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Strong Wind Damage of Roadside Trees by the Typhoon 7920 in Sapporo

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台風 9720 による札幌市内の街路樹の風害

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Abstract

The wind effect on trees and the effect of trees on the wind in an urban area were investigted in this paper. A detailed survey on the trees which were blown down by Typhoon 7920 clarified the effects of the topography, buildings and structures on the wind in an urban area.

Behind mountains and around tall buildings, the wind damage of roadside trees was severer. It was noted that the rate of wind damage of roadside trees was larger in the city center than in the suburbs.

1. Introduction

The wind in an urban area is clearly affected by tall buildings and structures. Tall buildings deflect wind down towards the ground, producing unpleasant high speeds in the pedestrian area. The strong wind leads to increase the heat loss from a person walking near the building. And the individual feels a drop of temperature with the high wind. In the northern region, such as in Hokkaido, Japan, high winds make walking and living partially difficult.

Windbreaks and windshelters are used to protect cultivated field from high winds. The effect of windbreaks as a means of wind protection on a housing estate was investigated using models in a wind tunnel (Takahashi, 1979).

It is the purpose of this study to clarify the effect of trees on the wind and the impact of wind on trees in an urban area.

Wind structures in an urban area have been studied by many workers. These

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studies are classified according to the subject into two groups. In the first group, the upper wind blowing over an urban area has studied. Shiotani *et al.* (1950) measured the changes of structure of wind on a 75 m tower in Tokyo. Brook (1971) measured the wind at three different heights in a city center, and reported that the intensity of turbulence decreased with height and was largely controlled by the surface roughness. The frequency at a spectral peak increases near the ground in an open area (Fichtl *et al.*, 1970). The increase of the frequency of spectral peaks is more remarkable in urban areas (Jacson, 1978; Iwatani, 1979).

In the second group numerous workers have studied the wind properties around the tall buildings. Earlier studies were done by Arakawa *et al.* (1971) around the Boeki Center Building in Tokyo. Kobayashi (1972) clarified the strong winds around tall building caused by two air flows; first the downward flow at the front wall and the other convergent flows near the side walls of the building. Gust factors near tall building were nearly a constant 1.5 when the wind speed was more than 4.5 m/sec (Shiotani *et al.*, 1977). Strong wind damages have been studied in the mountainous forest. Windy areas in mountainous region are affected remarkably by the lay of the land (Yoshino, 1957). Takahashi *et al.* (1974) reported that the changes of land surface from, such as construction of roads through the forest caused wind damage of trees. Yamamoto (1979) listed the types and the causes of strong wind damage on trees, and referred them to the condition of trees to protect trees from strong wind damage.

Typhoon 7920 caused serious damage to roadside trees in Sapporo City, Hokkaido. About eighteen hundred of roadisde trees were damaged by the typhoon in Sapporo. In this paper, the conditions of trees damaged by high wind in Sapporo were examined in detail and analysed to clarify the impact of strong wind on roadside trees in urban areas.

2. Synoptic aspects of Typhoon 7920 and wind damage on roadside trees in Sapporo

A weak tropical cyclone formed at 1500 JST, 4 October, 1979 to the southeast, 250 km off Truck Island, and intensified into Typhoon 7920 at 1500 JST, 6 October. The typhoon moved slowly to the northwest and landed on Wakayama Prefecture at 0900, 19 October. The typhoon was closest to Sapporo when it was moving at 2100, 19 October on a southeasterly course 300 km from Sapporo. And the typhoon transformed into a extratropical cyclone at 0300, 20 October, 100 km to the west of Iturup Island.

There are 74,000 trees lining the streets of the Sapporo Metropolitan area. The number of trees which were damaged by Typhoon 7920 and replanted were 1,776. The ratio of damage is approximately 6.6%. The ratio of damage differed from species to species. Black acacia (*Robinia pseudoacacia*) was the species that was most damaged by wind among the trees lining the streets in Sapporo, willow (*Salix baylonica*) was second and mountain ash (*Sorbus commixta*) was third as shown in Table 1.

Table 1. Numbers of roadside trees damaged by the Typhoon 7920 and the ratio to the number of planted trees.

