THE SECOND REPORT
ON THE STATE
OF THE WORLD'S

FOREST GENETIC RESOURCES

COUNTRY REPORT

JAPAN

The Second Report on the State of the World's Forest Genetic Resources

Country Report (Complementary report)

Japan

August 2023

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Forestry Agency
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Preface

With growing awareness to crisis on global environment, achievement of the Sustainable Development Goals (SDGs) became a central concern. Sustainable forest management is one of the Goals, and other aspects of forest are also closely related to most of the 17 Goals.

Forests deeply involves in climate change, biodiversity loss and land degradation. It is critically important to strengthen broad efforts to challenge these issues through sustainable forest management.

As reported to FRA 2020, two-thirds of Japan's total land is covered with forest. Forest landscape varies from alpine to coastal, from subarctic to subtropical and from planted stands to wilderness areas.

Historically, wood harvest gravely deteriorated Japanese forests especially during the WW II and thereafter, causing huge land disasters in all parts of the country. This ignited nationwide concern to forest restoration and the government of Japan had pushed ahead steady establishment of the planted forests. The present forest landscape has been formed in this context.

In this trend, national program of forest tree breeding was developed and has been propelled. Excellent varieties of fast growth and/or other traits as pest tolerance and climatic hardiness has been developed. Relevant research activities with cutting-edge technologies are also undertaken.

All the while, forest genetic resources have been more or less declining quantitatively and qualitatively under environment shift and shrinkage of natural forests. To cope with this, collection and preservation of forest genetic resources are in place with regard to the importance and the priority in use and preservation, to pass on for future generations.

Furthermore, international cooperation under JICA and ITTO frameworks and collaborative research activities are deployed for tree breeding in foreign countries.

This country report gives outlook of Japanese activities on tree breeding and genetic resource preservation as well as related topics on its forests, forest biodiversity and forestry. I wish it will serve member countries giving some insights on sustainable forest management and helping their activities.

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Acknowledgements

This report is compiled upon the achievements in the field of forest genetics and breeding as shown in the References. For the Chapter 1 and 2, state of the forest and the forestry, it is largely based on government Annual Report on Forest and Forestry in Japan and other official publications.

In consolidating the report, Dr. Takahashi and Dr. Yamada of Forest Tree Breeding Center, Forest and Forest Products Research Institute checked the draft and provided useful advices and relevant information. The Forestry Agency staff read and gave advices to the draft.

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Abbreviations and Acronyms

FFPRI	Forest and Forest Products Research Institute
FTBC	Forest Tree Breeding Center
FTGBP	Forest Tree Gene Bank Program
GRPF	Genetic Resource Preservation Forest
ITTO	International Tropical Timber Organization
JICA	Japan International Cooperation Agency
MAFF	Ministry/Minister of Agriculture, Forestry and Fisheries
SMTs	Specified Mother Trees
FSSA	The Forestry Seeds and Seedlings Act
WWII	The World War Two

Executive summary

1. Geography and Climate

Japan locates at the east end of the Eurasian continent, forming an archipelago extending over 3,000km from northeast to southwest. Mostly belonging to temperate zone, it also has subtropical and subarctic/subalpine forests. Surrounded by the Pacific Ocean and the Sea of Japan and occupied with mountain ranges, Japan is gifted with ample rainfall and snowfall far beyond the world average. Because the precipitation is larger than estimated vaporing for all parts of its land, Japan is potentially covered with forests. Under such circumstances two-thirds of the total land area, 250 thousand km^2, is covered with forests. Three-quarters of the total land is occupied by hills and mountains which are mostly forested.

2. Diversity of forest genetic resources

Forests in Japan are diverse, from subtropics to subarctic, from coastline to ridge top. Major forest landscapes are subtropical evergreen, temperate evergreen, temperate deciduous, subalpine/subarctic coniferous and mixed forests. Mangrove, swamp and alpine forests are also found. Number of native tree species is said to be 1,000 or 1,500. As majority of forests are historically utilized manifold, for fuel, fertilizer, wood and food, etc., pristine forests are limited. Japan is one of the biodiversity hotspots.

3. Values of forest genetic resources and contribution to SDGs

Japan is a developed country with large population (120 million) and relatively small land area. The social and economic assets concentrate in limited inhabitable flat areas while the country is largely mountainous. Consequently, demands for social benefits of forests especially soil conservation and flood prevention to protect those areas are very high. Forests also provide other economic, social, environmental and cultural benefits. Domestic wood production meets 40% of timber demand. Higher forest coverage with ample rainfall enables stable supply of quality water which makes tap waters drinkable all over the country. Agricultural activities and human inhabitation in coastal areas had been made possible by shelter forests protecting backlands from salt and sand. Natural forests and properly managed planted forests form rich terrestrial ecosystem and are important in sustaining biodiversity. Values as a space for health, educational and business activities are increasing. Forests are mother of Japanese culture – traditional food, furniture, house, garden, etc., are formed with forest genetic resources, not to mention cultural assets.

Japanese historic buildings, gardens including tea ceremony spaces are designed with wood, bamboo and Japan lacquer materials.

Benefits of forest genetic resources contribute to attainment of SDG's, chiefly in the context of climate change. Forests in Japan absorb CO_2 which accounts for 3.5% of national annual emission. More extreme weather condition calls for more necessity of disaster prevention and water conservation through forest conservation. Wood is a low LCA emission material compared to modern materials. Wood is a key material for better human welfare, notably with more comfort when used in living environment.

4. Trends in forest genetic resources and its drivers of change

Forests in Japan had gone through significant degradation since pre-modernized times, caused by over wood harvest and extraction of organic matters for livelihood, civil work and industry. In early half of 19th century growing population and expanding cities increased wood demand in both construction and fuel, which lead to soil erosion and flooding in many regions. The governing fiefs tried to make a remedy through harvest ban. In the modernizing time of later 19th century forests also had been often under harsh harvesting. Repeated disasters prompted forest and river policy reinforcement in early 20th with the objective of forest sustainability and control of disaster. However, in a while, Japan proceeded to economic and military expansion to Asian countries which increased wood demand to override forest sustainability. Succeeding military needs in WWII and after war reconstruction needs further deteriorated forest resource. In later 1940s and early 1950s flooding disaster took place all over the country.

Significant part – approximately 40% - of the forests are planted coniferous forests. This was formed through: i) rehabilitation from degraded forests and bare lands, ii) transfer from abandoned fuel forest, iii) transfer to coniferous plantation after pulpwood harvesting, iv) the outstanding site adaptation of Japanese traditional silvicultural conifer species. The major propelling force was afforestation programs for disaster prevention and profit expectation in forest owners to coniferous forestry backed by soaring wood price during huge wood deficit after the war.

Species used in afforestation was limited, as few tree species exceeded Japanese cedar, Japanese cypress and Japanese red pine in terms of site adaptability and seed/seedling production capability (i.e., seedling price), as well as ease of processing. Japanese larch and Sakhalin fir joined later to planted species. Hardwood species failed in most sites probably on account of narrow site adaptability. Introduced foreign species were unsuccessful in many test sites and did not get good perception.

Natural forests were exploited for fuel but abandoned after fuel revolution and partly transferred to coniferous planted forests. Aged former fuel forests of oak species are now suffering from wood borer beetle attack. Forests in scenic sites or habitat of precious plants/animals were protected as scenic reserve, national park or academic research reserve, later preserved as biosphere reserves or wilderness area.

5) Diversity of forest genetic resources

Some 1,000 or 1,500 native tree species are recorded or said to exist in Japan. 689 species are preserved in the national gene bank.

Diversity between species seems almost stable as, in the foreseeable future, large scale shrinkage of natural forests is not estimated. However, fragmentation, shrink or extinction of smaller, remaining populations is concerned for a number of species including those found only in mountaintops. Climate change and deer foraging pressure are major source of awareness.

Diversity within species were investigated in a number of species. Considerable genetic divergence was observed and attributed to historic migration from the continent and expansion/narrowing in Japan during glacial and interglacial periods, as well as to climatic difference between the Pacific Ocean side and Sea of Japan side.

6) Conservation of forest genetic resources

Forest Tree Gene Bank program is carried out for the objectives of i) collection of breeding material, ii) generating alternative demand for forest genetic resources, iii) conservation of fragile genetic resources by the Ministry of Agriculture, Forestry and Fisheries (MAFF). It is carried out mainly by Forest Tree Breeding Center (FTBC) and National Forest Management Offices. Major forest tree species with economic or social values and some endangered species are preserved in natural habitats. Approximately 700 species including useful breeding materials are kept in genetic preservation stands as well as preserving facilities. Collection of breeding material has been intensively implemented and evaluation conducted, forming an important breeding infrastructure.

7) Use and development of forest genetic resources

Life of Japanese nation has been historically dependent to forest genetic resources. Various use – foods, goods, housing, fuel, etc. – of the genetic resources were developed and took hold, of which the principal usage is timber, pulp and paper. As the private forestry developed, seed and seedling production and local varieties are established.

Circulation of seeds of inferior quality in early 20th century prompted legislation controlling seed and seedling production. Systematic breeding of excellent variety started after WWII in the process of nationwide afforestation program. Superior variety was developed by national/prefectural breeding organizations. Seeds and seedling production and dissemination were implemented by prefecture governments and private seed/seedling producers. Now the development of the 2nd generation breeding population for coniferous silvicultural species have become a center in tree breeding activities to produce recommended varieties in the context of climate change mitigation ('Specified Mother Trees'). In the meantime, less pollen or non-pollen varieties are now being developed as one of the solutions to coniferous pollen allergy, a serious social issue.

8) Breeding method and technologies

Current breeding method in Japan is outbreeding and mass selection, as well as cross breeding with congener species (larch). For the acceleration of breeding, genome-wide DNA analysis and development of DNA markers have been undertaken. The capacity building for those advanced genomic technologies is carried out in relevant university faculties and public research organizations.

