Railways and The Environment (part 3)

Railway Protection Forests—Reducing Natural Hazards and Enhancing Environmental Values

Makoto Shimamura

Introduction

Forests help protect people and their assets from natural hazards, including floods, debris flows, landslides, rockfalls, snow avalanches, snowdrifts, and high winds, in two main ways—directly by reducing meteorological and hydrogeomorphic forces that affect people, structures, and utility corridors; and indirectly by reducing soil erosion or improving watershed conditions and air quality. Both types of protection are more attractive than artificial structures for episodic natural hazards due to their relatively low costs and environmental friendliness.

Today, about 1500 km of Japan's 25,000 km of railway trackside is home to about 11,000 ha of railway protection forests.

Development of Railway Protection Forests

Railway protection forests are classified into nine categories, depending on their function: snowdrift, snow avalanche, sand drift, landslide, rock fall, flood, fire, wind, and natural springs. Each is explained below.

Snowdrift protection forests

About 90% of all railway protection forests in Japan are for snowdrift protection. They are mainly on Hokkaido and the northern part of Honshu. The most common species used in these forests is Japanese Cedar (*Cryptomeria japonica*) in Honshu and Norway Spruce (*Picea abies*) in Hokkaido (photographs).

The first snowdrift protection forests were planted in 1893 and are the 41 stands along the Tohoku Line between Mizusawa and Aomori. When this line started full operation between Tokyo and Aomori in 1890, winter services were very unreliable due to heavy snow. Trains were frequently delayed or trapped for days by drifts and all services carried emergency food and water for passengers and crews to guard against starving while trapped. Trackside wooden fences had proved ineffective because strong side winds and flying embers from steam locomotives easily destroyed them.

Seiroku Honda (1866–1952), the founding father of railway protection forests in Japan and the first Professor of Silviculture at the old Imperial University of Tokyo, devised a plan to plant snowdrift protection forests after seeing plantations developed by the Canadian Pacific Railway on his way home from academic studies in Germany. He planted the first protection forests in 1892, using German silviculture methods and continued to work training his successors as the protection forest adviser to the Railway Agency for more than 30 years.

Snow avalanche protection forests

The need to maintain forests on slopes susceptible to avalanches has long been known in Japan. This knowledge was integrated into the legal system and was also part of forest management practice in Japan; some feudal landlords designated part of their lands as snow avalanche protection forests, where neither cutting nor thinning was allowed.

After the 1890 opening of the Tohoku Line connecting cities along the Pacific coast of Japan between Tokyo and Aomori, new lines were built to connect cities on the Tohoku Line and districts on the Sea-of-Japan coast via the snowy and mountainous hinterland of northern Honshu. Snow avalanches became a problem soon after these new lines started operation. As an example, the Ganetsu Line opened

Snowdrift protection forest on Soya Line in Hokkaido (Author)

Snowdrift protection forest on Uetsu Line in Honshu (Author)

Snow avalanche protection forests on Joetsu Line in Honshu (Yosuke Masui)

Table 1 Lower Bound ACSD (δ) by Forest Type

Wood type	δ
Snowdrift	$\frac{700}{B}$ where, B = stand width (m)
Snow avalanche	The maximum of 25 or $30H(\sin\theta - 0.6\cos\theta)$ where, H = design snow height (m), θ = slope inclination
All other forest types	25

in 1914 experienced 75 avalanches in 1917, some causing deaths and injuries as well as serious property losses. As the result of lessons learned, the Railway Agency designated slopes prone to avalanches as snow avalanche protection forest areas and carried out necessary forestation. The Ganetsu Line was affected by some 250 avalanches in its first 20 years, but experienced only seven in the second 20 years after the trees reached maturity.

Snow avalanche protection forests are considered the most necessary and best disaster prevention measure because they mitigate or prevent the destructive potential of avalanches. Most are now found along railway lines in mountainous northern Honshu.

Sand drift protection forests

The Sea-of-Japan Honshu coast has many areas with extensive sand dunes and trains on new lines passing through these areas encountered frequent problems such as derailments and blockages due to sand drifts on tracks. The first trackside wooden fences built to block sand drifts were easily destroyed by gales and proved ineffective. As a result, sand drift protection forests based on traditional forestry methods were used as an alternative measure and planted along the Uetsu Line in 1921. Aeolian movement of sand stops completely as soon as sand dunes are revegetated, and the protective effects of sand drift protection forests are immediate and significant. Sand drift protection forests have also been established on the Hokuriku, San'in and other coastal lines.

Landslide and rockfall protection forests

Landslides, debris flows and rock falls are frequent natural hazards for railways in Japan's mountainous regions, where the ground is weak and precipitation high. As more tracks were built in cuttings through mountainous regions, more landslides, debris flows and rockfalls occurred, prompting railways to develop landslide and rockfall protection forests, which are now widespread across Japan.

