Preliminary investigations on the effects of branch withering and the thinning of trees for living snow fences in Northern Hokkaido, Japan

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ABSTRACT

We investigated the growth rate and branch conditions of *Pinaceae* trees that make up living snow fences, and examined their effect on drifting snow. In total, we examined 22 snow fences, all located in Hokkaido, Japan, consisting mainly of *Picea glehnii, Picea abies, and Abies sachalinensis*. Some trees, usually among those in the inner parts of the fence, had withered branches at heights of 1 ~ 2 m above the ground. Also, some trees will be thinned. But how does 1) the withering of their branches, and 2) their thinning affect the mitigation of blowing snow? This study is a preliminary investigation to address these questions. Our findings include the following: 1) The height-integrated mass flux of snow decreases as a function of horizontal distance, throughout the 30-m forest width. 2) The windspeed was found to be higher after thinning than before thinning. 3) The visibility in blowing snow in the sparse forest, on the other hand, is unchanged from that of the dense forest when the wind direction is nearly orthogonal to the forest and the roadway. These findings should be considered for further investigations on improving living snow fences using *Pinaceae* trees.

Keywords: Living snow fences, blowing snow, *Pinaceae* trees, withered branch, thinning trees

INTRODUCTION

Living snow fences (LSF) provide a wealth of benefits, not only from the interception of blowing snow, which reduces traffic problems *(1)*, but also from erosion control *(2)*, carbon sequestration *(3)*, aesthetic enhancement, and wildlife habitat *(4)*. LSF have also attracted much attention because they reduce the public cost of roadway maintenance *(5)*, and some LSF have potentially longer life cycles than other snow fences (i.e., plastic, metal). For instance, willow trees and shrubs, a major type of LSF in the United States, has a potential use for the fence because the plant is easy to propagate, has a rapid growth rate *(6)*, and has a suitable canopy height for the LSF *(7)*.

PREVIOUS MAJOR STUDIES OF *PINACEAE* TREES FOR LSF IN JAPAN

In Japan, the major tree genus for LSF is *Pinaceae* (including *Picea glehnii*, *Picea abies*, and *Abies sachalinensis*) for roadways, whereas some deciduous broad-leaved tree forests are also studied for use on scenic railroads *(8)*.

Major studies dating back to the 1950s reported several results regarding LSFs. The drag coefficients of trees were measured from the vertical wind velocity distributions toward the forest *(9)*, possible factors that may influence blowing snow interception were suggested *(10)*, and visibility in snow was measured to assess the effect of the fence during blowing snow *(11)*. We recently reported on the effect of forests as a snow fence, considering wind direction and comparing dense and sparse forests, finding that the dense forest was better for blowing snow prevention *(12)*.Consider some of these studies, *Pinaceae* have been planted and studied as a linear barrier upwind of a roadway for more than half a century in Japan. By 2009, such fences have been developed in 210 places along national roads in Hokkaido, with a total length of about 80 km *(13)*. Due probably to regional climate changes *(14)* and our recent investigations on the *Pinaceae* for blowing-snow prevention, several places of *Pinaceae* are often poorly functional for the blowing snow in Hokkaido. Moreover, about 40% of roadways every year in Hokkaido become blocked by blowing snow during the winter season. Therefore, we still need to investigate and maintain the *Pinaceae* trees in forests.

In Japan, the LSF are distributed mostly in Northern Hokkaido. For our selection of sites, we excluded non-forested regions, inconsistent tree conditions, non- *Pinaceae* fences, and non-accessible places. In so doing, we narrowed the LSF to 22 sites (Figure 1). For this study, we examine the *Pinaceae* at these sites, focusing on 1) existence conditions and growth rate of the trees, 2) the wind direction and windspeed as a function of tree height, 3) snow-drift transport rates measured simultaneously windward and downwind of the fence, and to clarify the thinning effect, 4) windspeeds and wind direction as a function of incoming angles of wind considering the thinned trees in the forest.