Tree	Ward							Total
	Chuo	Kita	Higashi	Shiroishi	Toyohira	Minami	Nishi	
Robinia pseudoacacia	487 *11.1%*	244 *8.0%*	131 *5.6%*	65 *1.3%*	2 *1.0%*	360 *27.3%*	5 *0.3%*	1,294 *6.0%*
Salix babylonica	116 *8.3*	30 *2.2*	5 *0.8*	10 *0.9*			65 *3.8*	226 *4.3*
Sorbus commixta	18 *2.6*			30 *0.8*	24 *0.9*	19 *4.5*		91 *0.8*
Platanus sp.	37 *2.4*			8 *0.6*	3 *0.5*	7 *4.0*		55 *0.8*
Ginkgo biloba	27 *1.0*			6 *0.4*		18 *4.0*		51 *0.8*
Populus nigra var. *italica*			12 *1.6*		1 *0.3*		20 *5.4*	33 *1.7*
Prunus sp.						9 *4.8*		9 *0.1*
Acer negundo	3 *0.4*							3 *0.1*
Others	4 *0.2*		2 *0.1*			7 *0.3*		14 *0.1*
Total	693	274	150	150	119	30	420	1,776

3. Methods

A continuous record of wind speed and direction was obtained from the 12 stations in Sapporo. These stations are the Sapporo District Meteorological Observatory, the Experimental Farm of Hokkaido University, the Hokkaido National Agricultural Experimental Station, the Government Forest Experimental Station and 8 stations affiliated to Sapporo City Hall. One of the 8 stations is located in the TV Tower at a height of 30 m. The wind sensor of Sapporo District Meteorological Observatory is 20 m high. The height of the sensors of the other stations are about 10 m. Positions and directions of all of damaged trees were plotted on the 1 : 5000 maps. The species and the features of the damaged trees and the soil surface conditions were noted. The diameters of the trunk near the ground and the root zone under ground were measured.

4. Results and analysis

4.1 Wind speed in Sapporo accompanied by Typhoon 7920

In Sapporo, northwesterly winds increased in speed around 17 h, 19 October when the typhoon was approaching and become strongest at about 3 h, 20 October. Maximum instantenous wind speed was observed 27.0 m/sec at 0300, 20 October at the Sapporo District Meteorological Observatory.

Return periods of the maximum instantaneous wind speed are 5.3 years in the growing season (May-October) and more than 37 years in October. The Ty-

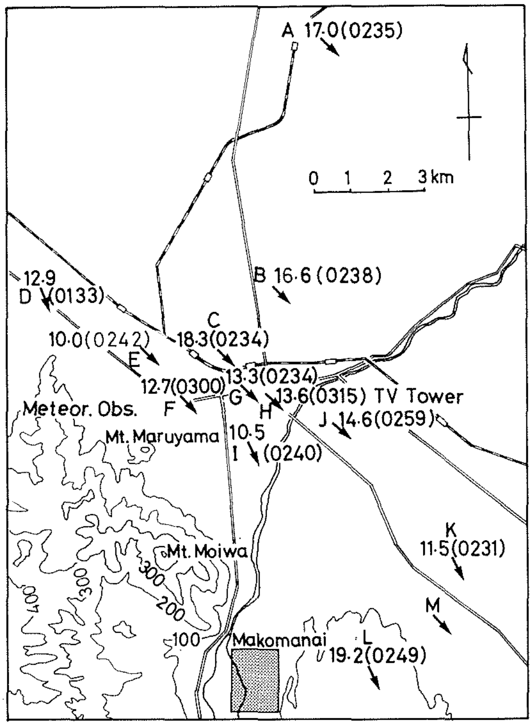

Fig. 1. Distribution of maximum of ten minutes mean wind speed, together with its direction and occurence time.

phoon 7920 had the characteristics of a typical wind typhoon and strong winds were observed at outer fringes of the typhoon. The maximum values of the 10 minutes mean wind speed and the directions are shown in Fig. 1. The wind speeds at stations A, B, C and K located in open areas were at about 40% stronger than those at other stations located in the city area. The wind direction was northwest at 9 stations and north-northwesterly at 4 stations.

Gust factors were estimated from the recording charts of instantaneous wind speed at Sapporo District Meteorological Observatory (F) and Hokkaido National Agricultural Experimental Station (M). Gust factors of the maximum instantaneous wind speed were 1.9 at Station F (in the city area) and 1.6 at Station M (in open area). The gust factor becomes constant at high wind speed (Iwatani *et al.*, 1979). The difference of gust factors at above two stations are due to the difference of the ground surface conditions and topography.