9) International cooperation

International cooperation for forest genetic resources has been deployed through Japan International Cooperation Agency (JICA) and ITTO. With these frameworks Japan has been engaging in breeding technology transfer program with Asian and African countries.

10) Future recommendations

Forest genetic resources in Japan now have two major challenges. One is a contribution to climate change mitigation with coniferous plantation forestry. With regard to more carbon fixation, direct contribution by developing fast growing, more CO_2 absorbing varieties are anticipated, while indirect contribution by developing more preferred variety by forest owners to secure replanting and future removal including HWP is also needed. Development of less pollen variety with superior growth property will accelerate this, as pollen allergy syndrome is an apparent shackle in disseminating silvicultural conifers of excellent growth.

Another is climate change adaptation and risk of extinction, especially of isolated and shrinking populations of rare species as well as of widely distributed but locally adapted populations. Emerging issue is deer foraging, the population increase of which is partly attributed to global warming.

For the achievement of SDGs, forest genetic resources will attract more expectation and awareness in terms of its environmental benefits. Although major deforestation is not a current risk, conservation of species and anticipated adaptation will be necessary interventions. Sustainable forestry production and more wood use in place of more GHG emitting materials should be promoted. Information on current status of forest genetic resources should be reinforced and monitoring should be duly implemented especially for natural populations, for better policy decisions and resource mobilization to secure benefits from forest genetic resources.

Part 1: The contributions of forest genetic resources to sustainable development

Chapter 1. Value and importance of forest genetic resources

1. Japan's economic, environmental, social and cultural conditions with regard to forests and the forest sector.

(1) Location of the country

Land of Japan locates at the east end of the Eurasian continent, forming an archipelago parallel to the continent. It extends over 3,000km from northeast to southwest. The largest mass of land, 'Honshu', is the world 7th island, next to Sumatra in Indonesia. It exceeds Victoria Island in Canada and Great Britain. Japan's total land area is 378 thousand km^2 of which 67% - 250 thousand km^2 - is covered with forest. Hills and mountains occupy three quarter of the total land, which are mostly forested. [1)]

(2) Climate

Japan mainly belongs to temperate climatic zone but also stretches out to both subarctic and subtropical zones. Mountains range along the four main islands, dividing the country to southeast (Pacific Ocean) side and northwest (Sea of Japan) side which greatly differ in climate. In winter, prevailing wind from the Continent picks up humidity from Sea of Japan and collides with mountain ranges giving huge snow to that side of the land.[2)] The wind loses moisture when coming over the mountain ranges and makes the Pacific Ocean side dry and sunny. In summer, prevailing wind from Pacific Ocean and typhoons carry enormous amount of water vapor and bring lots of rain in southeast side of the land, often causes land disaster and/or flooding. Japan's average annual precipitation is 1,680mm, approximately 1.4 times larger than the world average (1,171mm).[1)]

(3) Population and national economy

The population of Japan is 120 million (the world 11th) which grew rapidly after the WW II when it was around 70 million. The nation strived for reconstruction, industrialization and economic growth to be nowadays as one of the top developed countries. The GDP in 2019 is 5 trillion (the world 3rd). While it is gifted with forested lands, the forest resources were exhausted after WWII and the country became largely dependent on imported wood. However, in recent years, Japan's wood self-sufficiency rate has been increasing as the forests planted after the war have reached maturity and are now in utilization phase.

Fig. 1 Location of Japan

Cited from The Geospatial Information Authority of Japan website

(4) The environmental and social state of the country

Japan's Population density is 338 people per km^2 (the world 24th) and habitable area is less than 30% of the country. As a result, actual population density is thought to be approximately 1,100 people/km^2 which is as high as the world top 10th (Bangladesh). Most of the nation lives in downstream or seashore area which is vulnerable to natural disaster as flooding or tsunami. Main rivers streaming from the dividing ranges are generally short and steeply inclined. The water flow is rapid, all year round but fluctuating, peak flow reaches 100 times larger of the ordinary state. Potential flooding area occupies about 10% of the country where 51% of the population lives and 75% of the economic assets lies.[1)]

Due to higher level of precipitation, mountain slopes and hills have higher risk of potential soil erosion when developed as farmland or grassland. This is why most slopes are left forested while plain fields are largely exploited as farmland/grassland or inhabited/industrial area under development pressure. Consequently, figure of forested area hasn't made significant change over past 50 years. The Japanese word 'yama', indicating mountain, is a synonym to forest.

Japan is one of the biodiversity hotspots. Pristine forests are limited to preserved forests or national parks. Majority of forests have been once or more harvested for timber, fuelwood and pulpwood and therefore are now secondary or planted forests. As such, the landscape of former fuelwood forest around inhabited area is referred to as 'Zouki-bayashi' (bush of miscellaneous trees) which is very popular to the nation.

(5) The cultural state of the country

Before modernization, wood is a major material for construction, goods and fuel in Japan with ample forest resources. 2,509 ancient wood-based buildings are designated to national cultural assets as of 2020. Professional techniques to fix and preserve wood constructions are also handed down to generations. Such tradition, often referred to as `culture of wood', is still alive. 74% preferred wooden residence in a poll on purchasing/building dwellings in 2019. Actually, 58% of annual housing starts, and in case of independent residential houses 91%, was occupied by wooden houses in 2020. [3)]

In Japan, construction of public facility or multi-storied building was restricted in urban area after WWII having bombed severely by US, in terms of fire prevention and saving wood resource then exhausted. However, in recent years rationalization of fire prevention building standard and technology development in the wooden material and construction method enabled wood-based public facilities as schools. The enactment of the Public Buildings Wood Use Promotion Act in 2020 also encouraged the use of wood in such buildings. [3)] 12 storied wood-steel hybrid building was constructed in Tokyo 2021. In 2022, totally wood-based 11 storied architecture was built in Yokohama. Such cutting-edge high-rise constructions were designed to realize circular economy and low carbon society as well as aiming at attracting environment conscious customers and tenants by the innovative way of architecture presenting future lifestyle. [4)]

Bamboos are also traditionally utilized in various aspect of Japanese life. Edible bamboo shoots have been popular as one of spring vegetables. Bamboo canes are used in household goods as basket, container and mesh bowl, as well as housebuilding/garden works and artisan products like whisk/ladle for tea ceremony. Bamboo products are integral part of Japanese culture. [5)]

2. Economic, social, environmental and cultural value of forest genetic resources, in particular to sustainable forest management, adaptation and mitigation of climate change and food security

(1) Economic value

Forest genetic resource including NTFPs has been used in various aspect of nation's life and economy, namely timber for construction and households, charcoal and firewood, pulp and paper, organic fertilizer, food, fodder, medicines, etc. Wood has been principal material for construction work as it is superior in strength per weight compared to stone, steel and cement. Typical timber species are 'sugi' Japanese cedar *Cryptomeria japonica,* 'Hinoki' Japanese cypress *Chamaechiparis obtusa,*' Karamatsu' Japanese larch *Larix kaempferi,* 'Aka-matsu' Japanese red pine *Pinus pumila,* 'Hiba' *Thujopsis draborata,* 'Todomatsu' Sakhalin fir *Abies sakhalinensis,* 'Keyaki' *Zelkova serrata* out of which *C. japonica* and *C. obtusa,* are distinctively popular as building material. [3),6)]

Domestic wood production in 2020 is 31.15 million m^3 which accounts more than 40% of wood demand in Japan. The primary usage of wood is house construction, approximately 80% of low-rise residences (up to 3 stories) are wood based and about half of the wood used is of domestic origin. In terms of economic importance, forestry timber production is 246 billion yen ($ 1.9 billion) in 2020, which make up 0.05% of Japan's GDP. Non timber forest production including wild and cultivated mushrooms is 284 billion yen ($ 2.2 billion), which is 0.05%, too. Forestry labor population is 45 thousand in 2015, 0.08% of labor population. Wood processing industry output is 842 billion yen ($ 6.5 billion) in 2018, 0.15% of the GDP. The figures are very small compared to Japan's entire economy but forest genetic resources are deeply rooted in national economy and nations' life, providing primary material in housing market. [6),7),11E)]

(2) Environmental, social value

Forest prevents slope corruption by tree roots and reduces soil erosion by covering forest floor with understory vegetation and litter.

Based on this function, forests protect civil assets as residences, agricultural fields, industry facilities and public infrastructure as roads and railways from flooding and soil fall, thus supports human life and national economy in a rainy and mountainous country.

[8),9)]

Forests also provide quality water by holding/filtering rainwater in its surface soil and let it steadily flow down to rivers or underground streams. It is said mixed forest of coniferous and hardwood species has more capability in providing ample pure water. This enables household water, agricultural irrigation and industry water being continuously served, which is definitely important in human life, national food security and continuous development of manufacturing industry.[8)] Actually, tap water has due quality for drinking throughout the country, which is a great benefit Japanese people enjoy.

