Less precise matching of the patterns among samples under forest canopy is probably because their growth is limited by shortage of light and the influence of other environmental factors are obscured.

The pattern of the growth suggests that the growth conditions in 1994 were favorable while those in 1993 and 1995 were unfavorable. It is not true. The summer of 1994 was extremely dry with scarcely any precipitation in July (A.P. Abaimov, pers. comm.). Possible explanation of the discrepancy of growth condition and shoot extension growth is that the photosynthetic production of this year is not used for this year's shoot extension and diameter growth. It is used for the growth of the next year. This explanation agrees with the fact that shoot extension and diameter growth cease within an early period of a growing season.

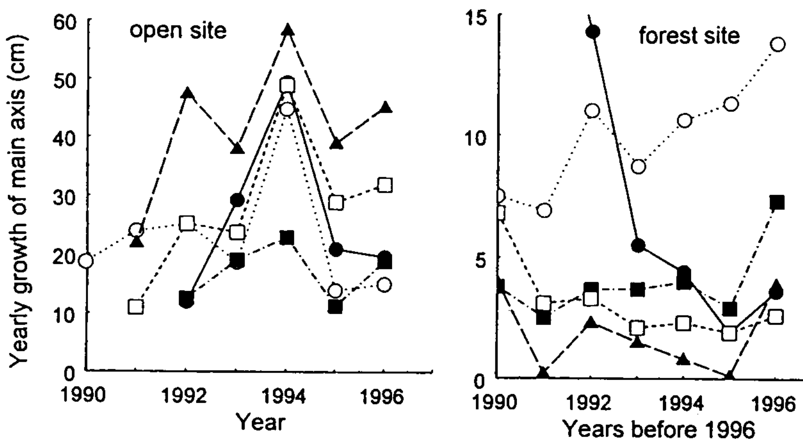

Figure 4. Among-year variation of the extension growth of main axes. Different symbols represent different sample trees.

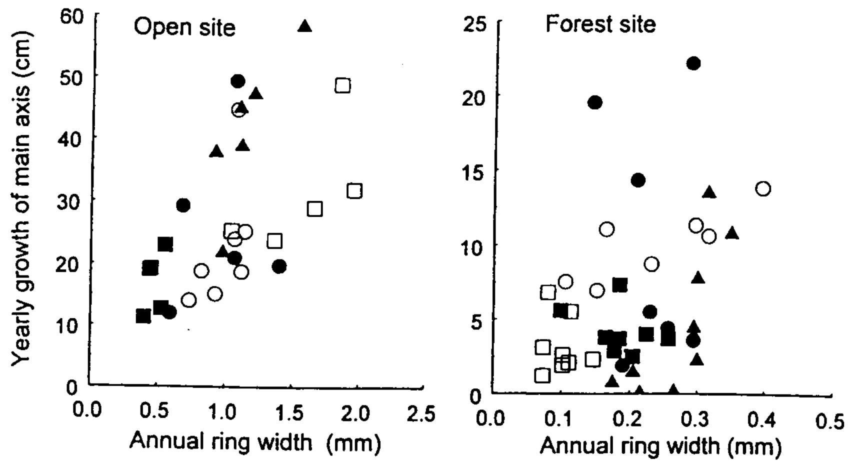

Figure 5. Relationships between yearly growth of main axis and annual ring width. Different symbols represent different sample trees.

4. Conclusion

When viewed from a distance, the vast area of taiga seems homogeneous. However, after two years study in 1994 and 1995 of the age and size structure of the northern larch forest, we recognized spatial and temporal heterogeneity of the process and pattern of the forest. Direct observation and experiments can hardly cover the entire range of the heterogeneity. Alternative approach to the possible effects of the climate change on the taiga ecosystem is the use of a mechanistic model of the system. We found a large year-to-year variation of the growth of larch trees, which is likely to be due to variations of climate conditions. The analysis of the growth variation, which can be directly observed, would give bases for the model construction.