1) EXISTENCE CONDITIONS AND GROWTH RATE OF TREES

We examined two to four living trees at each site, measuring the height of the canopy, as well as the lowest branch with and without withered branches. The age of trees were estimated from our previous investigation, reported in 1996 (written in Japanese).

The variety of trees are shown in Figure 2 and the height measurements are explained in Figure 3. The major trees used here for LSF are including *Picea glehnii*, *Picea abies*, and *Abies sachalinesis*. Figures 4.1, 4.2, and 4.3 show their relation between tree age and height. The average tree height is approximately 9.7 m (minimum: 4 m, maximum: 16 m) regarding 30 ~ 40-year-old trees. The condition of the trees at these sites should be related to the ambient environment but it was not examined closely. However, we found the growth rate of *Picea abies* to be much higher than those of *Picea glehnii* and *Abies sachalinesis*. That result suggests that the *Picea abies* is non-native species introduced almost a century ago and may grow without direct competition.

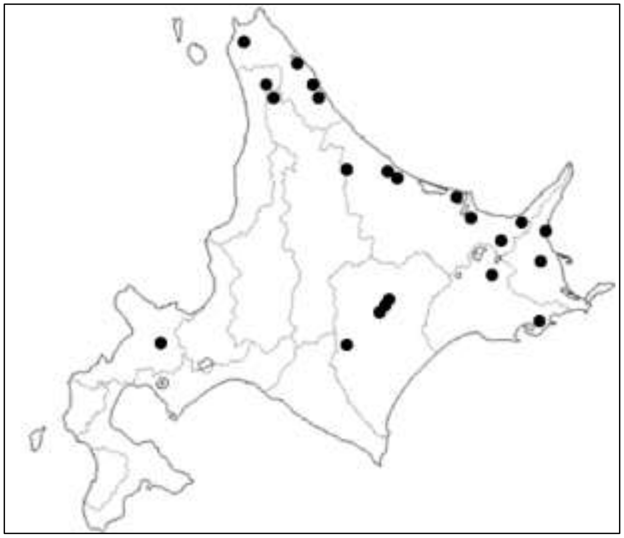

FIGURE 1 LSF study sites in Hokkaido, Japan.

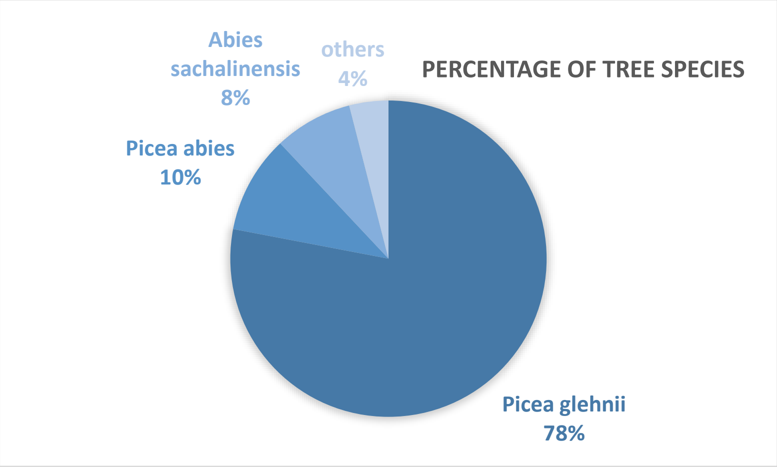

FIGURE 2 Tree species distribution at the 22 sites.

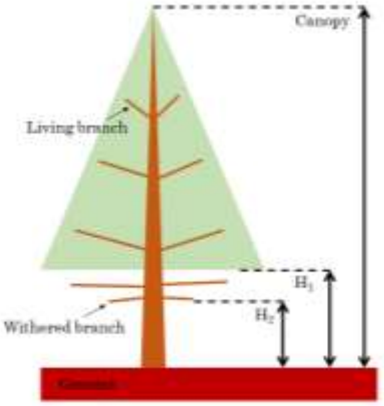

FIGURE 3 Height measurement parameters. Canopy, H_1, and H_2 are top height, minimum height of

living branch, and withered branch, respectively.