Forest also works as wind/salt/snow/dust shelter and insulation. Environmental hazards to farmland, road traffic, railway and residential area are mitigated by the surrounding/shelter forests which improves amenity to human activities. [8)]

Such service is very important for land of Japan as it is surrounded by sea and having long coastline. Japanese black pine *Pinus thumbergii* has good salt tolerance in its leaves and robust root development and good tree height which gives mitigation of tsunami disaster, sea wind, salt splay and sandstorm. That is why the species has been widely planted in coastal area, presenting 'hakusya-seisyo' - white beech and green pine - scenery, a typical natural landscape popular to Japanese nation. [3), 8)]

Japanese beech 'buna' *Fagus crenata* forests are known to be important habitat of various plants and animals under complex relationship as food chain and/or habitat formation. It is one of major tree species growing across the country, in temperate forest. *F. crenata* dominating forest usually forms well-developed ecosystem. [13)]

Forest genetic resources offer comfortable environment for recreational and creative activities. Business sector is asked to make workstyle shift and/or to implement employees-health-oriented management. Satellite office and remote working space is emerging in forested regions and coastal areas. Social needs for educational or nursery activities in more natural environment has been raising. As lifestyle shifts from material satisfaction to activity/experience-based satisfaction, activities in the forest such as forest athletic, tree house, trail running, mountain biking, nature observation, forest therapy, health improvement program with workout, nutrition and rest in forest environment are getting popular. [3), 11)]

Fig. 2 Forest trail dedicated to MTB (Photo: YAMABUSHI TRAIL TOUR)

(3) Cultural value

Forests often play essential role in historic and/or scenic sites. National forest in Higashi-Yama range, Kyoto is an excellent background of the famous 'Gin-kaku' temple, an integral part of the historic landscape and also for the other near-by temples in the old city. [8)]

Forest genetic resources contribute to cultural value by serving as material for miscellaneous goods and assets. A representative species of Japanese conifers *Chamaecyparis obtusa*, 'Hinoki' has been used for old temples and shrines because of its strength, durability, workability and fine texture. Other major material speices are conifer *Thujopsis draborata*, *Cryptomeria japonica*, and *Pinus densiflora* along with hardwoods *Zelkova serrata* and *Cinnamomum camphora*. As for goods *Fagus crenata* is popular for furniture, veneer lumber and lacquer ware base. [13), 14)]

Bark of *Chamaecyparis obtusa* has been used as the most authentic roofing material for temples and shires in Japan because it is water repellent. In case of Izumo-Taisha shrine, Shimane prefecture, 700 thousand pieces of the bark were used in periodic refreshment inauguration of, the one of the most famous sacred places in Japan. The 'urushi', traditional Japanese lacquer derived from resin of native tree species *Toxicodendron vernicifluum*, is an indispensable coating for cultural asset buildings and artisan works. [3), 8), 11E)]

(4) Contribution to the Sustainable Development Goals, in particular climate change and

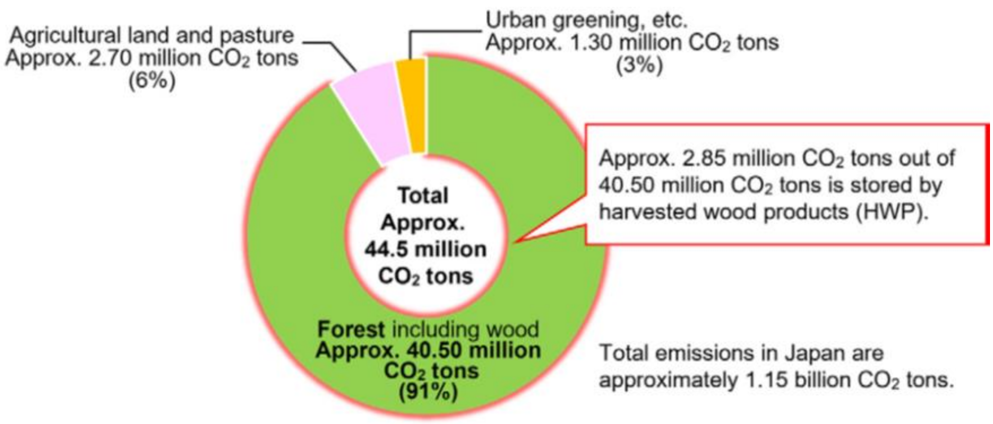
food security

Forests in Japan has estimated to have removed 40.5 million tons of CO_2 in 2020, including storage by harvested wood products (HWP), approximately 3.5% of total emission in Japan. Gross emission from a typical household, 4,150kg of CO_2, is yearly absorbed by 472 mean (36 to 40 years old) Japanese cedar *Cryptomeria japonica* trees. It is also a renewable energy resource which could replace fossil fuel. [3),]

Wood products store carbon for a long time when used as building material not only in house construction but also in commercial facilities, warehouses and high-rise buildings. Use of domestic wood products has been accounted for as emissions and removals arising from HWP and contributed to climate change mitigation targets since 2013. Japan reported 2020 HWP of 2.85 million tons of CO_2. [11E)]

Wood as building material also contributes to reduction of CO_2 emissions associated with buildings, since it consumes less energy during production and processing, compared to steel and concrete. A Life-Cycle-Assessment shows that wooden housing produces 40% less emission per floor area compared with that of non-wood housing. [11)]

Fig. 3 Carbon dioxide removals in Japan in FY2020 [11E)]



Based on the IPCC-AR5 climate scenario, it is estimated that in Japan the frequency of heavy rain and strong shower increase while number of rainy days decrease. [12)]

Such augmented frequency of such extreme weather is one of major risks. Because of its mountainous geography and limited downstream inhabitable area with dense population, accumulated industry/agriculture/infrastructure, land of Japan has high vulnerability to natural disaster, where soil conservation by healthy forests all over the country has great importance to social stability.

Forests provide benefits through wood products. They are preferred materials in construction in terms of such strong points as higher strength per weight compared to steel, humidity conditioning function by absorbing and releasing vapor, heat insulation for energy saving through its low inductance and psychological effect to give peace mind. Some care homes adopt wood floors and walls taking advantage of their shock absorption effect to rule out risk of elderlies getting injured when fallen off, or to mitigate caring workers' physical workloads. Such properties specific to wood bring better condition to human life. [3),11 E)]

Forestry is a principal industry and means of income in rural mountainous regions which extends for the majority of the country land. Forest industry people plays important role in keeping rural community and forest management. Forest roads are also used as an infrastructure to land management in such area.

Part 2: State of diversity in forests and woodlands

Chapter 2. State of forests

1. State of forests

Forested area in Japan is 25 million ha and covers two-thirds of total land. It potentially covers all of the country land, as annual rainfall in most dry region (Kagawa prefecture, 800mm) is larger than estimated annual vaporing (609mm). Planted coniferous forest extends 10 million ha which make up approximately 40% of total forest. The ownership of the forests is 57% private, 31% national and 12% public (local governments). [3)]

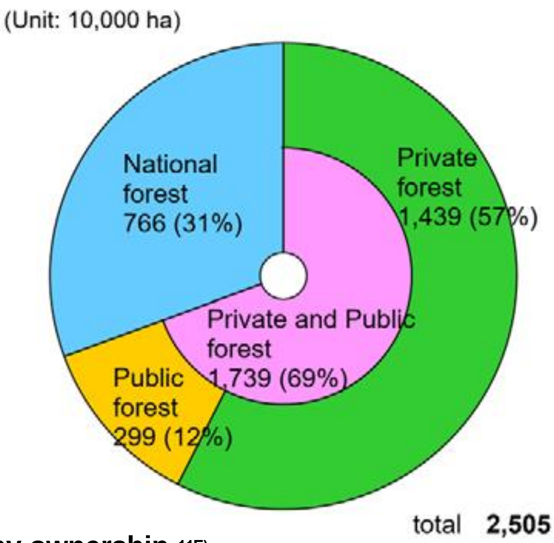


Fig. 4 Forest Area by ownership [11E)]

Japan mostly belongs to temperate climatic zone but type of vegetation varies greatly from south to north, from seashore to high elevation peaks. There are subtropical evergreen, temperate evergreen, temperate deciduous, subalpine coniferous/mixed forests. Site specific vegetation as mangrove forest, swamp forest and alpine forest are also found. Bamboo stands are seen around inhabited area as it is historically introduced species. [2)]

Planted forests are mostly formed after WW II , from late 1940s to early 1970s. Almost half of them are over 50 years and now harvestable. Major tree species are: Japanese cedar (*Cryptomeria japonica*, 44% of planted forest area), Japanese cypress (*Chamaecyparis obtusa*, 25%), Japanese larch (*Lalix kaempferi,* 10%), Japanese pines (*Pinus densiflora* and *Pinus thumbergii*, 8%) and fir (*Abies sachalinensis*, 8%), all of which are indigenous. [3)]

Forest stock is increasing to 5.2 billion m^3 in 2017, out of which planted forests consist 3.3 billion, approximately 60%. [11E]

2. Change in forest management, drivers of change in the forest sector and its effect to Japanese forests

   Forest in Japan are exploited historically along with its population growth. In the early half of 19th century (later Edo period) when the national population grew up to around 30 million, forests had been intensively harvested for timber needs for construction like castles and temples, chiefly in large cities such as Edo (Tokyo) and Osaka. Fuel wood harvest and organic matter collection for fertilizer also made large impact to forests. Such human activities degraded forests and consequently flooding disaster became serious. The governing fiefs tried to help this through harvest ban or entry inhibition. [8),10)]

   Meanwhile, increased wood demand prompted plantation forestry. Private forestry sectors and associated communities are formed which are nowadays known as notable forestry areas. [8), 10)]

   In later half of 19th century (Meiji period) Japan abolished its national isolation policy and moved to social and industrial modernization, taking in civil and military technologies from countries of the Europe and US. Wood use increased significantly along this change and forest resources are heavily harvested for providing construction timber, poles for mining and power lines, sleepers, packaging, pulping, etc. Forests were deteriorated and it had led to many flooding disasters. [8), 10)]

   In the beginning of the 20th century national forest policy was reorganized and protection institution was initiated. Sustainable forestry was encouraged in 1920s. However, military exploitation to east and southeast Asia from mid 1930s caused wood demand surge and so the WW II did in 1940s. Including reconstruction period after the war, wood demand for war and restoration activities made great harvest pressure to forests. Foreign currency shortage restricted wood import and accelerated domestic forest removal. Replanting activities were limited and abandoned hills and mountains became source of soil erosion, slope fall and enormous flooding. [8), 10)]

   Such situation alerted the nation urgent need to restore and protect forests. Forest establishment subsidy to forestry communities started after the war, and was aggressively propelled aiming at accomplishing forest establishment in 1.5 million ha of abandoned forest lands. In upstream remote area where voluntary planting was not likely, national afforestation program was carried out with the objective of landscape-wide soil conservation and disaster prevention. [8),10)]

Fig. 5 Disruption of national roads due to runoff sediment

(Kazama-ura village, Aomori Prefecture)

In contrast to wide extension of planting movement, species used are mostly limited to few indigenous coniferous species as *Cryptomeria japonica*, *Chamaecyparis obtusa, Pinus densiflora*. This is because *C. japonica* showed broad adaptation to various sites and good growth as far as soil moisture condition is good. It was also because mass seed/seedling provision system already existed for these coniferous species in the forestry sector to enable rapid exploitation of the seedlings. *P. densiflora* had outstanding hardiness to dry and poor soil of degraded/heavily extracted lands. Not to forget that growth and wood quality of these coniferous species enabled prospect of income for forest owners. [10),16)]

In coastal areas where sand blow has been made human life and agriculture production difficult in the backland of the beaches, ruling fief or magnate merchants of good will conducted planting *Pinus thmbergii* seedlings in the coast beach backlands in 18th and 19th century. Such artificially planted pine forest now exceeds 0.8 million ha which is approximately 3% of forest area in Japan.

