THE STATE OF THE WORLD's

FOREST GENETIC RESOURCES

COUNTRY REPORT

UNITED STATES OF AMERICA

This country report is prepared as a contribution to the FAO publication, The Report on the State of the World's Forest Genetic Resources. The content and the structure are in accordance with the recommendations and guidelines given by FAO in the document Guidelines for Preparation of Country Reports for the State of the World's Forest Genetic Resources (2010). These guidelines set out recommendations for the objective, scope and structure of the country reports. Countries were requested to consider the current state of knowledge of forest genetic diversity, including:

- Between and within species diversity
- List of priority species; their roles and values and importance
- List of threatened/endangered species
- Threats, opportunities and challenges for the conservation, use and development of forest genetic resources

These reports were submitted to FAO as official government documents. The report is presented on www. fao.org/documents as supportive and contextual information to be used in conjunction with other documentation on world forest genetic resources.

Country Report on the State of Forest Genetic Resources
United States of America

June 6, 2012 (Modified March 7, 2012)

Country Report on the State of Forest Genetic Resources – United States of America

EXECUTIVE SUMMARY

The forest land area in the United States of America has been relatively stable for the past 7 decades and represents about one third of the land area in the 48 continuous states. Approximately 25% of these forests are considered in some state of reserve status. The western forest ecosystems have a larger percentage of land area in protected status since the federal government owns a much larger percent of lands in the West. Despite the stability of the forest land base and the amount of forest is reserve status, there are threats to the nation's *in situ* forest genetic resources from invasive alien species, climate change and fragmentation.

Among forest-associated plant species, less than 1 percent has been determined to be extinct. However, 57 trees or trees/shrubs are officially listed as threatened or endangered by the US Department of Interior Fish and Wildlife Service. Most of these listed species are tropical with 35 from Hawaii and 13 from Puerto Rico and/or the US Virgin Islands. As required by law, these listed species have restoration plans that are in some state of implementation. Federal land management agencies also strive to conserve species that are considered "at risk". In addition, federal agencies manage for native ecosystems; thereby providing aspects of *in situ* conservation on their land base; which represents one third of all forest land in the US.

Ex situ conservation efforts within the US are extensive. Specific conservation collections are done by a number of organizations, including: the Center for Plant Conservation, the USDA Agricultural Research Service U.S. National Plant Germplasm System, the US Department of Interior (DOI) Bureau of Land Management Seeds of Success program, and the US Department of Agriculture (USDA) Forest Service. Breeding and restoration programs, predominantly housed in federal agencies and universities, represent over 150 different *ex situ* collections which include over 100 species of trees and tree/shrubs.

INTRODUCTORY NOTE: This report is the USA Country report that will provide information for FAO's report on the State of the World's Forest Genetic Resources. The layout of this report conforms to the format requested by FAO. Much of the information was taken directly from a number of existing published documents, specifically:

National Report on Sustainable Forests – 2010 (USDA 2011)
http://www.fs.fed.us/research/sustain/2010SustainabilityReport/documents/2010_SustainabilityReport.pdf

Forest Resources of the United States 2007 (Smith and others 2009)
http://www.fs.fed.us/nrs/pubs/gtr/gtr_wo78.pdf

