Extension of Larch Forest and its Meteorological Conditions at the Continuous Region of Permafrost in the Northern part of Mongolia

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1. Introduction

Hovsgul, the northernmost state of Mongolia, is located on the southern fringe of East Siberian *Light Taiga* zone, where permafrost is continuously distributed and deciduous conifer forests dominated by larch (*Larix* spp.) prevail. The climate of Light Taiga zone is too dry (annual precipitation: 200-400mm/yr) to support continuous closed forest vegetation normally. However, underlying permafrost layer holds significant amount of summer rain water enough to support closed larch forests tentatively in the active layer. Further, larch is very tolerant to winter freezing, and needs less water for evapotranspiration than such dominant evergreen conifers of West Siberian Dark Taiga as spruce and fir (Ohta et al., 2001, Sugimoto et al., 2002).

The light taiga ecosystem is thus maintained by a very delicate balance. Once a forest stand is cleared, resultant increase of solar radiation reaching ground surface causes the increase of active layer depth and severe desiccation of ground surface soil, which strongly inhibits the larch seed germination and seedling growth. In recent year, larch forests in northern Mongolia have suffered from frequent burning and insect (moths) outbreak as in other parts of Siberian taiga, but the recovery of forest by natural regeneration on damaged areas is thus very slow.

We are going to describe an example of natural forest regeneration taking place at the forest/grassland border, and to clarify the factors concerned, particularly meteorological conditions, to predict the effect of climate change on the forest, and to obtain useful information for future forest conservation in Mongolia.

2. Study site and methods

This field study has been made since June 2004 in Darad valley, one of the head water of the Enisei River, near the NW corner of Hovsgul state (Fig.1). Broad valley bottom supports an extensive stretch of wetlands, consisting of complex networks of water courses and many shallow lakes of various sizes. The wetland area is surrounded by hills covered by alternating forests and grasslands. The forest consists exclusively of Siberian larch (*Larix sibirica*), and grows on north-facing and northeasterly slopes (Fig.2-1), whereas frier south and southwesterly slopes are treeless and covered by grasslands. Grasslands and even the undergrowth of larch forests are always grazed by livestock. Heavy grazing pressure tends to increase grassland area at the expense of retreating forest stands.

The field survey was conducted on a hill at 50°58.9'N and 99°22.2'E. The east-facing gentle slope (mean gradient: 13°) stretching from the hill-top (altitude: 1,723m) to the foot (1,571m) served as the site for the study on the structure of forest/grassland border. The borderline ran more or less vertically along the slope, extending over two-thirds of the slope distance. It was noticed that a zone of very densely growing thicket of larch saplings existed between grassland and tall forest stand (Fig.2-2). Further, this sapling zone itself consisted of two apparently different parts, low (height<1.5m) and high (>1.5m) subzones (Fig.3).

Three cross sections of border zone (T, C and B-line) along contour lines at different altitudes were examined, by setting 11 sampling sites, representing respective types of plant cover (Fig. 3). At the 8 sampling sites, using quadrats of appropriate sizes, the size and number of all trees in the quadrat were measured (Table 1). To count tree age, stem section samples were collected from 3-11 trees per quadrat using an increment borer.

The land survey by means of GPS was applied to draw distribution map of larch saplings. Continuous observation of air

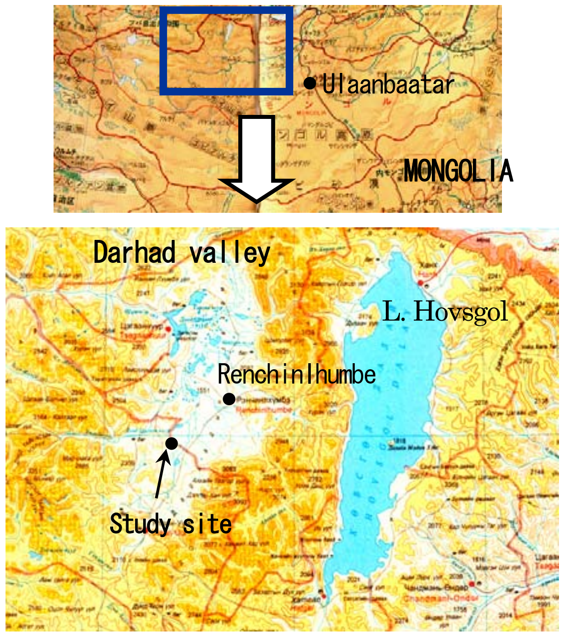

Fig.1 Field study site in Darhad valley in northernmost Mongolia.

temperature at 1-hour intervals has been kept since June and August 2004 by setting automatic recorders at the top and the foot of this hill, respectively. In late August 2005, soil water contents of surface soil (5cm and 20cm depths), were measured. At the same time, temperature profiles of surface layer down to 70cm depth under different parts of the forest/grassland border zone were observed in order to estimate the thickness of active layer, and the depth of surface soil was also measured by driving an iron rod.