Other railway protection forests

For more than 100 years, the Japanese rail network has used the benefits of forests in many situations. Protection forests surrounding springs secured the water supply for steam locomotives, stations, offices, huts, and quarters before it was possible to pipe water in. Fire protection forests with firebreaks are also a remnant of the steam age. Where tracks are exposed to extreme gales or floods, wind protection forests and flood protection forests have been planted.

Forestation Methods and Silviculture Systems

The forestation and silviculture systems used for railway protection forests are selected and adjusted to fit local conditions and functional needs. For example, snowdrift protection forests in Honshu are planted with Japanese Cedar, and with Norway Spruce in Hokkaido. Both species are evergreen, fast growing, and tolerate high densities; effective snowdrift protection is provided by a strip just 20-m wide.

Seiroku Honda recommended a minimum strip width of 40 to 60 m for preventing snowdrifts but his aim was to enable between one-third and one-half of the wood to be cut (using patch cuts) and reforested without sacrificing the snowdrift protection function. This method has both prolonged the longevity of the woods and generated revenues, making it possible to sustain the forests for more than 100 years.

Snow avalanche protection forests are also planted with Japanese Cedar, which can grow even under heavy snowpack conditions. The renewal procedure of small patch cuts and replanting used for snowdrift protection forests is inappropriate for avalanche protection because mountain slopes require continuous, dense, forest cover. Consequently, avalanche protection forests are renewed by thinning and planting individual trees (silviculture selection), so the protection is constant. Sand drift protection forests are like avalanche protection forests in terms of the silviculture system, but the Japanese Black Pine (*Pinus thunbergiana*),

Table 2 Upper Bound Yield Ratio (ρ) by Tree Species

Species	ρ
Larch, pine	0.8
Cedar, spruce	0.85
Fir	0.9

The ratio relates the actual trunk volume to the stand maximum trunk volume.

which is suited to coastal soils and climate, is planted instead.

In all railway protection forests, seedlings are usually planted at a relatively high density of 3000 to 5000 per hectare and then thinned periodically so that the stand reaches maturity and full protection in no more than 20 years. The Aggregate Cross Sectional Density (ACSD) (δ), meaning the total stump cross section (m^2) at breast height per hectare is the index used for all railway protection forest types (Table 1). Each stand is measured periodically and the trunk volume is controlled by thinning, so the stand condition is maintained between the upper bound determined by ecology and the lower bound required for protection. The majority of railway protection forests are logged 40 to 50 years after planting.

The ACSD bounds for woodland types are specified in the Railway Protection Forest Code, which prescribes the standard procedures for planting and maintaining railway protection forests. The Code restricts the maximum permissible reduction in ACSD at each thinning to 0.15 or less. A long-term thinning regime is planned using a stand density control diagram for each tree species.

Artificial reforestation is generally unsuccessful for landslide and rockfall protection forests, because such forests are mainly on slopes with nutrient-poor soils. The main silviculture goal in these woods is to maintain and preserve existing vegetation.

Challenges and Perspectives

For more than 100 years, the principle of railway protection forests has been founded upon silviculture of monocultures, enabling maximum timber yield and revenue at cutting. In the past, railway protection forests provided timber for railway sleepers, buildings and other structures. Sale of these products provided the revenue needed for silviculture treatments.

Currently, there is little cutting because the generated revenues do not cover cutting costs. As a result, the ecological, functional and aesthetic conditions of railway protection forests have deteriorated, because monocultures require constant intervention, not only to establish seedlings, but also to tend mature trees in order to maintain ecologically healthy conditions. These interventions are expensive because labour costs have risen sharply over the last few decades.

On the other hand, greater environmental awareness at local and international levels has led people to consider and appreciate the value of planting more forests, woodlands and trees and safeguarding and managing them as a productive resource. Increasingly, forests are valued for goods and services beyond lumber and protection from natural hazards; one such value is forests for recreation, nature conservation and landscape.

One JR East experiment in progress is based on long-term management strategies to transform planted protection forests to more diverse ecosystems, requiring less silviculture attention and enhancing environmental value to the railway.

Although modern railways can often withstand many of the natural hazards they encounter without protection offered by railway forests, we value them as helping our technology coexist in harmony with the environment. ■

Makoto Shimamura

Dr Makoto Shimamura is Director of the Disaster Prevention Research Laboratory at the Research and Development Center of the JR East Group. He joined JNR in 1978 and transferred to JR East in 1987. During his 30-year career in both organizations, he has worked to preserve and enhance railway protection forests. He received his doctorate from the University of Tokyo in 2008.