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INTRODUCTION TO THE US AND US FORESTRY SECTOR

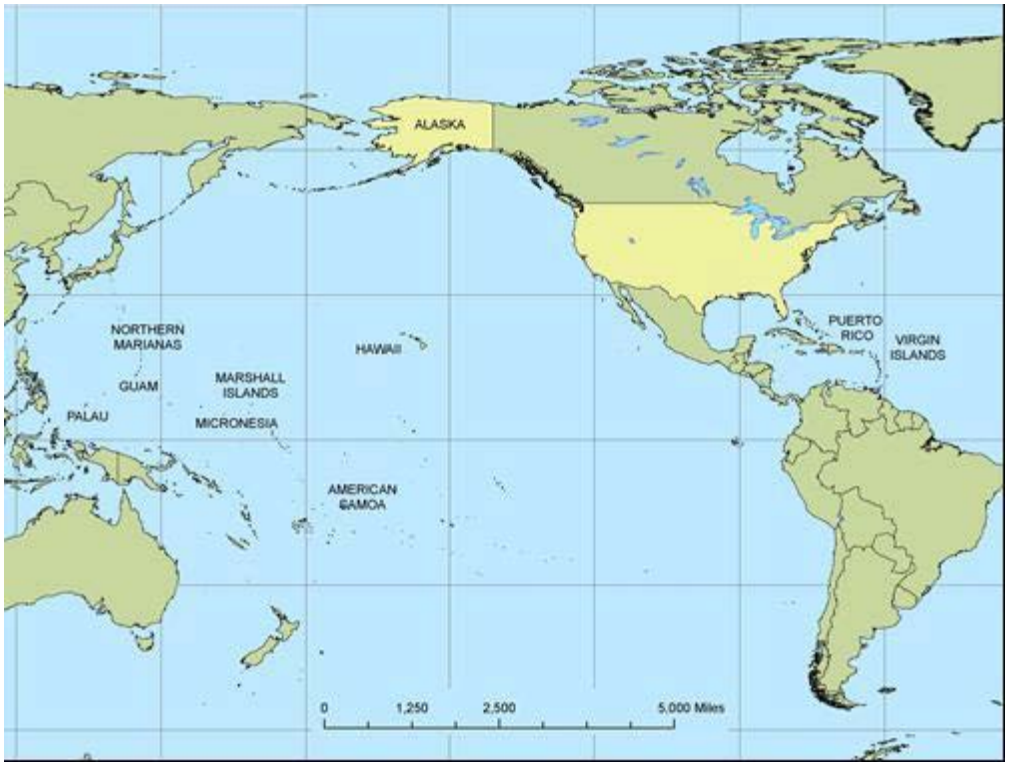
The main landmass of the United States, containing 48 of the 50 States, is situated in mid-North America (Figure 1), has a central plain with hills and low mountains to the east and rugged mountains and wide valleys to the west. The State of Alaska, on Canada's western border, is dominated by Pacific and Arctic mountains, a central plateau, and the Arctic slope.

The U.S. Caribbean Islands are composed of Puerto Rico and the U.S. Virgin Islands. In general, the Caribbean Islands are a 4,000-km arc of islands, tectonically uplifted from the sea floor separating the Atlantic Ocean from the Caribbean Sea. Low-lying islands often are capped with limestone from ancient coral reefs, and other islands exhibit volcanic activity that has pushed up steep peaks that divert the moisture-laden north-easterly trade winds upward, greatly increasing rainfall.

The U.S. affiliated Pacific Islands include American Samoa, Guam, the State of Hawaii, the Republic of the Marshall Islands, the Federated States of Micronesia, the Commonwealth of the Northern Mariana Islands, and the Republic of Palau. These islands span a vast and diverse area, beginning with Hawaii, 4,000 km west of the U.S. mainland, and extending to Southeast Asia. Land masses vary widely and include small coral atolls, small sand islands, moderate-sized islands of mixed limestone and volcanic substrates, and large, high-elevation, volcanic islands.

This report presents data only for the 50 States.

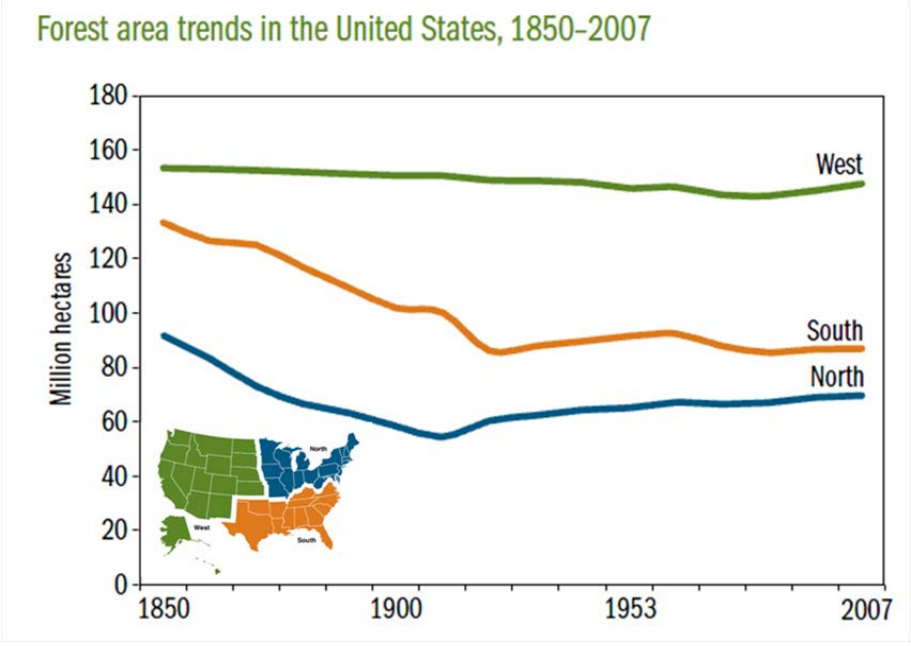
Figure 1. *Geographic location of the United States, territories and freely associated islands.*