During 1950s and 60s, as fuel wood and wood charcoal was replaced to fossil fuels, utilization of fuelwood resources – broad leaved forest - decreased. In turn, emerging chip wood demand was filled with such domestic hardwood resources as yen was not strong enough to allow woodchip import. Hardwood forest owners were quite willing to harvest hardwoods and plant coniferous trees expecting future profit for construction timber, as matured coniferous forest of utilization stage was then exhausted. Considerable part of coniferous planted forest resource was formed under such atmosphere. [10)]

Transfer from hard wood forest to coniferous planted forest progressed after WWII stalled in 1980s due to increasing pulpwood import and decline of coniferous timber price under strong yen. The influence of vegetation transfer to forest genetic resources became small. All the while, emerging factor like climate change, explosive increase of wild deer population and subsequent browsing pressure, and sticking factor like pine wilt damage are supposed to make negative impacts to Japanese forest genetic resources.

3. Challenges and opportunities for forests in Japan

(1) Disaster prevention and soil/water conservation

Forests where its environmental services like water/soil preservation is strongly desired are designated to protection forests, either natural or planted stands, with restriction to felling and land development by the Minister of Agriculture, Forestry and Fisheries (MAFF) or prefectural governments. Such forests cover 12.2 million ha, make up 49% of total forests, that is 32% of entire national land. [11E)]

Fig. 6 Soil erosion protection forest in Suwa-city, Nagano [11)]

(2) Management of planted forests

In recent years, as the planted forest resource is coming under harvesting age class, use of domestic wood has been soaring due to material shift from hardwood to softwood in plywood sector and decrease of import of timber during pandemic. All the while, replanting in private forests is estimated to done only in around 30% of the harvested stands. [3]

Such low replantation ratio in planted forests is a major challenge in Japanese forest policy. If not replanted after removal, there will be a higher risk of soil erosion and/or soil fall resulting from poor ground vegetation and decomposition of wood roots. A substantial part of planted forests is left untended under long lasting wood price stagnation, to resulting in overcrowded stand with absence of naturally regenerated trees. Promotion of replanting is an urgent issue in Japanese forestry.

Increase in frequency of strong shower and heavy rains raises awareness to environmental services as soil conservation and biodiversity in planted forests formed all over the country. Thinning and other appropriate management is essential. However, plantation forestry in Japan has been a low-profitable industry and proper management of plantation forests has been likely to be postponed or left untouched. The promotion of such activities is a major challenge in Japanese forest policy. [3]

(3) Effect of climate change and conservation of vulnerable species/populations

One of Japanese popular tree species is Japanese beech *Fagus crenata* growing nationwide. However, it is pointed out that under global warming its habitat in western half of Japan – Kyushu, Shikoku and the Pacific Ocean side of western Honshu - will disappear in 2090s. In its eastern half of Honshu and Hokkaido, the habitat is said to shrink significantly. The habitats in the lower isolated mountain tops is thought to disappear and accelerate population extinction. [17]

This is more urgent for endangered tree species *Abies veitchii* var. *shikokiana* of which distribution is limited to only three mountain tops in Shikoku main island. Habitat shrinking and population size reduction seem already ongoing, and the risk of species' extinction is high. Forest Tree Breeding Center (FTBC) began *ex-situ* preservation of the species, collected seeds from these populations to be preserved in National Forest Tree Gene Bank Program of the Forestry Agency (FTGBP). [18),19]

(4) Deer foraging

Population of wild deer has been rapidly expanding in recent decades all over the country and its negative impact is increasing ever. Its habitat area became 2.7 times larger from 1978 to 2018. Almost 70% of reported silvicultural loss caused by wildlife are attributed to deer. Bark/leaf removal of planted trees lead to growth inhibition, death and/or loss of timber value. Loss of understory vegetation or degradation to mono- or oligo- species community which deer do not prefer has been reported, giving negative effect to soil preservation and biodiversity. It is discussed that absence of next generation seedlings in a small fragile population is a serious issue for forest genetic resources. [3)]

(5) Pine forest pest control

Socially and economically important genetic resources *P. densiflora*, *P. thumbergii* and *Pinus luchuensis* are susceptible to pine wilt nematode *Bursaphelenchus xylophilus* originated from North America; infected trees wilt and die. Since the first case recorded in 1900s it has spread over the country, being a severe threat to coastal shelter forests and mountain soil conservation forests. Continuous control measures have been implemented by national and prefectural governments and damage in 2019 was reported to be 300 thousand m^3 which is 1/8 of the record high in 1954. However, it remains the largest forest pest in Japan. [3)]

(6) Change in use of bamboo and its effect to forest resources

Bamboo resource is traditionally utilized in various aspect of life in Japan. Bamboo shoots have been popular as a kind of vegetable. Bamboo canes are utilized in manufacturing kitchen goods, family groceries, garden materials and artisan work. These domestic productions, however, considerably reduced in recent decades due to replacement with plastic material and competitive imported goods from Asian countries. It led to poorly managed bamboo forest around villages and their invasion to the planted forests. [3)]

Chapter 3. State of other wooded lands

There is no applicable figure for other wooded land based on FRA definition. Area of forests with tree cover less than 30%, including temporarily understocked area to be regenerated, is 1,085 thousand ha as of March 2017 [15], which is equivalent to 4.3% of total forest extent.

Under moist climate, lands left without human intervention usually become covered with trees of pioneer species as pine, birch, alder, willow etc. Lands under specific condition (coastal sand dune, swamp, alpine zone, etc.) may stay not forested - with scarce tree cover or low bush.

Chapter 4. State of diversity between trees and other woody plant species

1. Number of species

About the number of tree and other woody plant species, the third stage of National Forest Inventory by Forestry Agency (2003-2007) identified 1,200 woody plant species 20) across the country. Other literature says the number of native tree species to be approximately 1,000 21) or 1,500. 22)

Though number of species recognized as 'forest genetic resources' is not determined in Japan, 689 tree species (of which 440 are indigenous) are collected as of 2022, in FTGBP as genetic resources of forest sector having current or potential value for human use.

2. Trends in number of species

Literature nor dataset regarding trend of number of species of woody plants does not exist, however, according to the 4th version of the Japanese Red Lists (2012) published by the Ministry of Environment, Japan, 357 tree species are classified as endangered species. 22)

3. Drivers of change in the number of species and threat to species

(1) Fragmentation and shrink of habitat, decrease of population size

Japan has considerable number of relict tree species having been survived from Glacial period and now merely found in a limited area of specific environment. They are of genus pine, spruce, birch, willow and maple etc. Habitat loss or fragmentation are likely to occur by forest harvest, transfer to plantation or land development, etc., which lead to population decline. This worsens pollination condition to cause seed production decline, inbreeding and reproduction of low survival, low fertile successive generation. Invasion of competing species, spread of forest pest and animal browsing may accelerate the population decline. Habitat shrink to mountain peaks by climate change and regeneration inhibition by dear browsing are recent concerns. 23), 24), 25)

(2) Forest pests

Pine wild disease is attributed to rapid decrease of Japanese endangered tree species *Pinus amamiana* population, which is found only in limited southwest islands of Japan, Yakushima and Tanegashima. Logging exploitation is as well. The state of genetic diversity of the population has not yet seriously declined but based on the observed pollination difficulty successive reduction of genetic diversity is worried about.

Chapter 5. State of diversity within trees and other woody plant species

1. State of diversity within tree species

(1) Diversity across the main mountain range

In some Japanese tree species, forms and/or properties of leaves, stems and branches differ between populations found in the Pacific Ocean side and the Sea of Japan side across the main mountain range which extends from northeast to southwest. This is thought to correspond to different climate condition aforesaid. The examples are as follows.

The popular silvicultural tree species *C. japonica* is categorized in two regional population types; the Pacific side and the Sea of Japan side. The former is characterized by straight and long scale leaves which have large angle against branch stem and the latter is by curved and short scale leaves which erupt with small angle against branch stem. It is said such character of the latter gives less risk of catching heavy wet snow and so is optimized to snowy climate. It is also well known that those from the Pacific side show poor performance when planted in the Sea of Japan side. [26]

A native coniferous tree species *Cephalotaxas harrintonia* grows up to 5m high and is commonly seen in the Pacific side. In contrast, a variation *C. harrintonia* var. *nana* is mostly seen in the Sea of Japan side, with flat-on-the-ground stem and height of 1-2m.

A common flowering bush species *Hamamelis japonica* var. *discolor* which distributes in the Sea of Japan side has stem and branches of increased flexibility which endures heap snow. It is a variation of *H. japonica* which is commonly seen in the Pacific side of the country. Such difference is thought to be an adaptation to winter climate – snowy in the Sea of Japan side and sunny in the Pacific side.