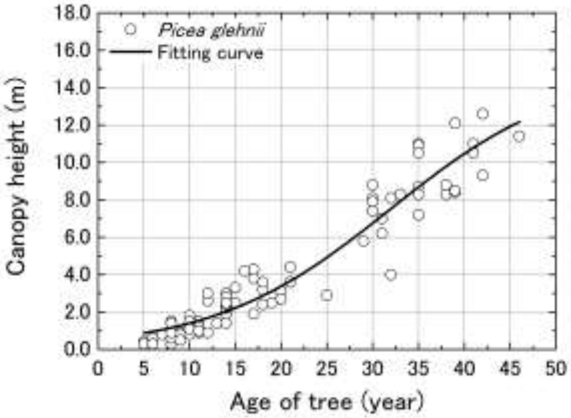

FIGURE 4.1 *Picea glehnii* tree age and height. Fitting curve is the logistic function and the determination coefficient is approximately 0.92.

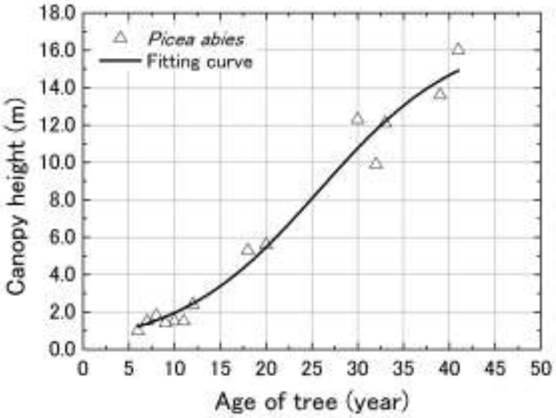

FIGURE 4.2 Same as Fig. 4.1 except for *Picea abies.* Determination coefficient is approximately 0.97.

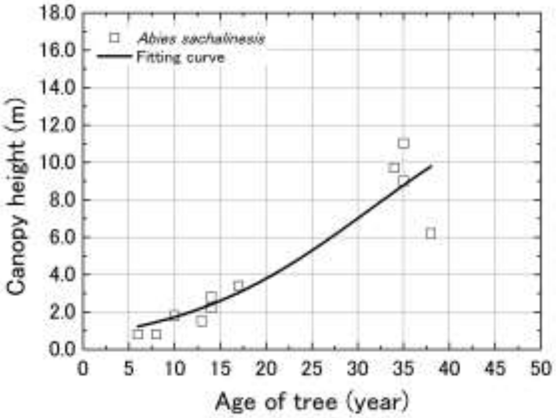

FIGURE 4.3 Same as Fig. 4.1 except for *Abies sachalinesis.* Determination coefficient is approximately 0.84.

Regarding the tree conditions, we occasionally found withered branches, more frequently in the inner parts of the forest. As the mass flux of snow decreases with increasing height from the ground, we measured the lowest living branch height (H_1) and lowest withered branch height (H_2) following the definition shown in Fig. 3. The height H_1 increases as a function of canopy height with some variation (Fig. 5). The variety of living branch height probably depends on the distribution of trees in the forest, which depends on the insolation. The height H_2 also varies, but does not exceed about 2 m. The statistical results tell us that some forests could be considered for tree thinning to keep the branches growing healthfully. Such thinning would be useful if it is demonstrated that the lower parts of living and withered branches are effective for preventing blowing snow.

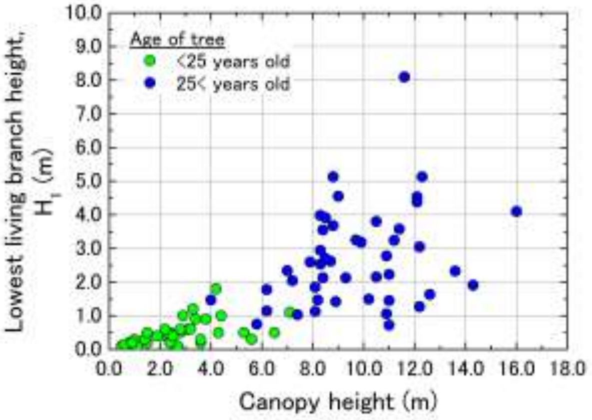

FIGURE 5 The lowest living branch height H_1 versus canopy height of *Pinaceae* trees.