Forest Land Area

From the broadleaved forests of the East to the conifers of the West, the United States continues to benefit from a large and diverse inventory of forests distributed across the Nation. Total U.S. forest area in 2010, as defined in the National Report on Sustainable Forests—2010 (USDA 2011), amounts to 304 million hectares, or about one-third of the Nation's total land area (Figure 2). Since the beginning of the past century, the size of this inventory has been relatively stable, and the forests it represents remain largely intact. This stability is in spite of a nearly three-fold increase in population over the same period. It is in contrast with our more distant past, where nearly 300 million acres of U.S. forest were lost between the advent of European settlement and the beginning of the 1900s; in fact two thirds of that total occurred between 1850 and 1900. The forest area's stability during the past century is partially the result of stable ownership patterns and land-use designations. For example, 14 percent of U.S. forests are currently protected under wilderness or similar status, and this number has changed little since last reported in 2003 (although the increased use of protection easements and similar instruments on private lands would indicate that the total amount of forest under some form of protection is increasing). A more important factor in maintaining overall forest area in America, however, is the fact that throughout the past century, losses of forest land in some areas (particularly those adjacent to growing urban areas) have been offset by gains in others (abandoned agricultural lands returning to forest, for example).

Figure 2. *Forest area trends in the United States, 1850-2007 (from USDA 2011).*

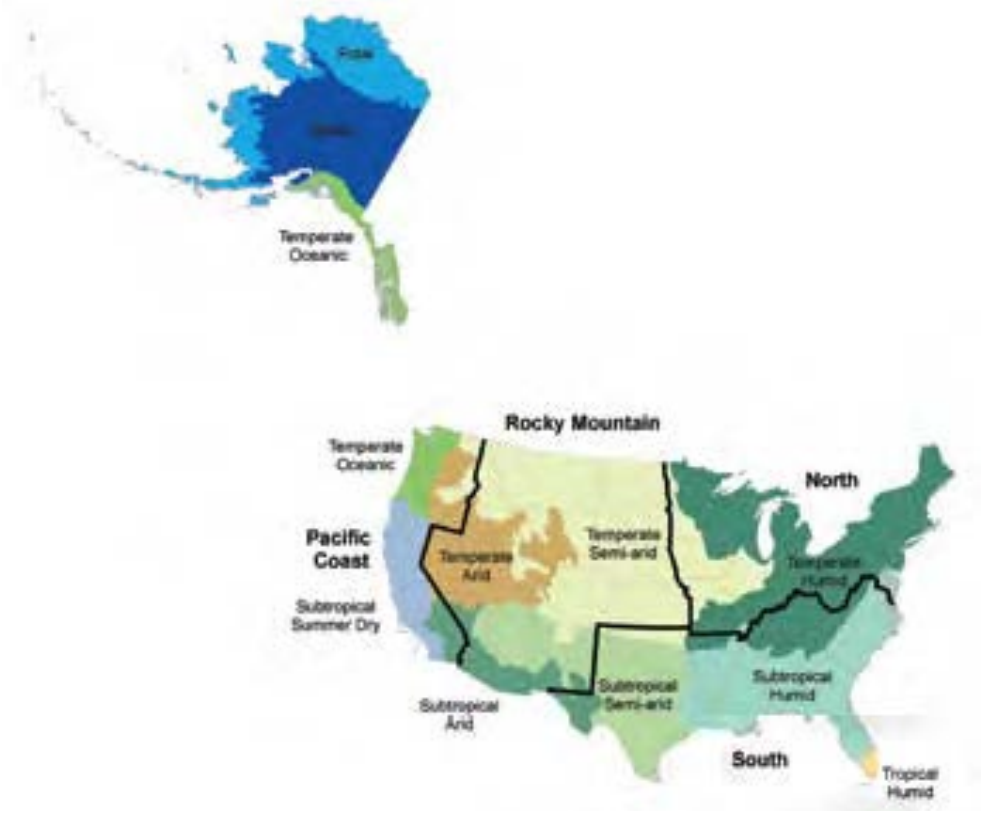


Although the size of forest area may be relatively stable, other indicators paint a more troubling picture about forest sustainability. Common knowledge, data on urban development and land (Theobald 2005), and anecdotal evidence strongly suggests that the area of forests impacted by fragmentation has been increasing at a steady rate. Impacted areas include lands on the fringes of major population centers and in rural areas where growth in smaller centers and in the number of second homes continues to drive development and thereby fragmentation. This conclusion is supported by the information on the impacts of housing development on forest area.

Forest Types of the US

Forests in the United States are diverse, reflecting the wide diversity of climate, physiography, geology, soils, water, and human intervention. The following discussion from Smith et al. (2009), frames the 2007 Forest Inventory and Analyses data in the context of Bailey ecoregions (Bailey 1989) and describes the forest cover types (Eyre 1980) of the conterminous United States both by Resources Planning Act geographic region and major ecoclimatic zones (see Figure 3).

Figure 3. *Reporting zones for the Resources Planning Act and major ecoclimatic zones for the US (from Smith et al. 2007).*



