Coastal Disaster Prevention Forests in Japan

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Japan, an island country, has the total of 370,000 km² of land area, 76% of which is covered by mountains. Hills and plains distributed along the coast have been and are very important as the sites for livelihood and production activities of the people. As the country is made up of a chain of islands extending from south to north along the east fringe of the Eurasian Continent, it has a long coast line, reaching a total of approximate 30,000 km. The coastal zones are dotted with coastal forests more than 100,000 ha in the total area. The coastal forests have an important function of preserving environmental integrity, such as protection against damages caused by strong wind, sea water droplets, shifting sands, and seismic tidal waves, as well as prevention of fog. By such a function, the coastal forests protect farm land, residence, industrial facilities, and traffic (such as national highways) behind the coastal forests. In addition, the coastal forests are utilized as various parks due to their verdant spectacle. These forests are called the coastal disaster prevention forest.

Kind and function of coastal disaster prevention forests

Although 17 kinds of protection forests are specified in the law, the following 4 kinds are designated with the purpose of preventing disasters in coastal zones; windbreak forest, shifting sand control forest, tidal wave control forest, and fog prevention forest. Their distribution is given in Table 1. Although their function is diverse as described above, each of them is given a specific name representing the prevention of a disaster which is most liable to occur in each location.

1) Coastal windbreak forest

Windbreak-effect of forest is recognized to reach 5H to the windward, and about 30H to the leeward, when the forest has an appropriate density and its height is taken as H. Due to this effect, forests can prevent mechanical and physiological damages of crops and fruit trees caused by strong wind, resulting in higher yields and better quality than those without forest. In addition, the coastal windbreak forest aims at trapping and filtering salt of sea wind.

The spray generated from white-crested waves on the sea or from waves washing shore is made up of minute sea water droplets with a diameter less than several-ten micron, and is carried to inland up of by wind. This is called salt spray. Although the amount of salt spray shows a decrease with the distance from the seashore to inland, a considerable amount of sea water droplets is trapped by a forest as given in Fig. 1. The

Table 1. Areas of coastal disaster prevention forests (ha)*

Region	Windbreak forest	Tidal wave control forest	Shifting sand control forest	Fog prevention forest	Total
Hokkaido	40, 885	979	1, 745	52, 375	95, 984
Honshu	9, 867	12, 863	3, 047	—	25, 777
Shikoku	121	41	246	—	408
Kyushu	3, 021	2, 172	3, 034	—	8, 227
Okinawa	859	—	3, 612	—	4, 471
Total	54, 753	16, 055	11, 684	52, 375	134, 867

*Quoted from "Japanese Forestry Census, 1983"

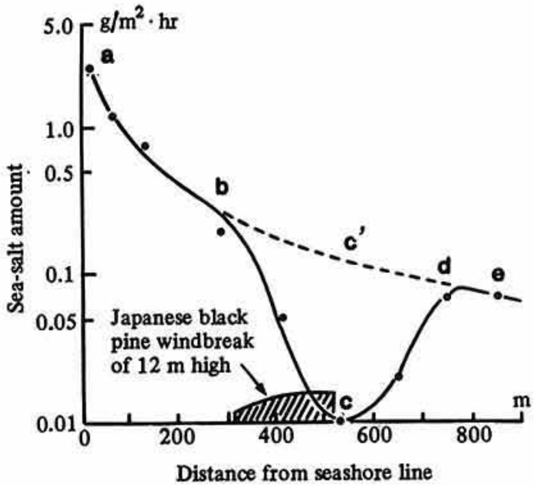

Fig. 1. Trapping of sea water droplets by a windbreak forest[2)]

trapping activity of needle-leaved Japanese black pine (*Pinus Thunbergii* Parl.) forests is especially high. The amount of sea water droplets trapped per unit amount of needle-leaves is the greatest at the forest side facing the sea, and it decreases exponentially toward the inland side of the forest. In Fig. 1, the curve a–b–c–d–e shows actually measured data, while the curve a–b–c'–d–e was estimated on an assumption without forest. The difference between both curves expresses the trapping by the forest. The decrease of sea water droplets caused by trapping activity of forest is shown up to the distance about 25 times of forest height to the leeward.

2) *Shifting sand control forest*

This forest aims at preventing scattering of sands from ground surface by wind. There are many sandy beaches and sand dunes along the coast of Japan. Particularly, in the coastal zone located at the Sea of Japan side of the country, strong seasonal wind causes shifting sands which buries houses and farm lands under the sands. It has been a serious disaster since old days.