In Japanese beech *F. crenata* which widely distributes in the country, a clear cline of leaf size is recognized from the Pacific side (smaller) to the Sea of Japan side (larger). This is thought to be an adaptation to soil moisture condition in the spring leaf extension time, wet with melting snow in the Sea of Japan side and drier with less snow and sunny weather in the Pacific side.[28]

(2) Diversity originating from migrating routes from the continent

In the Glacial periods Japan was connected with Eurasian continent by two land bridges – Sakhalin bridge and Korean peninsula bridge but not covered with glaciers. This allowed plant species to migrate from the continent and get settled in Japan. Species who prefer warm climate survived only in refuges along the coast of western Japan. Later in interglacial period they expanded their habitat to north-eastern Japan. This expansion progressed separately, in the Pacific side and Sea of Japan side, divided by central ranges. Species migrated from Siberia through northern Sakhalin bridge settled in Hokkaido and successively to central Japan. They were forced to reduce their habitat in interglacial period and isolated to alpine mountains of Hokkaido and central Honshu. These factors – migration routes, refuges, central range barrier and dislocation along climate fluctuation are thought to have created genetic diversity of the tree species. [27)]

Cited from The Geospatial Information Authority of Japan website

Fig. 1-2 Japan and the Eurasian Continent

(3) Diversity attributable to refuge and isolation in last glacial and post glacial period

Japanese cedar *C. japonica* is principally a plantation species yet has a number of natural growing sites across the country. From 29 natural population, richer genetic diversity was found in in southwestern populations compared to northeastern populations. [26)] This indicated *C. japonica* reduced its distribution range to refuges in western-Japan coastal areas in the Glacial period and expanded again to north-eastern Japan during the inter- or post-glacial period. In a genetic differentiation study with 14 natural population, a clear genetic structure was found between populations of Pacific Ocean side and Sea of Japan side, which was consistent with diversification of physical traits identified from observations as leaf size.[29] In addition, these populations were respectively associated with (estimated) refuge sites in western Japan, and genetic distance between the populations indicated genetic flow from the Sea of Japan side to the Pacific Ocean side during expansion in warmer periods. One of the western populations located closer to the Pacific Ocean side was found to be genetically closer to the Sea of Japan side populations, which suggests fast expansion from that population to northeastward along the Sea of Japan side. This was supportive to the result from 29 natural populations above, lesser genetic diversity in northeastern populations. On the other hand, in Yakushima island (the world natural heritage site) natural population, which is thought to have had been the most southwest refuge of *C. japonica*, level of genetic diversity of natural population was distinctively high among investigated populations. A clear genetic structure was identified, too, against adjacent Kyushu main island population. It was thought to come from low genetic flow and long isolation by sea strait. [29]

Pinus pumila, a conifer species, is thought to have migrated in the Glacial period from Siberia through Sakhalin to Hokkaido and central Japan mountains. Later in the succeeding inter-glacial period the populations were retreated to higher ridges in these areas and isolated. The genetic structure of *Pinus pumila* reflected the expansion, retreat and isolation history of the species, i.e., genetic distances between Hokkaido populations are large, indicating they experienced a long time of isolation, while those between central Japan populations are small suggesting they established recent past. [30]

(4) Diversity attributable to expansion of distribution

One of the well analyzed natural tree species in terms of intra-species genetic diversity is Japanese beech *Fagus crenata*. It distributes from northeast region (Hokkaido) to southwest (Kyushu) and there is a distinct cline in size of leaf and nut. [31] SSR analysis from natural domestic 23 population revealed that genetic diversity was larger in southwest population and smaller in northeast population, which implies the population started to expand from southwest refuges to northeast habitats after the last glacial maximum. [32] There is also a physical cline between the Pacific Ocean side populations and the Sea of Japan side populations that the former shows flat, umbrella like crown form whereas the latter shows conical crown form, in addition to that of leaf size aforesaid. [33] Furthermore, chloroplast DNA analysis indicated existence of the Pacific Ocean strain and the Sea of Japan strain. [27] The same genetic divergence was also found in SSR analysis above.[32] There results suggest that the species' populations had been separated into two groups by central mountain range during isolation in the last glacial period and also in the process of recolonization to northeast in the post glacial period.

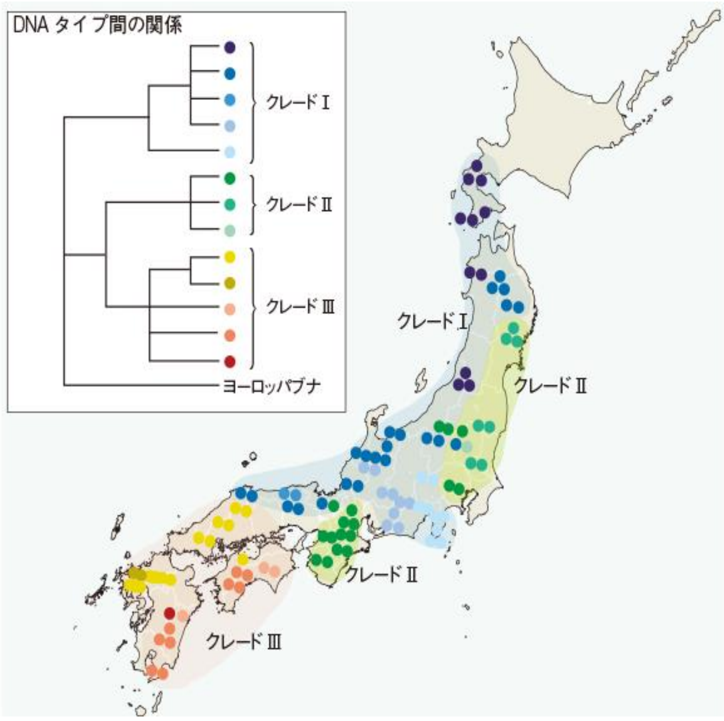


Fig. 7-1* Genetic population structure of *Fagus crenata* obtained from chloroplast DNA analysis [27]

Colored dot shows DNA type of an individual sampled tree, dots of similar colors show a phylogenetic clade. As a whole, two strains are recognized - Pacific side (clade II, III) and Sea of Japan side (clade I).

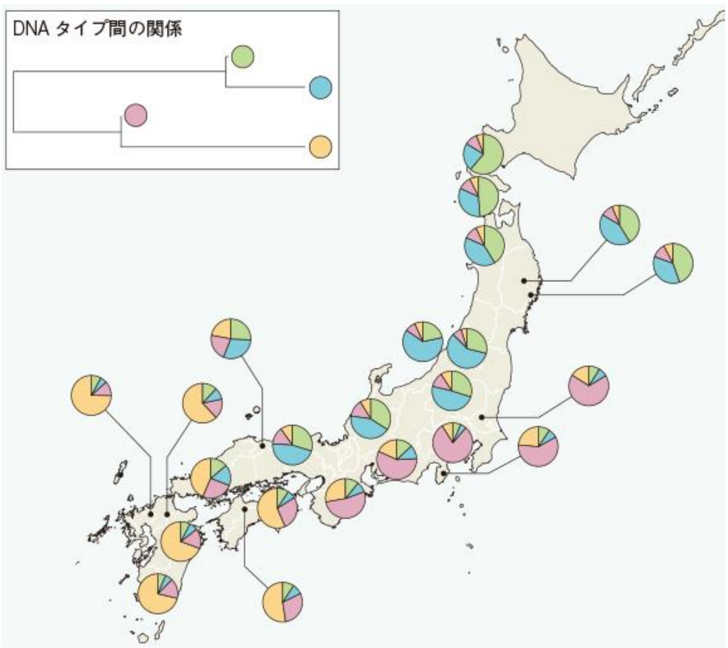


Fig. 7-2* Genetic population structure *F. crenata* obtained from nuclear DNA analysis [27], [32]

A genetic divergence is seen between Sea of Japan side and the Pacific side, also between eastern Pacific and western Pacific populations.

＊ cited from 'Illustrated guideline for seed and seedling transfer for native tree species' Tsumura Y and Suyama Y ed.(2015) [27]

2. Trends in genetic diversity

In Japan, trends in genetic diversity are not monitored, however, because forest area is not in decreasing trend and transition from native forest to plantation is no longer practiced, it can be said that risk of genetic diversity in species with ample habitat range is small. All the while, in case of species only with isolated small populations, climate change and land development pressure will be a considerable threat to genetic diversity and the species' survival.

3. Research for assessing and/or monitoring the genetic diversity, capacity building

Identification of haplotype, genetic distance of populations, genetic diversity of population and genetic structure have been executed by developing genetic makers for both nuclear and organelle DNA. Results for 43 tree species are currently consolidated and published as a guideline for seed and seedling dislocation. [27)]

Part 3: State of forest genetic resources conservation

Chapter 6. *In-situ* conservation of forest genetic resources

1. State of *in-situ* conservation efforts and its approach, main players

In-situ conservation is a most desirable means for conservation of forest genetic resources. However, forests have been heavily utilized historically and undisturbed forests are very limited (figure does not exist but probably less than 10% of total forests). Most of such forests remain in Wilderness Area, national parks and Protected Forests in national forest.

In-situ preservation is conducted by the FTGBP through designating protected forests in national forest. 319 sites are designated for preservation of genetic diversity for 94 major silvicultural or rare tree species. [34] The preservation started with establishment of Protected Forests targeting respective forest genetic resource (Forest Tree Genetic Resources Preservation Forest (GRPF)) in national forest, which later incorporated to Rare Population Preservation Forest (RPPF) which is designed to preserve rare or valuable tree population. Number and area of designated sites of major tree species are reported though the questionnaire.

GRPF has been designated under consultation process by FTBC as a managing organization of FTGBP, academic researchers in forest ecology/heredity and competent Regional Forest Office on the intended species population. Planted forests are designated if appropriate.

For successful *in-situ* preservation, monitoring of the target population on growth, propagation, survival and recruitment is important. It is executed by researchers of the national gene bank with interval of several years.

2. Challenges for *in-situ* conservation efforts

Decrease in number of trees of preserved species and/or loss of successor generation is a major challenge while these sites themselves are well protected in general. Notably, wild deer foraging is one of the most serious and urgent drivers attributed, giving fatal effect to tree population. Sai-no-ko *Pinus parvifolia* and *Rhododendron quinquefolium* RPPF population in Nikko, Tochigi prefecture have serious damage by debarking tree trunk and browsing regenerated seedlings of the species. [35] Effective protection measure is called for.