3. Results and discussion

Growth of larch communities

Individual tree density per ha decreased from 17,100-23,200 in the low sapling zone to 45,200-102,800 in high saplings, and eventually to 1,233-3,664 in the tall forest site (Table 1). Average stem diameter was fairly uniform (21-31mm) in both low and high saplings, but was variable in the tall forest (70-125mm) (Fig.4). High saplings were more than twice as tall (1.64-2.38m) as low saplings (0.67-0.92m). The estimated age of trees was almost 12 years in saplings of both sizes, while that of the tall forest site trees ranged between 45 and 123 years. These results indicate the growth rate of larch trees under prevailing environmental conditions.

Fig.2-1 Panoramic view of extension of Siberian larch forest in Darhad valley.

Fig.2-2 Field study at high sapling in extension of Siberian larch forest.

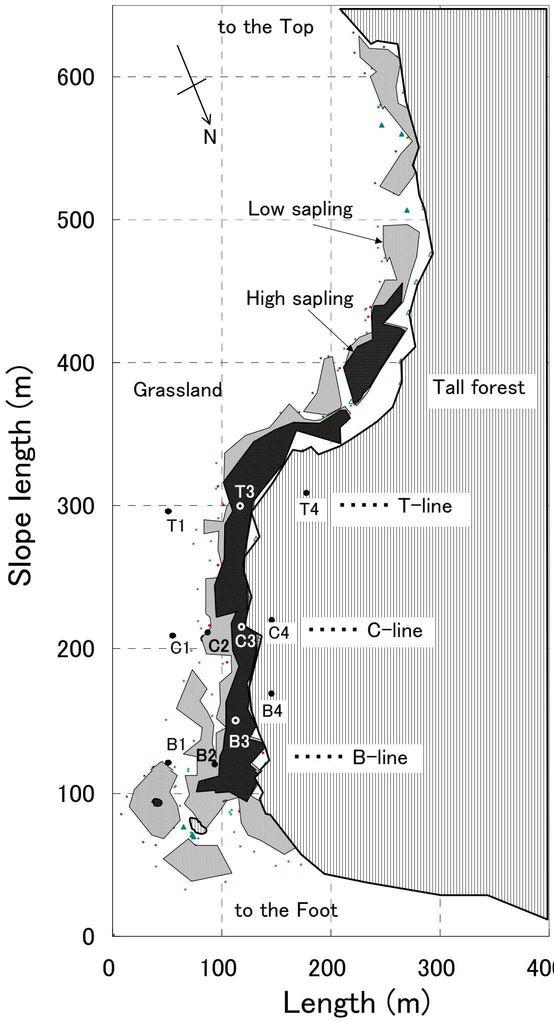

Fig.3 Map of the forest/grassland border zone studied, showing the position of 11 sampling sites.

Table 1 Observation results on trees at each site along T, C and B-line.

Kind of community	Low sapling	High sapling	Tall forest
Quadrat	5×5m	5×5m	30×30m
Site (Altitude: 1622m) along T-line	T2	T3	T4
Density of tree growth (×10000/ha)	—	10.28	0.38
Average tree hight (m)	—	1.8	—
Average stem diameter (mm)	—	21	70
Average tree age (years)	—	12.5	46.3
Site (Altitude: 1606m) along C-line	C2	C3	C4
Density of tree growth (×10000/ha)	1.71	4.52	0.27
Average tree hight (m)	0.67	1.6	17.3*
Average stem diameter (mm)	22	26	84
Average tree age (years)	12.0	12.4	45.0
Site (Altitude: 1586m) along B-line	B2	B3	B4
Density of tree growth (×10000/ha)	2.32	5.48	0.12
Average tree hight (m)	0.92	2.4	20.0*
Average stem diameter (mm)	23	31	125
Average tree age (years)	11.7	11.7	43.0

*: Highest tree

Air temperature

The minimum and maximum air temperatures, observed continuously since June and August 2004, were -38.8℃ and 30.9℃ on the hill top, and -46.7℃ and 32.1℃ at the slope base, as shown in Fig.5-1 and Fig.5-2. Reverse minimum temperature gradient toward higher altitude indicates the formation of temperature inversion layer in winter. Daily range of summer air temperature was larger at the foot than on the hill top.