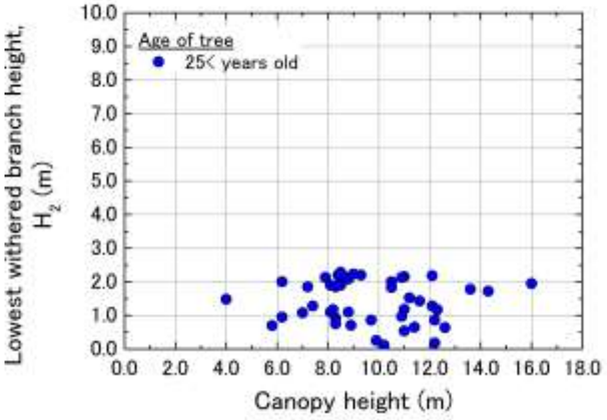

FIGURE 6 The lowest withered branch height H_2 versus canopy height of *Pinaceae* trees.

2) WIND AND SNOW DRIFT OBSERVATION IN THE FOREST

To clarify the effect of the trees on blowing snow, we observed the windspeed and mass flux of snow as a function of height from the ground in Northern Hokkaido during the winter season of 2015 to 2016. The observation point lies along National Route 40, and is shown in Fig. 7. The trees in the studied area were planted in 1985, and the fence has a distance exceeding 5-km long.

We chose the highest trees in the shelterbelt. Here, the forest width is about 30 m, the highest canopy is 13 m, and living branch height averages about 2 m. The main species are *Picea glehnii* and *Abies sachalinesis*. The dominant wind direction is west, so the wind direction towards the forest is approximately 45 degrees. Behind the forest is grass farmland (open space), with a blowing distance of more than 300 m before reaching the LSF.

FIGURE 7 LSF site at N44°54'76", E141°53'72" (left), and a picture of National Route 40 at the observation point (right).

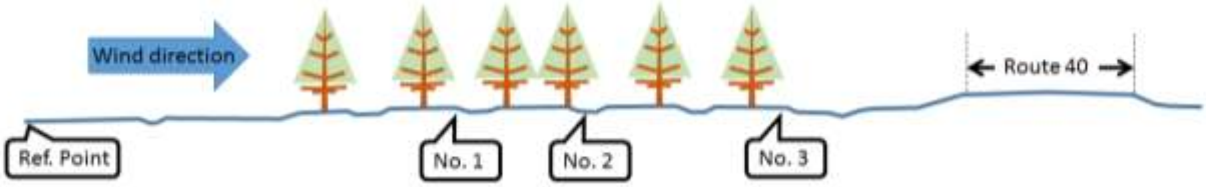

FIGURE 8 Observation points in the LSF site near National Route 40. On the left hand side is the reference point. Distances to measurement points 1, 2, and 3 are about 53, 61, and 72 m, respectively. Wind direction is from west to east (left to right).

We placed wind gauges and net-type snow trap at three points perpendicular to the road, as shown in Fig. 8. The gauges and trap measured windspeed, wind direction, and snow-drift transport rate. At each observation point, we set windspeed gauges at heights of 7.0, 3.0, 1.0, and 0.5 m, and set the net-type snow trap at heights of 3.0, 1.0, 0.5, 0.3, 0.1, 0.07, 0.05, and 0.02 m respectively. Measurement durations averaged 5 to 20 minutes. We recognized three episodes of blowing snow, but we could measure blowing snow only one time, on February 17th, 2016 when the wind was westerly. The distance from the reference point to the boundary of forest and open space is about 45 m. We assume that the windspeed at the boundary equals that at the reference point. Therefore, distances of each point from the boundary are 8, 16, and 27 m, respectively.