3. Capacity building

Human resource building in this sector is carried out in relevant universities and research institutions, namely ecology and forest science.

Chapter 7. *Ex-situ* conservation of forest genetic resources

1. State of *ex-situ* conservation efforts

Ex-situ preservation is implemented through FTGBP of the Forestry Agency. It preserves 46,000 items of 689 species based on the usefulness of the tree species. [45] The objectives are; i) collection of breeding material of major silvicultural tree species, ii) contribution to generating alternative demand for forest genetic resources, iii) conservation of fragile genetic resources that is rare or endangered tree species. Implementing organization is FTBC.

Molecular and non-molecular characterization has been carried out for tree species collected with the objectives of i), ii) and iii) above by FTBC. To date, non-molecular trait-based characterization has been done for 12 species to obtain information for future breeding. Non-molecular characterization for 8 species has also done for both future breeding and genetic structure/population identification.

With the objective iii) above, FTGBP have collected 60 tree species to date in terms of vulnerability to extinction, necessity for preservation and suitability to *ex-situ* conservation. This stock accounts for 17% of 357 endangered tree species in Japan.

2. Approaches used for *ex-situ* conservation

The collection – propagation - preservation activities of *ex-situ* conservation begin with field sampling of scion followed by grafting or cutting propagation to establish a conservation stands. In-facility freezing preservation of vegetative organs and germplasms (seeds and pollens) are also implemented. The conservation stands make up approximately 2/3 of the collected items while germplasms are the rest of it. In addition, DNA preservation has been undertaken recently.

Conservation stand is genetic reserve for tree breeding, an important genetic resource of the intended species by population. They are established as successor population by collecting seeds from superior natural/planted population in national or private forests. These stands are usually located in the vicinity of the source forest, but in some cases are placed in a distant locality with the objective of provenance test. 375 stands which accounts 931ha are set up all over the country preserving 19 tree species, using seeds from 234 seed sources.

Collected tree species include major silvicultural conifers as *Cryptomeria japonica* and

Chamaecypress obtusa, natural hardwoods as *Zelcova serrata*, *Quercus crispula*, *Fagus crenata*, *Castanopsis sieboldii* and *Betula platyphylla,* which are important in Japanese forest landscape. Rare species namely *Alnus trabeculosa* and *Picea koyamai* are also preserved. Such activities are largely conducted by breeding researchers and technicians in FTBC.

3. Needs and challenges

The gene bank now undertakes conservation of species/populations of higher extinction risk under climate change, including information on their natural distribution. It has also embarked on in-facility preservation of vegetative organs for the species which have a risk of genetic contamination in the open-air stand preservation.

Part 4: State of use, development and management of forest genetic resources

Chapter 8. The state of use

1. State of forest genetic resource use in Japan

The principal commercial use of forest genetic resources is wood products. 31 million m^3 log equivalent is produced in 2020, of which timber is 12 million m^3 (38%) and veneer accounts 4 million m^3 (14%), both of which are mostly coniferous. Chip for pulp and fuel makes 13 million m^3 (43%). [11), 11E)]

Other examples of well-known uses are: various bamboo species such as ‘madake’ *Phyllostachys bambusoides* for bamboo products, *Quercus acussima* used for mushrooms culture such as Shiitake, ‘urushi’ Japan lacquer made from resin of *Toxicodendron vernicifluum*, *Chengiopanax sciadophylloides* young shoots as popular wild vegetable, temple/shrine roofing material made from bark of Japanese cypress *Chamaecyparis obtusa*, pine resin, camphor from *Cinnamonum camphora*, parfum and drink from sap of *Betula platyphylla*, salt cured leaf of cherry blossom *Cerasus speciosa* used to wrap ‘sakura mochi’ a popular rice cake eaten in March. However, these uses are economically minor compared to timber.

2. Trends in production of forest reproductive material

Forest reproductive material (seedlings for silviculture) in Japan has been largely coniferous. In 1960s, 17 billion seedlings were shipped to planting. It was principally for forest restoration program after WWII and forest conversion from redundant hardwood fuel forest to coniferous timber forest. With the accomplishment of the restoration and termination of the conversion, the seedling production gradually decreased to 56 million in 2013, and stagnated to 65 million in 2019. The production has been monitored by prefectural governments and summarized by Forestry Agency. [36)]

Hardwood reproductive material production is very small compared to that of conifers. *Quercus* species and *Zelkova serrata* are examples but the demand is limited.

Traditionally, production of forest reproductive material has been carried out by private seed/seedling producers who collect seeds/scions from locally established seed/scion sources and provide propagated material to users. In recent decades use of silvicultural varieties developed by national or prefectural breeding organizations has been increasing. The main drivers of the change are; better growth and pest tolerance of bred varieties, increasing demand for non-pollen or less-pollen varieties of Japanese cedar *Cryptomeria japonica* and Japanese cypress *Chamaecyparis obtusa* developed by these authorities, national climate change mitigation policy to ask forest sector to use planting material originating from the quick growing 'Specified Mother Trees' (SMTs) varieties bred in these organizations.

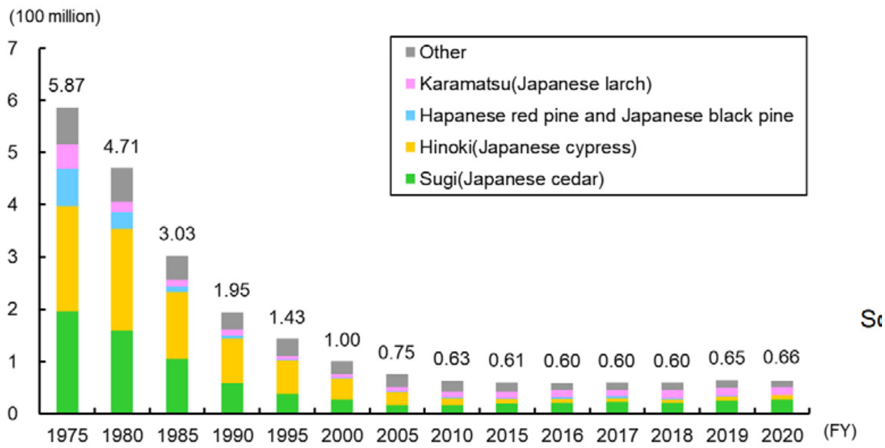


Fig. 8 Trend in annual production of seedlings for planting [11E]

3. Players in production of forest reproductive material

Seed/seedling producers are mostly small entities and are often private farmers. However, some forest industry companies have been showing interest and coming into the nursery business in recent years, focusing to production of the SMTs-origin material to meet climate mitigation policy.

4. Supply and demand

For seed and seedling producers surplus and deficit of seed/seedling is always an issue. Producers side (seed/seedling producers) and consumers side (forestry association, national forestry offices) meet periodically on regional basis to discuss current and future needs and production. Domestic supply basically meets demand under such coordination process. Japanese cedar seedling supply prediction for 2022 is around 31 million where demand prediction is 27 million which makes a surplus of 4 million. Larch supply and demand is tighter –surplus negligible in 2022 and deficit of 0.1million in 2023. [37] There is practically no importation, and this is partly because past introduced species – foreign pines, spruces, etc. - had been generally unsuccessful in Japan.

5. Challenges and opportunities

The major challenge the forestry reproductive production sector has is aging of human resource and decrease of producers. Number of producers was 20 thousand in 1975 but since then continually declined to eight hundred in 2019 while output per producer is gradually increasing. [38)]

The prominent trend in recent seedling production is a shift to containerized seedlings. It enables more efficient raising work and shortened production time. It offers more solid root block and better developed lateral root to wider possibility of planting season and ease of planting – with hoe or some purpose-built appliances. It also fits to machine planting. Technical extension program to producers and seedling users is exploited nationwide. The shipment has been enlarged from 89 thousand in 2009 to 19 million in 2019 which accounts almost one-thirds of the country's seedling provision. [39)]

Chapter 9. The state of genetic improvement and breeding programs

1. State of tree breeding and improvement in Japan

In Japan, traditional experience-based tree breeding has been practiced in old log provenances namely Yoshino, Kitayama and Kiso, which specialize in certain variety of Japanese cedar or cypress. In 1954, modern science-based systematic tree breeding ('plus-tree selection program') was initiated in national scale, introducing mass-selection breeding method from leading countries as Sweden. Field selection was carried out to select over 9,000 plus-trees across the country for major silvicultural species* [40].

* Most of them are coniferous species controlled under the Forestry Seeds and Seedlings Act (FSSA): *Cryptomeria japonica, Chamaecyparis obtusa, Pinus densiflora, Pinus thunbergii, Larix kaempferi, Picea glehnii, Picea jezoensis, Abies sachalinensis, Pinus luchuensis*

FTBC reserved those plus-tree clones, and propagated to evaluate and rate them in the test fields. Clones of those plus-trees were provided to prefectural governments' forestry research stations and propagated. The stations established seed orchards / scion gardens and provided the propagated materials (seeds or scions) to private seed/seedling producers within the prefecture for raising/marketing of superior seedlings to be planted. These superior seedlings make up approximately 70% of *C. japonica* and *C. obtusa* seedlings for afforestation, the chief silvicultural species in the country. The objective of the breeding program was improving genetic characters for forestry productivity: growth, stem form, wood quality and disease/pest tolerance.[40]

From 1980, FTBC started outbreeding between the selected superior plus-tree clones and planted more than 200 thousand progenies in more than 100 test sites. From these sites excellent 2nd generation plus-trees were selected in terms of growth, stem stiffness, stem straightness and lesser pollen production character. As of March 2021, 611 *C. japonica*, 301 *C. obtusa*, 109 *L. kaempferi* and 33 *A. sachalinensis* varieties were selected. They also have a role of parent material for the 3rd generation and further progeny stands establishment is now going.[40]

From the 2nd generation plus-tree clones, FTBC has been selecting production population of similarly good growth, stiffness, stem straightness and lesser pollen production. They are designated by the government as Specified Mother Trees (SMTs). The Forestry Agency promotes use of planting stock originating from these SMTs for increased CO_2 absorption and carbon fixation in national and public afforestation programs including subsidized private activities. This is based on the Act on Special Measures concerning Advancement of Implementation of Forest Thinning, aiming at achieving national CO^2 absorption commitment under Kyoto protocol and Paris Agreement. To date, 190 varieties of *C. japonica*, 58 varieties of *C. obtusa*, 77 varieties of *L. kaempferi* and 20 varieties of *A. sachalinensis* are selected* by FTBC and prefectural governments, of which majority are selected from the 2nd generation plus-tree clones.[40)]

*As of March 2021

2. Priority traits

(1) Growth

The important traits in the national tree breeding program are height and diameter growth, stem straightness, stem stiffness. The 2nd generation plus-trees are expected to present high competency to weeds (for less weeding cost) and shorter rotation period (for increased forestry productivity) by their rapid early growth.