4.2 Strong wind damage of roadside trees in Sapporo

a. The directions of the broken or uprooted trees

The directions of the broken or uprooted trees were drawn on the map as shown in Fig. 2. The map contains several interesting points about the features of wind which blew over Sapporo. The directions of the wind which damaged the roadside trees are shown in detail on the map. The directions of the broken or uprooted trees are the same as that measured by wind vanes in the northern

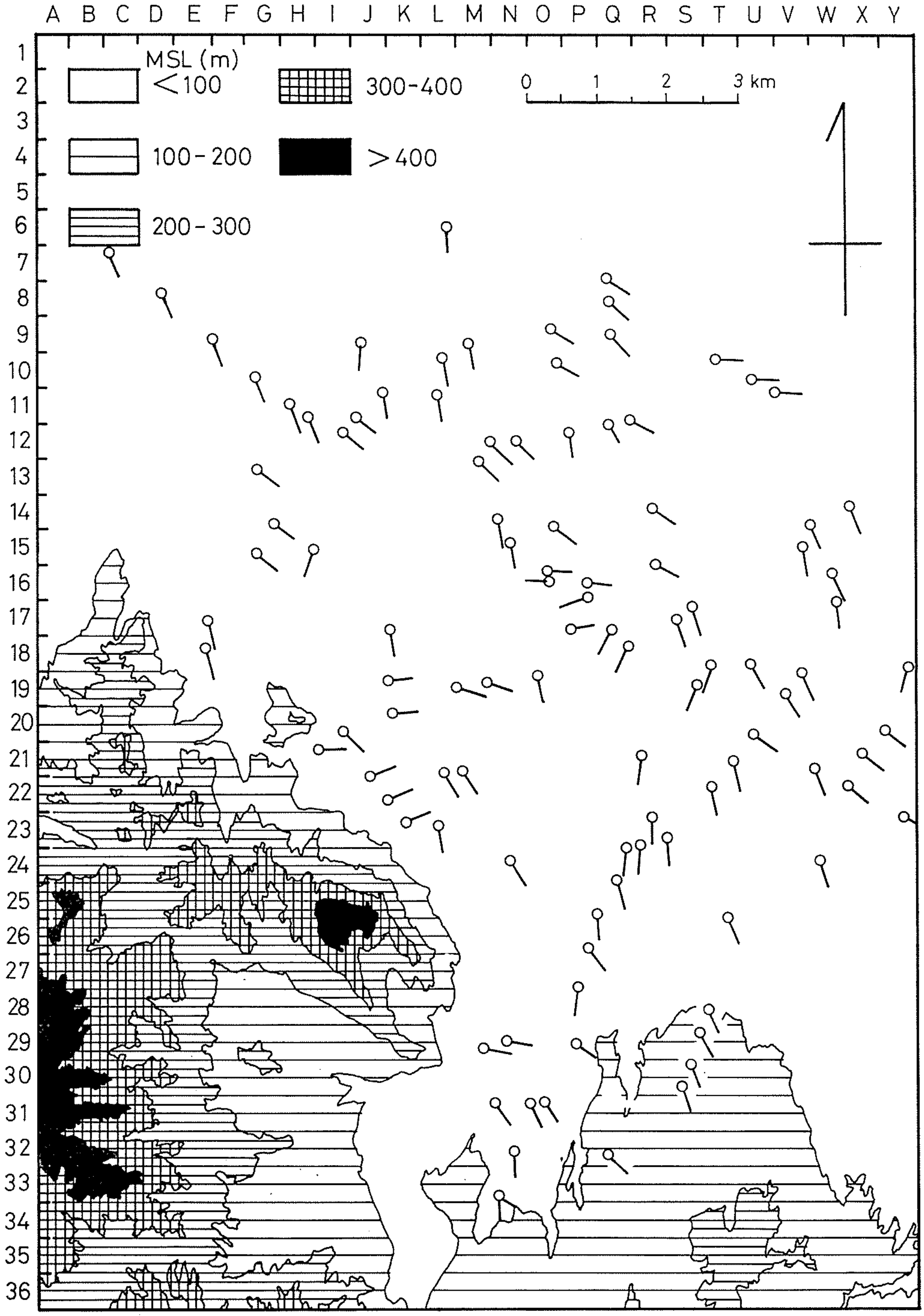

Fig. 2. Distribution in directions of broken or uprooted trees by strong wind in Sapporo.

and eastern regions where the densities of houses are not so high and the ground are quite flat. In the western and southern areas, the direction of the broken or uprooted trees vary. This may be attributed to the effect of topography. Strange to say but wind in the lee of Mt. Maruyama and Mt. Moiwa are seen in waved fashion. The direction of the broken or uprooted trees in the city center varied by the influence of buildings and structures.

b. Directions and locations of the broken or uprooted trees in Makomanai Housing Estste, southern Sapporo

Makomanai Housing Estate was begun to develop about 20 years ago. Many types of buildings and various open spaces are arranged in the housing estate.