Eastern U.S. forests stretch from the Atlantic Ocean west to the Great Plains (see Figure 3). The North region is predominantly in a temperate humid ecoclimatic zone. Distinct climatic seasons are characteristic of this zone—seasons in which temperatures and precipitation show strong annual cycles. Forests of this zone comprise both broadleaf deciduous and evergreen trees. Softwood forests and mixed softwood and hardwood forests extend along the entire length of the northern parts of this zone, where summers are cool and winters cold. In the middle and southern reaches of this zone, forests are dominated by tall hardwood species that provide a continuous dense canopy in summer but shed their leaves completely in winter.

The northernmost forests of the temperate humid zone (Figure 3) are heavily forested with second- and third-growth forests. The area is dominated by northern oak-hickory (*Quercus - Carya*) and maple-beech-birch (*Acer-Fagus-Betula*) forests on the uplands and by elm-ash-cottonwood (*Ulmus-Fraxinus-Populus*) forests in the bottomlands (figure 4). The southernmost reaches of these forests run down the crest of the Appalachian Mountains. Red maple (*Acer rubrum*) is a common early-to-mid-successional transition species to the north, giving way to yellow-poplar (*Liriodendron tulipifera*) in the southern portion of this zone. Introduced pathogens have forever changed the diversity of northern forests. For example, chestnut blight nearly eliminated American chestnut (*Castanea dentata*), and Dutch elm disease severely diminished American elm (*Ulmus americana*) populations. Before the accidental introduction of Dutch elm disease, American elm was the most planted urban street tree in the United States. More recent introductions, such as beech bark disease, emerald ash borer, Sudden Oak Death disease, and dogwood anthracnose, are also substantially influencing the composition of North American forests.

The South region is predominantly in a subtropical humid climatic zone (figure 3) except for an area that covers most of Kentucky and Tennessee, which is in a temperate humid zone, and a small area in southern Florida, which is in a tropical humid zone. The subtropical humid zone in general is characterized by the absence of very cold winters. Forest is the natural vegetation of large areas here, with much of the sandy coastal region of the Southeastern United States covered by a second-growth forest. Large areas of pine in plantation and natural stands occur throughout the coastal plain and piedmont regions, along with southern oak-hickory (*Quercus-Carya*) on upland hardwood sites and oak-gum-cypress (*Quercus-Liquidambar-Cupressus*) in the bottomlands. Oak-pine (*Quercus-Pinus*) mixtures are common at the northern and western fringes of the southern forest (figure 4). Agriculture is prominent in the coastal plain and in the bottomlands along the rivers, where the productivity of rich bottomland soils historically have led to considerable forest clearing. The forests of the South region account for 30 percent of the unreserved forest area of the United States and 27 percent of all forest land.