When the wind velocity at the height of 1 m above ground reaches 5–6 m/s in sandy area, sands on the ground surface begin to roll. Further increase of wind velocity induces jumping and flying of sands. The majority of sands travel at the height lower than 50 cm above ground even in case of fairy strong wind with wind speed of 15 m/s. The amount of travelling sands is proportional to the cubed wind speed higher than the threshold wind speed (5–6 m/s). Therefore, even a short forest can give a very great effect in suppressing shifting sands. According to an experiment carried out in Tottori coast, a forest composed of two rows of Japanese black pine trees which were 2 m tall and planted at 1×1 m density for a length of 11 m was able to trap a large amount of sands during the period of 4 months from December to April, as shown in Table 2.

Table 2. Area and volume of shifting sands accumulated by a 2-row Japanese black pine windbreak[1)]

	Covered area (m^2)	Volume (m^3)
Windward side	127	25.3
Leeward side	170	50.9
Total	297	76.2

3) *Fog prevention forest*

Sea fog frequently comes to Sanriku coast and east coast of Hokkaido in summer every year. The dense fog interrupts solar radiation, lowers air temperature, and hence damages crop growth. It also obstructs traffic. The fog prevention forest traps fog particles by its branches and leaves and makes vortexes in the wind flow, by

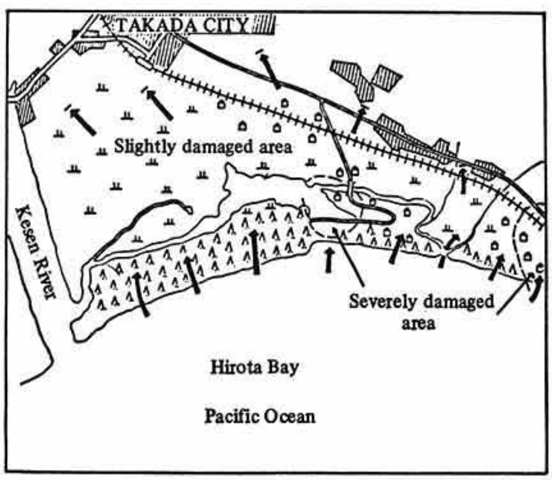

Fig. 2. Effectiveness of a Japanese black pine shelterbelt in preventing damages due to Chilean seismic tidal wave[1)]

Table 3. Reduction of velocity and energy of seismic tidal wave by a shelterbelt (Coastal forest[1])

	Shelterbelt width (m)							
	11	22	36	51	69	92	120	161
Velocity of wave passing through	9	8	7	6	5	4	3	2 (m/s)
Wave energy absorbed	27	49	66	78	88	94	97	99 (%)

which fog particles in the upper air are brought down and exposed to the trapping of the forest.

According to the observation in east coast of Hokkaido, the fog density behind an Yezo spruce (*Picea jezoensis* Carr) forest of 8 m in height and 180 m in width was 20–80% of that measured in front of the forest. The amount of fog particles trapped by the forest was as much as 5–6 times of the amount trapped by grassland.

4) Tidal wave control forest

An earthquake belt lying off the Pacific coast of Japan frequently causes earthquake. The big earthquake induces tidal wave which attacks Pacific coast. Therefore, many tidal wave control forests are distributed in the coasts of Tohoku, Kanto, Chubu, Kinki, Shikoku, and Kyushu. They can reduce the destructive power and height of the tidal wave by absorbing the energy of the tidal wave. A calculation made for the case that the tidal wave with the wave height of 10 m and speed of 10 m/s is passing through a forest belf (shelterbelt) gave the relationship between the width of the forest and the wave energy absorbed by the forest as shown in Table 3. Destruction of houses and various facilities placed on the coastal area by floatage such as fishing boats and driftwoods, or sweeping-away of various materials by waves can be avoided by the tidal wave control forest. For example, when the Chilian seismic sea wave hit Japan in 1960, a big difference in damages as shown in Fig. 3 was apparently recognized between an area with the tidal wave control forest and the other without the forest, in the coast of Rikuzen-Takada City, Tohoku region.