As shown in Fig. 9, the windspeed ratio decreased across the forest especially the height of 7 m but the windspeeds nearest the ground (1.0 and 0.5 m) increases after passing through point No. 1 (8-m from the boundary). The result tells us that the living branch may reduce the windspeed, but the withered branch does not. To evaluate the snow drift passing across the forest quantitatively, we integrated the height of the mass flux of snow including saltation, creep, and suspension snows at each point (Fig. 10).

We noticed an interesting phenomenon in which the windspeed does not decrease near the ground level in the forest, but the total snow drift transport rate decreases as a function of the horizontal distance, throughout the 30-m forest width, even when withered branches are in the inner part of the forest. Further studies should address how the withered branch effect depends on windspeed and direction, visibility in snow, and snow transport rates.

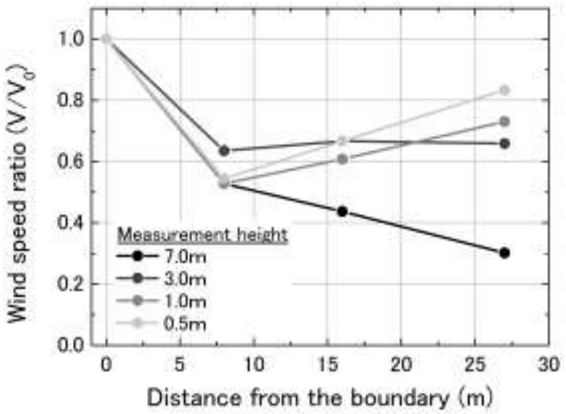

FIGURE 9 Windspeed ratio at four heights and at each observational point. Windspeed ratio: windspeed at each point (V) / the reference point (V_0).

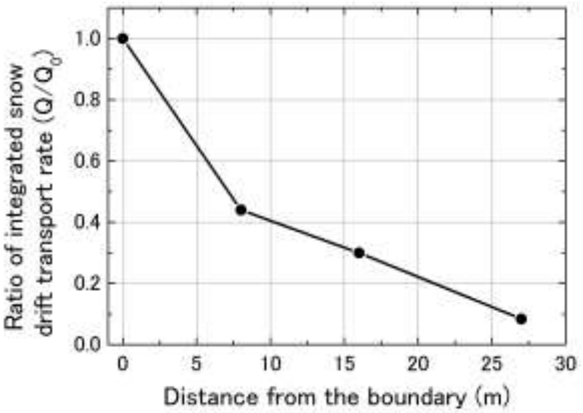

FIGURE 10 Ratio of integrated snow drift transport rate at each observational points. The ratio is expressed as integration of measured snow drift transport rate (Q) / the reference point (Q_0).

3) THINNING EFFECT FOR WINDSPEED OBSERVATIONS

Where blowing snow is a problem, we need a management strategy approach to keep LSF trees growing using cost-effective public funds. In general, *Pinaceae* forests need 13 to 23 years to grow into adult trees and some branches are withered due to interference between neighboring tree branches and a low annual insolation *(13)*. In this study, we first evaluate the thinning effect for blowing snow and we will take the result into consideration to help improve management policy.

The observation points are shown in Fig. 11. We observed windspeed and direction, and traffic visibilities to clarify the effect of thinning trees during the winter season of 2015 to 2016. The shelterbelt is created along Route 238 national-road in 1993. Species of trees are mainly *Picea glehnii*, and *Picea abies*.

FIGURE 11 Map of observation site at N44°51’71”, E142°38’74” (left). Top view of observation site near National Route 238 and thinned trees area expressed in red box (left), and a picture of measurement point inner part of the forest (right small picture).