Forests of the western coterminous States stretch from the Great Plains west to the Pacific Ocean. The predominantly arid forests of the Rocky Mountain region contrast to the predominantly temperate oceanic and Mediterranean-like forests of the Pacific Coast.

The Rocky Mountain region predominantly spans the temperate arid, subtropical arid, subtropical semiarid, and temperate semiarid climatic zones (Figure 3). This region stretches from prairies in the

east to extensive mountains and plateaus separated by wide valleys in the west and dry deserts in the southwest. Forests of the region cover about 20 percent of the land area and are diverse and variable

Figure 4. *Major forest types of the U.S.*

depending on elevation and moisture availability. The higher elevations support subalpine fir (*Abies lasiocarpa*) , lodgepole pine (*Pinus contorta*), and Engelmann spruce (*Picea engelmannii*). The middle elevations and slopes include interior ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), lodgepole pine, western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), and aspen (*Populus* spp.). Within this forest cover, the main environmental contrasts in the types of vegetation are not simply related to elevation but to a combination of elevation and topography. We may locate the main forest types on an elevation-topographic gradient. Although spruce dominates the lower plateaus to the north, shrub vegetation is more common in the drier south.

The higher elevations of this region contain forests of Interior Douglas-fir, ponderosa pine, lodgepole pine, and aspen. The lower elevations are dominated by sagebrush (*Artemisia* spp.) and juniper (*Juniperus occidentalis*), and low desert areas contain a variety of cacti and shrubs. Interior ponderosa pine forests are found to some extent throughout the Rocky Mountain region (Figure 4). Most ponderosa pine is found in Arizona, Colorado, Idaho, Montana, New Mexico, Wyoming, and the Black Hills of South Dakota.

Most of the other softwood forests of the Rocky Mountain region are confined to Idaho and Montana and include western white pine (*Pinus monticola*), hemlock-Sitka spruce (*Tsuga - Picea sitchensis*), western redcedar (*Thuja plicata*), and larch (*Larix occidentalis*) forest types. Combined, these types make up only 2 percent of all the forest of the region. Hardwood forests cover 10 million acres in the Rocky Mountain region, or about 7 percent of all the region's forest land. Generally found in small patches or groups and along streams, quaking aspen (*Populus tremuloides*) and cottonwood (*Populus fremontii*) are prominent hardwood species in the western part of the region. On the eastern prairie, hardwood forests are predominantly elm-ash (*Ulmus-Fraxinus*) or cottonwood-willow (*Populus-Salix*) stringers along rivers and streams. Scattered bur oak (*Quercus macrocarpa*) and hackberry (*Celtis occidentalis*), as well as hickories (*Carya* spp.), may be found on the upland sites in eastern Kansas.

The climate zones of the Pacific Coast region are a mix of temperate oceanic in coastal Oregon and Washington, subtropical summer dry in western California, and temperate arid, subtropical arid, and temperate semiarid in the eastern portions of the region.