(2) male strobili amount [42)]

Japanese cedar *C. japonica*, which occupies 44% of planted forests and Japanese cypress 'Hinoki' *C. obtusa* which consists 25% of them, are both wind-pollinated species. Their pollens are a cause of pollen allergy by which 40% of the nation is said to be affected, being one of the top social issues every spring. It gives patients runny nose and unstopping tears which lead to concentration inhibition and/or sleeplessness. It is referred to as 'syndrome of the nation'.

The government tries to mitigate the syndrome by three forestry measures: i) to promote removal of mature trees and their utilization, ii) to replant them with no/less pollen varieties, iii) to reduce emission of pollen from cedar plantation. To meet these needs, FTBC has developed more than 200 cedar/cypress varieties which bears no normal pollen or very small amounts of male strobili.

Varieties with very low amounts of male strobili were found in the 1st generation plus-tree clones. Plural individuals having such character were outbred and progenies showed heredity on the amounts of male strobili. To date, FTBC and prefectural forestry research stations developed 147 less-pollen *C. japonica* varieties and 56 less-pollen *C. obtusa* varieties.

In addition, male-sterile cedar – bearing strobili in which normal pollens aren't formed at all – was discovered in 1992 and the following research works found out that this trait was governed by mutation at single nuclear locus and expressed recessively –

phenotypically expressed only in case of homozygote of mutated gene. To date, four loci of such male-sterility were found. Crossbreeding of male-sterile clones with superior variety is now undertaken to develop new male-sterile clones with superior growth performance.

In addition, the latest generation of Japanese cedar/cypress production population - SMTs - is requested to fulfill a pollen criterion which is less than half of average amount of male-strobili with recognition to the gravity of pollen allergy.

3. Current and emerging technologies used in tree breeding

(1) Cross breeding [41]

While the principal breeding method in Japan has been mass selection, crossbreeding with congener species was implemented in Japanese larch *L. kaempferi* breeding. Hokkaido prefectural government forestry division undertook inter-species cross breeding of *L. kaempferi* var *japonica* x *L. gmelinii* to develop a crossbred larch which shows better growth than ordinary larch and more resistance against wild mouse nibbling and shoot blight. At present, extension program is being exploited in the region.

(2) Development of DNA markers to identify no-pollen related loci [42]

In order to replace nationwide-planted pollen bearing cedars and cypresses, superior growth performance variety with male-sterility will be a key. With such seedlings became widely used in forestry industry, the cedar and cypress plantations will leave from current status 'source of the pollen dissemination'. To create such variety, using superior individuals with male-sterile gene as breeding material is a possible approach. However, male-sterile gene possessing superior trees are usually heterozygous, and identification of such heterozygotes had been difficult as those heterozygotes bear pollen. To overcome this situation, FFPRI and FTBC developed DNA markers to identify male-sterile genes, which is quite useful for distinguishing heterozygotes and non-possessing trees. To date, about 20 male-sterile heterozygote plus-tree clones have been identified from more than 3,000 cedar plus-trees. These heterozygote clones will be a useful resource for developing male-sterile varieties.

4. Main players and stakeholders of tree breeding

The development of new varieties is mostly conducted by public organizations. Presence of private sector is minimum, which could be attributed to the necessity of long-term investment.

Major stake holders are seedling producers and prefectural governments (forestry division). Seedling producers organize association in prefecture basis and are principal users of bred forest reproductive material from those organizations. Forestry division of prefectural government, as an administrative and advising body to forest owners and seed/seedling producers, choice and/or develop variety which fit to local climate. They propagate superior varieties and SMTs for relevant seeds/seedlings producers.

5. Challenges and opportunities

In order to realize further and significant increase of productivity in forestry sector, the 2nd generation population has been formed in the national breeding program. Establishment of the 3rd generation population will be the next target as well as the development of the 2nd generation production population –SMTs. Building more propagation system including prefecture forestry experiment stations and private producers will also be indispensable.

Shortening of breeding cycle is another major challenge. It has already been shortened from 30 years to 15 years by research on age-age correlations. From now on, simultaneous development of growth performance and other characters such as male strobilus amount will be required, and contribution to mitigation and more adaptation to climate change will be pursued. To deal with them, further accelerated breeding technique utilizing genome information will be important. Building genome information infrastructure and more precise phenotype evaluation of corresponding trait will be demanded.

Chapter 10. Management of forest genetic resources

1. Management of forest genetic resources in Japan

In Japan various local varieties have been used in traditional plantation forestry. A chief example is cutting cultivars of Japanese cedar *C. japonica* in Kyushu district (southwestern main island), where tens of clonal local varieties are still popular. From Edo period (17 and 18 century) established traditional forestry areas were formed all over the country. Examples of the notable area are: Kesen-numa, Kaneyama, Yamizo, Nishikawa, San-mu, Tenryu, Yoshino, Hita and Obi, from northeast to southwest. Each area boasted its original variety of specific wood quality. Kesen cedar has light color and fine skin, San-mu cedar has fine straight year rings and fits for joinery work, Yoshino cedar has very straight and tight year rings and fit for sake barrel making, Obi cedar has coarse year ring and bendable, suitable for shipbuilding. In the meantime, shortage of reproduction material became serious in 1930s induced circulation of inferior seeds of unknown origin in domestic market. This prompted legislation of the Forestry Seeds and Seedlings Act (FSSA) to establish quality mother tree designation and protection, as well as seeds/seedlings transfer restriction for climate adaptability.

For the sake of successful afforestation, seeds and seedlings of *C. japonica*, *C. obtusa*, *P. densiflora* and *P. thunbergii* are subject to transfer restriction stipulated in FSSA. For example, *C. japonica* seedlings produced in warmer, less snowy region should not be shipped to cooler, snowy region for forestry planting. The regulation is based on traditional silvicultural and biogeographical knowledges, and recent forest genetic research supports this restriction as borders of genetic population structure were consistent with, or at least not contradict to, the distribution restriction by the Act.

There is no particular legal restriction of transfer nor planting for other tree species. However, the FFPRI issued a warning on the risk of outbreeding depression by genetic contamination across genetic population for 10 domestic tree species, based on genetic structure of natural population identified through nuclear DNA and organelle DNA analysis.[46] In line with this, a guideline was published to show the need for genetic consideration for seedling transfer of 43 tree species (including 10 species above).[27]

2. Consequences of changes in the forest sector for forest genetic resources

Afforestation policy on degraded forests during 1960s and 1970s and transition from hardwood natural (fuel) forest to coniferous timber forest founded vast planted forests up to deep mountain areas, especially in western Japan where private owned forest prevails. However, as wood price declined in 1980s and profitability of plantation forestry reduced, the Government shifted forest policy towards mixed forest management in remote mountain areas as stated in the national Forest and Forestry Basic Plan, while keeping promoting plantation forestry in areas where better management condition as mild slope and enough road infrastructure allows sustainable management. The mixed forest policy is addressed to approximately 1/3 of the plantation forests.

3. Needs, challenges and opportunities for improving forest genetic resources management

As for plantation forestry, use of the SMTs-origin seedlings is recommended in the context of both better productivity in forestry and contribution to climate change mitigation, as stated in Chapter 9. The Government of Japan set a target to raise the ratio of such seedlings to be planted to 90% by 2050. Also, for the sake of resolving pollen allergy issue, transition in *C. japonica* and *C. obtusa* planted forests from ordinary varieties to no- or less- pollen varieties is anticipated, as they occupy almost 30% of total forests in Japan. To cope with such obvious needs, enlargement of breeding material collection is crucial. As stated in Chapter 6 and 7, FTGB continue to advance collection, keeping and trait evaluation of the useful materials.

As for forest genetic resources in natural forests, development threats or transition threats are not obvious as stated in Chapter 4. However, the preservation of the extant relict small populations for some tree species is an urgent challenge. In such cases genetic diversity of the populations is likely to decline and number of individuals is to shrink. All the while, recent genetic study revealed regional genetic structure and genetic divergence in a number of widely distributed tree species over the country. Distinction between northern population and southern population, and/or the Pacific Ocean population and the Sea of Japan population were clearly identified. It is advised transferring seeds/seedlings across the population should be avoided in order to keep genetic structure, diversity and adaptation to climate, as referred to in Chapter 5 and 10.

Part 5: State of capacities and policies

Chapter 11. Institutional framework for the conservation, use and development of forest genetic resources

1. Legislations, regulations, institutions, policies and strategies related to management of forest genetic resources

(1) The outlook of laws and institutions concerning forest genetic resources are as follows; Conservation of forest genetic resources is propelled under the Forest Act, the Nature Conservation Act, the Act on the National Forest Management Law, etc., and administrative institution as FTGBP and Protected Forest of national forest management. They are referred to in Chapter 2 and 6.