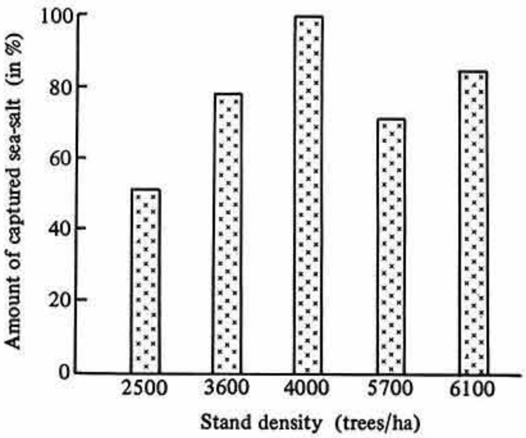

Fig. 3. Amount of captured sea-salt as related to densities of Japanese black pine stands[3]

Methods of establishing coastal disaster prevention forests

The coastal disaster prevention forests are established on the coastal sandy area in most cases, so that it is usual to carry out several preparatory works prior to the planting of seedlings. At first, a foredune which is parallel to a seashore line is constructed at a site closer to the sea than a pre-determined site for the forest. In the past, the foredune was constructed as follows: A fence, 1 m tall, was constructed to reduce wind speed around it. As a result shifting sands were deposited around the fence. This process was repeated, whenever the wind blew, and thus a foredune was produced. By this method, it took 15 years to produce a 6 m tall foredune. Recently, however, the foredune is constructed easily and quickly by using bulldozers. After the construction, the surface of the foredune is fixed by dune plants such as *Elymus mollis* Trinius, *Ischaemum anthephoroides* Miq. *var. eriostachyum* Honda, *Carex kobomugi* Ohwi, American beachgrass, etc. Then, wind-break fence is installed as a lattice network on the inland side of the dune, and planting is made inside the fence network. In areas with strong wind, straw mulch or tiny screen is used inside the network. Distance of the fence is mostly 10–20 m, and materials available on the spot, such as brush, reed, bamboo, etc., are used to construct the fence.

The coastal sandy land of Japan has generally poor environmental conditions for plant growth, such as strong wind, lack of nutrient and water, and large fluctuations of soil surface temperature. Japanese black pine is the most important species tolerant to such harsh conditions, and planted widely in coast areas from southern Hokkaido to Honshu, Shikoku and Kyushu. It forms established forests in those areas. To promote the growth of the planted trees, soil-improving trees such as *Robinia pseudo-Acacia* L., *Elaeagnus umbellata* Thunb., *Albizzia chinesis* Merr., etc are often mix-planted with the former.

Portions facing the sea of coastal forests are prone to be suffered from damages by salty wind or shifting sands. Japanese black pine forests in Ibaraki coast facing the Pacific which has gentle sea wind and those in Sakata coast facing the Japan Sea which has strong seasonal wind in winter don't show normal tree growth within a distance of 50 and 150 m, respectively, from the sea–side fringe of the forests to inland. Therefore, in order to secure a sufficient forest height for a full manifestation of the disaster-preventive function of forest, a great width of the forests belt is needed. Including an additional width required for regeneration, the width of forest belt of 100–150 m will generally be needed in the Pacific coast, and 200–250 m in the Japan Sea coast.

Tending of coastal disaster-prevention forests

As 10,000 seedlings are planted per ha in establishing coastal disaster prevention forests, thinning becomes necessary according to the growth of the forests. A standard of thinning applicable to the coastal disaster prevention forests in any region of Japan has not yet been established. However, the following thinning is proposed to the coastal forests of Japanese black pine in Yamagata Prefecture: When the stand of 10,000 seedlings/ha grew up to the height of 3–4 m after about 10 years, a half of them were cut. When the tree height reached 7–8 m after 20–25 years, the cutting is made to give the density of 3,000 trees/ha. Then, at the height of 13–14 m after 50–60 years, the density is reduced to 1,500 trees/ha. Needless to mention, poorly grown stands facing the sea are not subjected to the cutting.

As a trial, the effect of different densities of forest on trapping of sea water droplets was examined with a coastal forest of Japanese black pine in Ibaraki Prefecture. Five stands with almost the same tree height, 5–6 m, but different densities, i.e. 2,500, 3,600, 4,000, 5,700, and 6,100 trees/ha were used. Leaf quantity of each of them was estimated, and the amount of sea water droplets trapped by each of them was measured. As given in Fig. 3, the stand with the density of 4,000 trees/ha showed the highest trapping capacity in term of the amount trapped/ha.

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