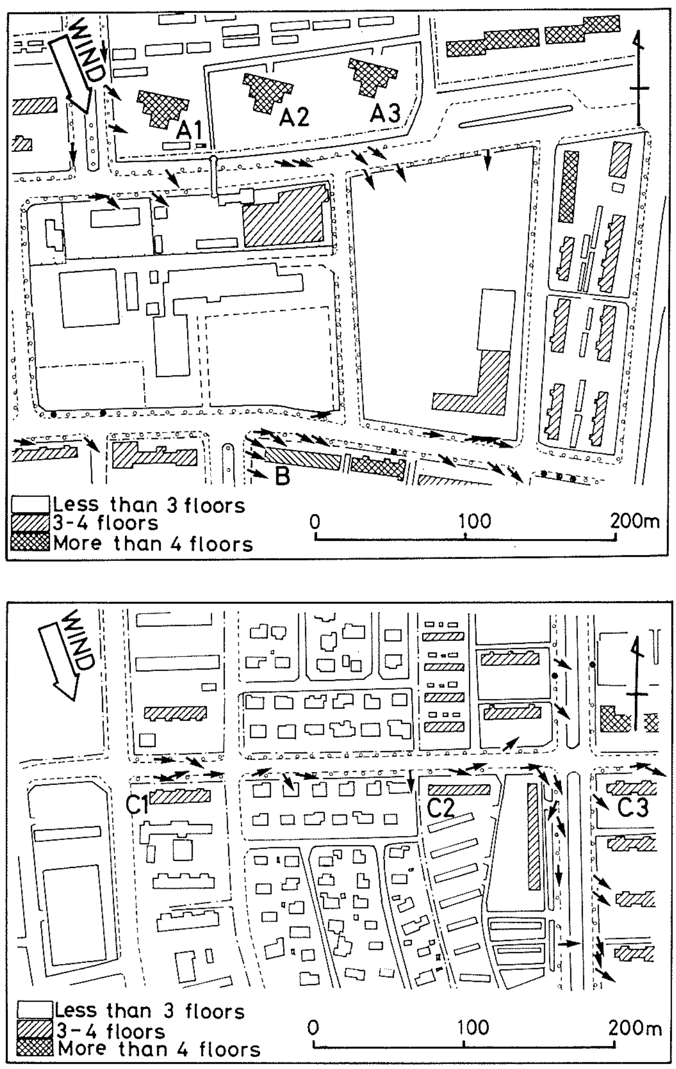

Fig. 3. Broken or uprooted trees at Makomanai Housing Estate. Arrows and solid circles denote direction and location of damaged trees.