Soil conditions

Soil water contents on a volume basis at 5cm and 20cm depth were 20% at all sites across the middle part of grassland/forest border zone, except for the higher values (30%) at 5cm depth in the sapling zone (Table2). Based on the measured underground temperature profiles, the thickness of active layer was estimated to be the largest (4.68m) under grassland and the least (1.54m) under the high sapling as shown in Fig.6. The surface soil layer was mostly 70cm thick. Figure 7 illustrates the schematic cross section of the study sites based on the results stated above.

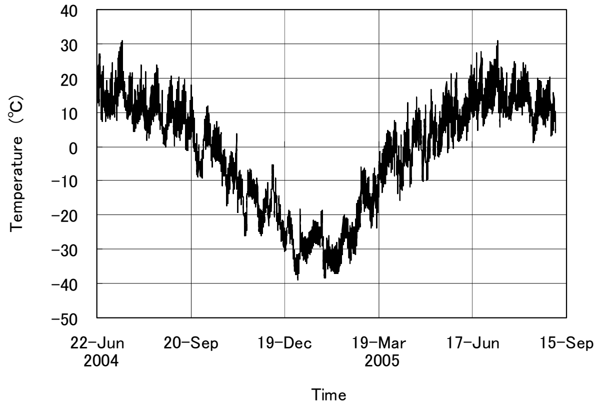

Fig. 5-1 Changes of air temperature on the top of hill.

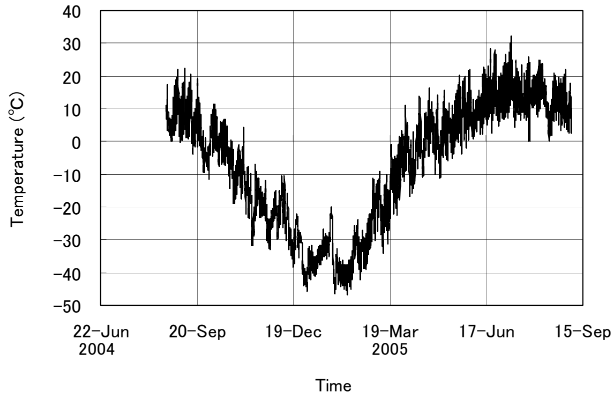

Fig.5-2 Changes of air temperature on the foot of hill.

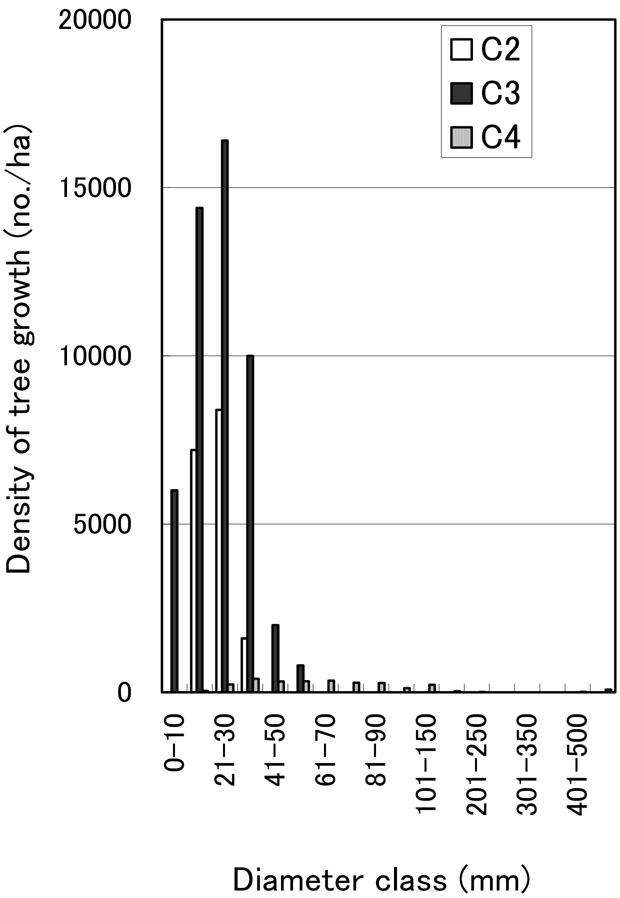

Fig.4 Distribution of growing tree density against tree size along C-line.

Table 2 Volumetric water content of surface soil at sampling sites along C-line.

Site	C1	C2	C3	C4
Volumetric water content (%)				
Soil at 5cm depth	31	38	27	27
Soil at 20cm depth	22	28	24	23

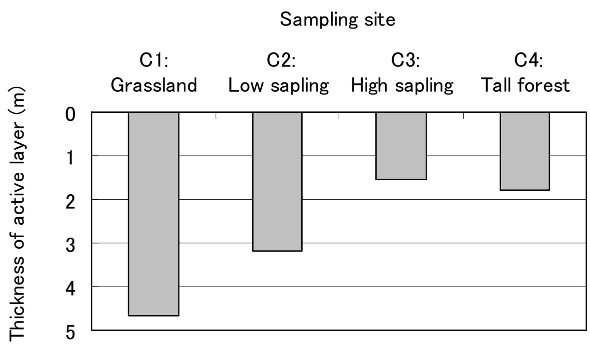

Fig.6 Estimated depth of active layer under different parts of the forest/grassland border zone.