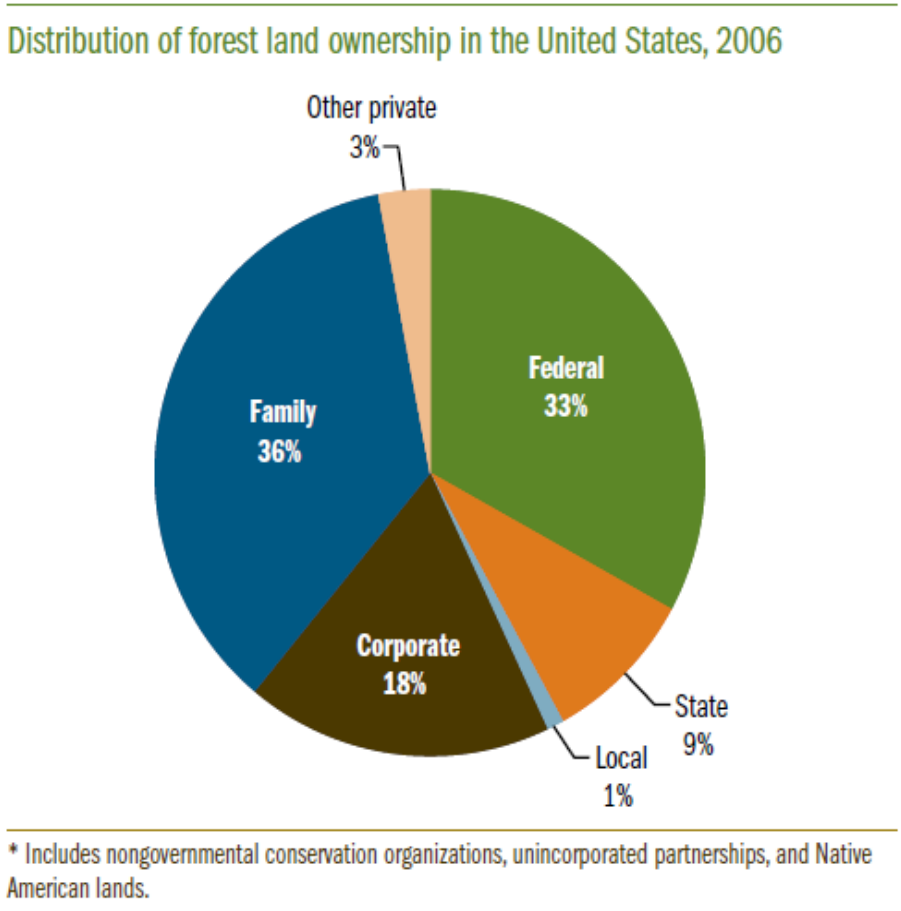
The temperate oceanic climatic zone is situated on the Pacific coast and comprises roughly the western third of Oregon and Washington. This coastal zone receives abundant rainfall from maritime polar air masses and has a rather narrow range of temperature because it fronts on the ocean. Natural vegetation of the temperate oceanic climate of North America is needleleaf forest. In the coast ranges of the Pacific Northwest subregion, Douglas-fir (*Pseudotsuga menziesii*), western redcedar (*Thuja plicata*), and spruce (*Picea sitchensis*) grow in magnificent forests. The high snowcapped mountains have a well-marked subalpine belt. Important trees here are mountain hemlock (*Tsuga mertensiana*), subalpine fir (*Abies lasiocarpa*), whitebark pine (*Pinus albicaulis*), and Alaska-cedar (*Cupressus nootkatensis*). The alpine zone has a rich flora of shrubs and herbs. North Pacific coast forests are dominated by mountainous topography bordered by coastal plains along the ocean. Altitude is critical to forest composition, ranging from mild, humid coastal rain forests to cool boreal forests at higher elevations. Coastal forests include western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*),

Douglas-fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sitchensis*), redwood (*Sequoia sempervirens*), and red alder (*Alnus rubra*). Higher elevations have mountain hemlock and fir.

Forest Ownership

Over half of the forest land in the United States is privately owned and, of this, over half is owned by families and individuals. The other 44 percent of the forest land is controlled by Federal, State, and local governments (Figure 5). Land ownership differs widely by region; in the West 70 percent of the land is publicly owned, while in the east, 81 percent of the land is privately owned (Figure 6).