Development of forest genetic resources had started in 1954 under national Forest Tree Breeding Program embarked by tree breeding stations of national forest management body of MAFF. Now it is authorized by the National Policy on Research and Development in Forest and Forestry established by MAFF, and implemented by FTBC, an independent administrative body, and prefectural forest research organization. It's stated in Chapter 9.

Use of forest genetic resources are mainly governed by FSSA. Besides transfer restriction on seeds and seedlings referred in Chapter 10, the Act stipulates designation of quality seed source, regulations on production, distribution and labelling of seeds/seedlings and registration/notification system for producers/distributors.

(2) Institution and policy for production and distribution of forest reproductive material

Production and distribution of forest reproductive material is regulated by FSSA. The law stipulates: i) designation of seed/scion source area, ii) registration of seed/seedling producers, iii) labelling, iv) certification of seeds/seedlings and v) restriction of destination stated in Chapter 10. These regulations focus on securing quality and credibility of seeds/seedlings in their production, trade and labelling. It is based on the recognition that it is very important to secure accuracy of information on such imperceptible features from appearances provenance, variety, winter tolerance etc., which affect future forest harvest., Together with, difficulty of recovery of loss in survival/growth/harvest/healthiness that would be proved only after planting and considerable long growing period, and difficulties of tree replacement once planted, are rationale of this Act.

i) Designation of seed/scion source area

Trees stands considered to be a source of excellent seed or scion may be designated by MAFF or the prefecture governors. Seed/seedling producers are asked to use such sources in collecting reproductive material. To date, more than 5 thousand seed/scion sources for 5 major silvicultural species are designated, as reported in electronic formats.

ii) Registration of seed/seedling producers

Registration to prefecture government is mandatory for all seed/seedling producers. Any breaching to this law may bring revocation of the registration, which lead to prohibition of their business.

iii) Labelling obligation and requirements in distribution

Seed/seedling producers must put a label showing tree species, name and address of the producer, place of seed/scion collection, type of designated seed/clone source and place of seedling nursery when shipping. Distributors must display the same information when they open or change packages and redistribute. Breach to these provisions (deceiving indication, etc.) will incur fine and may lead to revocation of registration.

iv) Certification of seeds/seedlings

Official certificate of seed/seedling source is available by application. MAFF or prefectural official may give the certificate by witnessing collection and packaging of the seeds/scions.

v) Restriction of destination in seed/seedling shipment

The MAFF designate seed/seedling distribution area according to producing areas in terms of climatic adaptability of the seeds/seedlings. Seed/seedling producer or distributor must not ship seed/seedling to the destination other than these distribution areas.

Such regulations are applied to domestic seed/seedling production and distribution under the prefecture governments' administrative and technical guidance. [43)]

2. Main institutions/stakeholders dealing with forest genetic resources and their responsibilities

The main institutions/stakeholders dealing with forest genetic resources and their respective roles are as follows;

i) MAFF: deals overall policy on forestry genetic resources, especially for breeding and use.
ii) FTBC, a division of national research organization FFPRI, plays a central role in developing new varieties especially the next generation of silvicultural species, as well as in collecting breeding material and preserving rare forest genetic resources.
iii) FFPRI engages in ecological and genetic research of forest tree species and of endangered species conservation.
iv) Forestry research organizations had been established in all prefectures and play a major role in propagating developed varieties to provide to seed/seedling producers, as well as developing regional new varieties and ecological/genetic research of local forest genetic resources.
v) Private seed/seedling producers provides all of forestry seedlings planted in forests. They organize associations on prefecture basis and act as main components of supply side players in regional reproduction material matching mechanism.
vi) Local forestry associations (usually plural associations are organized in a single prefecture) and Regional National Forest Management Office (usually covers national forests located in plural prefectures) under the Forestry Agency are major seedling users and participate in the coordination mechanisms as demand side players.
vii) Forestry divisions of the prefecture government are in charge of policy administration and technical extension to seed/seedling production and distribution sector, empowered by FSSA. They are also positioned as local organizer to coordinate all stakeholders stated above.

3. National coordination mechanism

In order to make seedling production meet domestic demands, regional meetings are organized every year by the prefecture governments and regional national forest offices as referred to in Chapter 8. Producers (breeders and seed/seedling providers) and consumers (forestry associations, national forestry offices) discuss coming years' production/consumption matching. Domestic production surplus and deficit for domestic demand are avoided this way.

4. Needs and opportunities for institutions on forest genetic resources

Silvicultural reproductive material had been largely coming from local source including designated seed/scion source in the law above. However, since government-lead science-based breeding program took off, it is becoming a mainstream of source of reproductive materials, as mentioned in Chapter 8. Now the program-based seedlings make approximately 70% of total seeds/seedlings planted in Japan.

The current largest driver of such stream should be climate change mitigation policy calling for silvicultural measure to encourage use of planting material of higher growth and better wood quality to contribute to maximum carbon fixation in the plantation forest. In 2013, the Act on Special Measures concerning Advancement of Implementation of Forest Thinning was enacted. It promotes use of SMTs origin seedlings in afforestation programs - the second generation silvicultural planting materials. Based on this Act, MAFF designate excellent mother trees - SMTs - of such planting material. The FTBC and local governments take every effort to develop and promote such mother trees as stated in Chapter 9.

Chapter 12. International and regional cooperation on forest genetic resources

1. Recent international cooperation activities

Japan has involved in overseas cooperation activities in tree breeding with a number of countries through cooperation framework as JICA and ITTO. Examples are:

i) Fast growing tree species breeding program in Indonesia
ii) Acacia hybrid breeding in Vietnam (collaboration with private company)
iii) Improvement of teak nursery practice in Myanmar
iv) Drought tolerant tree species breeding in ASAL in Kenya

2. Benefits from international cooperation activities

Chief benefits derived from overseas cooperation is a relationship with the beneficiary country and a comprehensive knowledge on the situation and challenges the beneficiary country is facing in the field of development/conservation of forest genetic resources. Such relationship and knowledge are quite useful for planning future contribution to the sustainability in the developing countries and consequently to the global issues. The human relationship with administrative and/or leading forest sector people is another privilege, which helps us to retain global point of view when dealing with administrative and/or research and development work on cooperation on forest genetic resources. Furthermore, developed genetic resources of excellent property would, in case imported to Japan, contribute to material procurement stability in domestic wood industry.

3. Challenges and opportunities for strengthening international cooperation

Human resource to provide technical assistance should be equipped with enough technical knowledge and research capacity for forest genetic resources. Such personnel is often limited and/or basically occupied with domestic development and conservation needs. Human and financial allocation to forest genetic resource in research and/or administrative sector should be reinforced.

Part 6: Challenges and opportunities

Chapter 13. Recommended actions for the future

Forest genetic resources in Japan had been under heavy human pressure until several decades ago. Current circumstance is much better, since fuel revolution removed fuel wood harvest pressure, trade liberalization of agricultural products lowered farmland development needs helped hills and mountains keep away from reclamation. As a result, forest area has not marked significant reduction for more than 50 years.

In the aspect of use and development of forest genetic resources, carbon absorption in the forests and fixation in HWP, especially in buildings where use of wood enables long-term carbon storage, as well as a mitigation effect derived from substitution of other construction materials, will continue to be one of the chief needs for the forest genetic resources. It would highlight the growth superiority of coniferous silvicultural species against most temperate hardwood species. SDGs calls for more human friendly living environment and use of wood products is, and will be, one of the solutions, leading to achievement of the low carbon society.

This means the coniferous planted forests will get more importance as highly productive and workable materials. In this context, sustainability of silviculture will be highlighted, which requires, for example, varieties of greater early growth for reducing weeding work to realize higher labor productivity and to cope with labor force shortage in the nationwide population decrease. Avoiding mammal damage by quicker growth will be also important. Less pollen producing varieties are expected to mitigate the huge allergy loss to economy and life of the nation. These anticipated characters are crucial for continuous utilization of planted forest resource in this country for the future, and for the promotion of replanting which will be a key for the sustainable use of such useful resources. Furthermore, pine wilt resistant variety will be a core measure to keep shelter and tsunami-mitigating function along the coastline. In developing these varieties and securing genetic diversity, broad collection of breeding material is indispensable.

Meanwhile, coniferous planted forests themselves had been more or less created for soil erosion control and disaster prevention. Accordingly, they cover so much part of the land – approximately 40% of all forests and almost 30% of the national land – in some areas up to the deepest part of mountain. Additional expansion of planted forest is no longer of priority, and planting regeneration should be pursued in areas with better access and more favorite operation condition. Other types of planted forests may be induced to mixed forest with partial harvest, in terms of improving biodiversity and keeping soil stability. Natural forests with hardwood tree species will be re-evaluated as a place for biodiversity, water resource conservation, recreational activities and remote work.

As for conservation of forest genetic resources, large scale forest shrink will not be likely as above. Nevertheless, climate change which may proceed faster than potential of natural adaptation - genetic divergence or migration of population - will be a major risk for irreversible changes, followed by change in occurrence/spread mechanism of forest pests and increasing deer foraging pressure, to sustainable management of forest genetic resources. It is obvious especially in case of small population sized species. Continuous monitoring of species distribution and its genetic situation are essential. *In situ* preservation like establishment of new protected area and/or *ex situ* preservation by the relevant organization should be implemented as necessary.

Systematic and comprehensive information and easy access to forest genetic resources is a prerequisite to the preventative/ad hoc measures above. In Japan traditional knowledge on forest genetic resources is abundant as the nation has long used tree species in various way. Meanwhile, systematic set of information on species distribution with academic or administrative background are limited, namely Phytosociological Relevé Database (PRDB) of forest vegetation by FFPRI,[44] administrative forestry inventory for silvicultural and popular tree species by respective prefectural government and nationwide statistical stock estimation by tree species carried out by Forestry Agency. These databases have been utilized in research works on effect of climate change. Information on population - genetic diversity and geographic divergence - has been so far consolidated and published as illustrative work for 43 native tree species.[27] More accumulation of information on species distribution and population genetic status will be anticipated.

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