Meteorological conditions for larch sapling emergence

Larch saplings proved to be 12 years old in both low and high zones, though the zones look quite different from each other. Probably, the nearest to grassland, the worse has been the conditions for the saplings.

The saplings are thus estimated to have emerged from seeds in 1994. According to the meteorological observation at Renchinlhumbe (26km away from the present site), monthly precipitation in that year amounted to 35.7mm in May, when larch seeds start to germinate, and 113.3mm in June as presented in Table 3. These amounts are significantly more than corresponding yearly averages. Especially, June in 1994 received more than twice as much rainfall as compared with normal year. Besides, there were no danger of late spring frost to seedlings, since the daily minimum air temperature never fell below the freezing point after May 31st in 1994. Dry days without rainfall did not continue for more than 7 days during the 1994 summer. These conditions were not filled in 5-years periods immediately before and after 1994, as shown in Table 3. To summarize, 1994 was a rare year favorable for the germination of larch seeds and seedling emergence.

4. Concluding remarks

Conditions other than meteorological may be needed to produce dense thickets of larch saplings on the edge of existing forests. Abundant seed supply is of course important. The mast year of larch seeds, which is said to occur at 4-5 years intervals, may therefore offer another condition. Where on the forest edge the thickets are produced depends apparently on edapic conditions, e.g. exposed mineral soil surface without grass and litter cover.

In spite of the rarity of chances for these conditions to be fulfilled simultaneously, the natural regeneration of this type of various ages is quite frequently observed throughout larch forests of northern Mongolia, as the most important process of recovery from natural and human-made disturbances.

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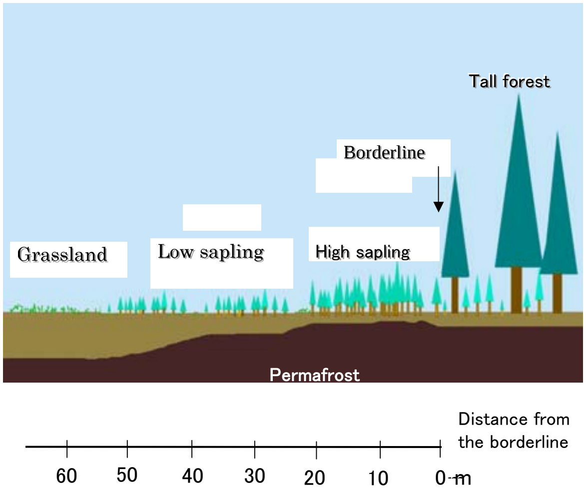

Fig.7 Schematic cross section of the forest/grassland border zone.

Table 3 Monthly precipitation records during 1989-1999 at Renchinlhumbe (Moron Meteorological Station, 1989-1999)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1989	1.4	0.0	0.0	2.8	21.9	55.8	76.9	98.9	5.8	0.0	1.4	2.1	267.0
1990	4.0	0.7	0.7	10.0	17.5	47.7	127.5	59.3	21.9	0.9	9.0	2.6	301.8
1991	6.2	1.4	3.3	3.5	20.6	49.7	43.7	65.5	47.2	1.4	8.5	2.9	253.9
1992	5.1	0.0	2.5	2.1	8.7	24.8	59.6	104.2	51.1	13.6	4.5	2.7	278.9
1993	0.0	3.6	1.2	2.3	6.6	35.2	88.9	61.5	30.3	12.5	3.4	7.8	253.3
1994	1.8	6.3	4.5	5.3	35.7	113.3	68.1	56.4	58.8	2.5	6.2	5.6	364.5
1995	0.7	2.2	2.8	4.8	14.0	38.2	57.2	44.2	8.4	8.4	0.8	4.2	185.9
1996	5.8	5.2	1.9	1.9	16.5	24.4	91.3	53.8	38.9	0.0	0.5	0.7	240.9
1997	0.4	0.0	0.4	0.0	16.5	59.0	88.7	65.0	21.9	5.6	5.5	0.6	263.6
1998	1.9	1.4	1.2	11.5	20.3	25.4	106.2	58.6	19.6	1.6	7.1	1.0	255.8
1999	2.4	0.0	2.2	1.1	2.9	25.4	113.2	48.0	5.9	2.1	9.5	4.4	217.1