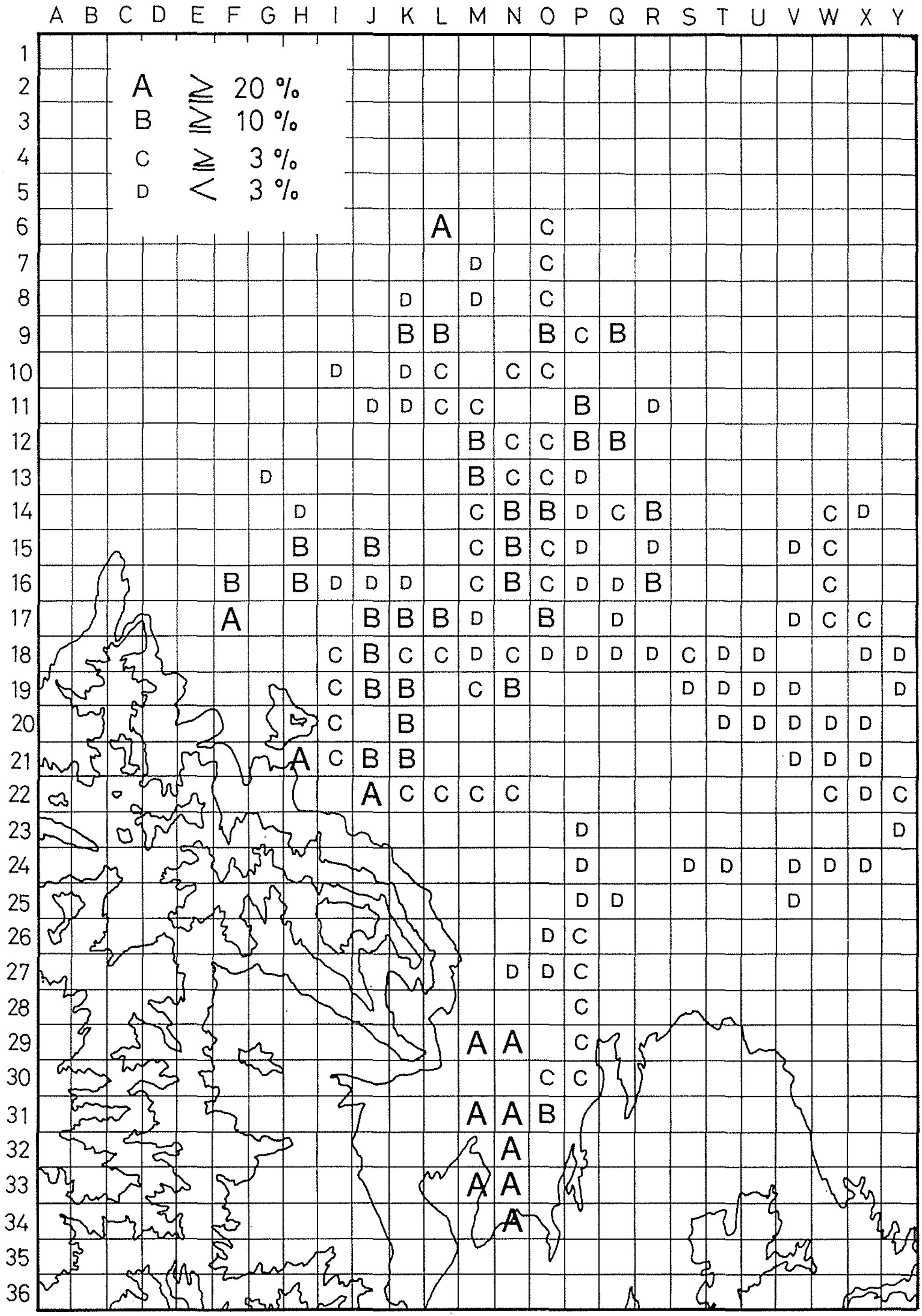

Fig. 4. Regional distribution of damage percentage of black acacia due to strong wind.

Strong wind damage in the housing estate was hardest in Sapporo. Directions and locations of the broken or uprooted trees in the housing estate are shown minutely in Fig. 3.

Buildings A 1, A 2 and A 3 in Fig. 3 are the high rise flats with eleven floors and the tallest type of building in the housing estate (Photo. 2). Strong wind blew through the open spaces between those tall buildings and damaged the roadside trees planted in leeward. Buildings B, C 1, C 2 and C 3 in Fig. 3 are the low densities with four floors. Damage of roadside trees in windward of those building was very remarkable.

c. Spatial distribution of the ratio of strong wind damage

To determine the spatial difference of strong wind damage, the main area of Sapporo was divided by a 500 m grid. The ratio of strong wind damage, the rate of the broken or uprooted trees to the total of planted trees before the damage occurred, was analysed on the black acasia which sustained the most damage. The number of the planted trees was given in each grid block. The maximum was 154, the minimum was 24, and the mean was 110. The ratio of wind damage were classified into 4 grades, namely over 20%, over 10%, over 3% and under 3%, as shown in Fig. 4. Two singular points are seen in the figure. First, in the leeward area of two mountains, Mt. Moiwa and Mt. Maruyana, the damage was very severe. And the areas almost coincided with the areas where the wind directions were seen in waved fashion in Fig. 2. Second, the ratio of damage in the city center seems slightly more intense compared with that in the rural areas.

Using the price of land as an index of urbanization (Todokoro, 1975), the ratio of strong wind damage was averaged as the grade of urbanization except for the areas near mountains in Table 2. It can be seen from Table 2 that the higher the price of land, the larger the extent of damage of roadside trees. This fact seems to indicate that urbanization affected the growing environment of trees.

Table 2. Damage percentage of black acacia by strong wind as related to the land price

Price of land (10^4 yen/m^2)	Ratio of damage (%)
$\geqq 20$	8.9
$\geqq 10$	7.4
< 10	6.8

5. Conclusions

(1) Maximum instantaneous wind speed of the Typhoon 7920 was 27.0 m/sec at the Sapporo District Meteorological Observatory, and return period of it was 5.3 years in the growing season (May-October).

(2) In rural area, directions of the broken or uprooted trees were the same as those of maximum wind speed measured at the meteorological stations, but were different in the city center and lee of the mountains.

(3) Regional distribution of strong wind damage of black acacia showed that the rario of damage in the city center was slightly larger than that of in the rural area.

It may be pointed out for future works that the growing environments of the trees in urban area, such as space of root zone, soil conditions, the form of trees and noxious gasses must be investigated in detail.

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Photo 1. Uprooted roadside trees.

Photo 2. High rise flat in Makomanai Housing Estate.