The width of the forest is about 30 m and the average height is about 7 m. The long branches interfer with neighboring trees. Following our report regarding the management approach *(13)*, we thinned the southern part of the trees shown in Fig. 11 and we placed wind gauges at seven points and visibility gauges windward (open space, point A) and at downwind (near the national-road, point C). Here, snow metal fences with a height of 1 m are set at windward along the shelterbelt (see Figure 11; right picture). We defined here that points B, C, and D are sparse, dense, and partly dense forest, respectively. We measured windspeed for a 10-minute average and wind direction with prevailing wind direction due to bearing azimuth of 16 directions. For the visibility in snow, we used a median value of 10 minutes. We excluded data when the windspeed was less than 5 m/sec. after being converted to 7 m height, and excluded data in which the visibility in snow exceeded 1 km. To evaluate wind direction dependence while considering only orthogonal angles from the national-road, we carefully analyzed the windspeed and the visibility.

Figure 12 shows the results of the windspeed ratio as a function of wind direction. The speed is normalized by the windward point A. The normalized windspeed at point C is 0.28 ~0.42 with the wind direction range of 45 ~ 135° and the result of the windspeed at point B is slightly higher than that at point C. This result is acceptable.

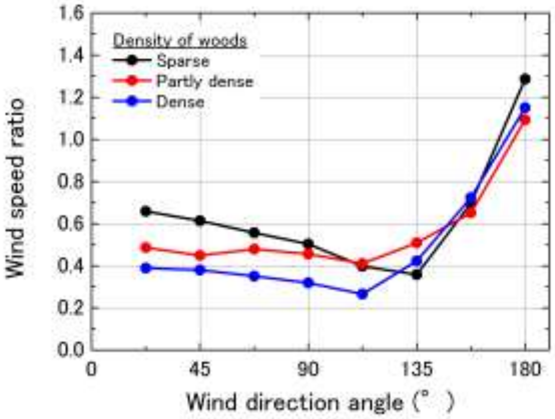

FIGURE 12 Windspeed ratio depending on the wind direction angles from along the national-road direction.

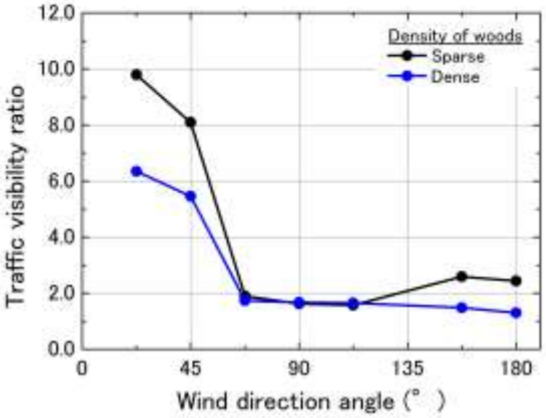

FIGURE 13 Visibility ratio of sparse and dense forest, at the point B and C, respectively.

Figure 13 shows the results of the visibility in snow at point C, which is normalized to data point A. The visibility is about the same at points B and C when the wind direction is about orthogonal to the national-road. On the other hand, the visibility in snow at point B is higher than that at point C, which changes with the wind-angle direction when close to the national-road. The thinning work wonders at the point B when the wind-angle direction is acute from the national-road.

SUMMARY

We investigated the condition of *Pinaceae* trees for living snow fences (LSF) distributed in Northern Hokkaido, Japan. We found the following:

1. Most LSF trees are *Pinaceae* trees including *Picea glehnii*, *Picea abies*, and *Abies sachalinesis*. We occasionally found withered branches especially in the inner part of the forests in all places.
2. The total snow drift transport rate (integrated height data from 0.1 to 7 m) decreases as a function of a horizontal distance over the ~30-m wide forest even when the withered branches exist at a height lower than 2m from ground.
3. We measured the windspeed as a function of wind direction dense forest (non-thinning trees) and sparse forest (thinning trees). We found that the windspeed ratio in sparse forest slightly increased from that in the dense forest. The measuring point at close to the sparse forest shows that the visibility in snow increases as a function of the direction of the wind toward the national-road. The visibility in snow close to the sparse forest, on the other hand, is unchanged from that of the dense forest when the wind direction is nearly orthogonal to the forest.

Finally, future studies of withered branches and thinning effects should be studied continuously over windspeed and direction, visibility in snow, and snow transport rates.

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