Figure 5. *Distribution of forest land ownership in the U.S.*

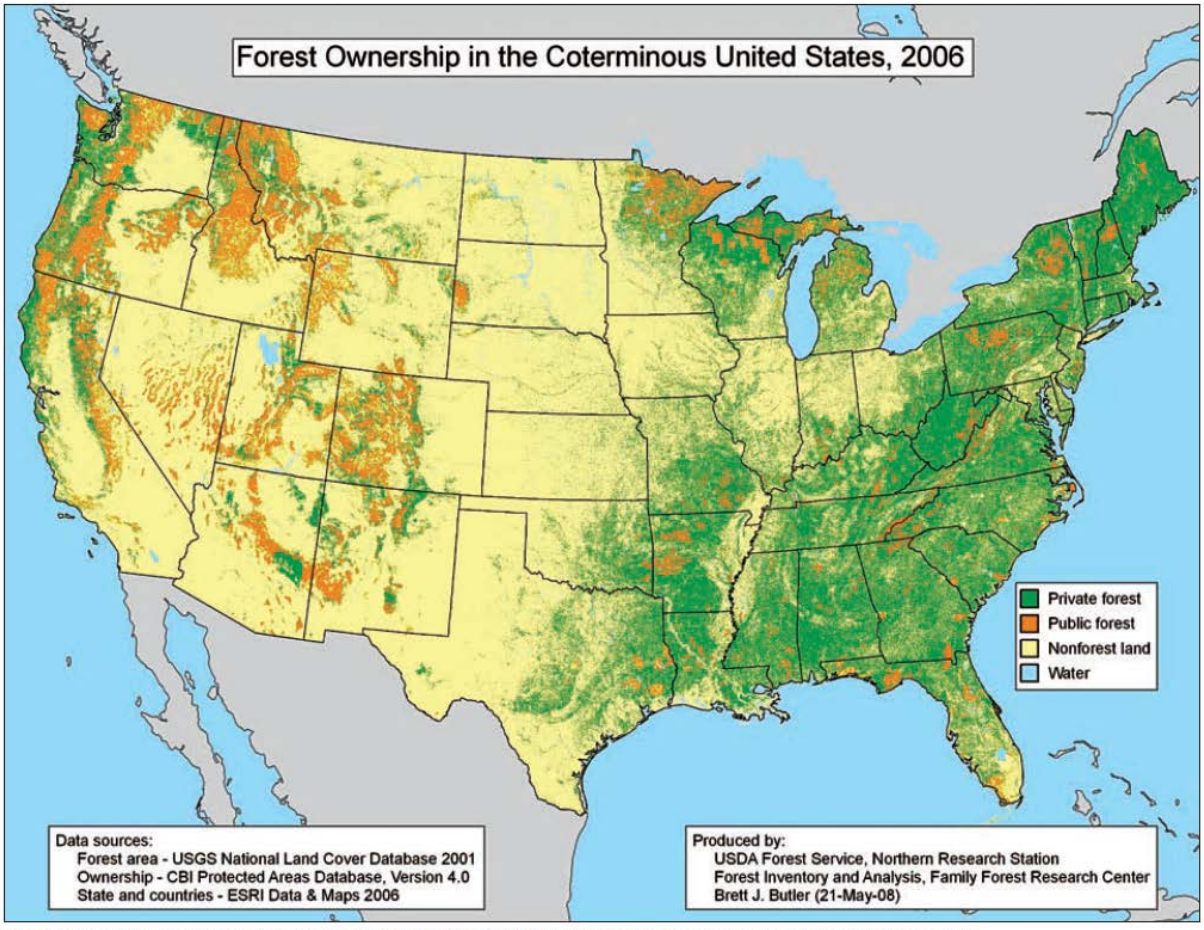


Forest Function and Growing Stock

Approximately 10% of US forests are considered in some state of reserve status (Table 1. IUCN Classes 1-5). The remainder is either production forest or multiple-purpose forest. Most forests are naturally regenerated, less than 12% are planted forests.

Forest volume has increased over the last two decades (Tables 2 & 3); even with a constant forest base, increasing population and overall increase in demand in forest products. While demand for wood

Figure 6. *Forest land ownership in the coterminous U.S.*



CBI = Conservation Biology Institute. ESRI = Environmental Systems Research Institute, Inc. USGS = U.S. Geological Survey.

Table 1. *Forest area of the US by designated function (from Global Forest Resources Assessment 2010 – Country Report – United States of America; Table 3.2.3,* http://www.fao.org/docrep/013/al658E/al658e.pdf*)*

Forest Function	**Year**		
	1987	**1997**	**2007**
Production:	**76,632**	**82,520**	**90,007**
All planted public and private	*10,305*	*16,274*	*35,363*
Corporate natural	*29,142*	*30,506*	*30,319*
National Forest System natural forest	*12,349*	*12,892*	*13,088*
Noncorporate natural forest	*24,792*	*22,848*	*21,236*
Conservation of biodiversity	**69,980**	**72,878**	**75,277**
Reserved forest, IUCN 1-5	*17,950*	*20,819*	*30,225*
Reserved forest, IUCN 6	*12,416*	*12,416*	*12,416*
Alaska unreserved natural	*39,176*	*38,663*	*30,369*
National Land Trust	*437*	*980*	*2,266*
Multiple purpose	**149,723**	**144,796**	**138,738**
TOTAL	**296,335**	**300,195**	**304,022**

products has increased with time, total wood removal from forests has decreased (Table 4), but imports have increased (Figure 7). Wood products production is declining relative to growing consumption, with increasing imports filling the gap. But note that the recent 2008 recession has disrupted long-term trends in consumption and trade. We are waiting to see if the old status quo reemerges.

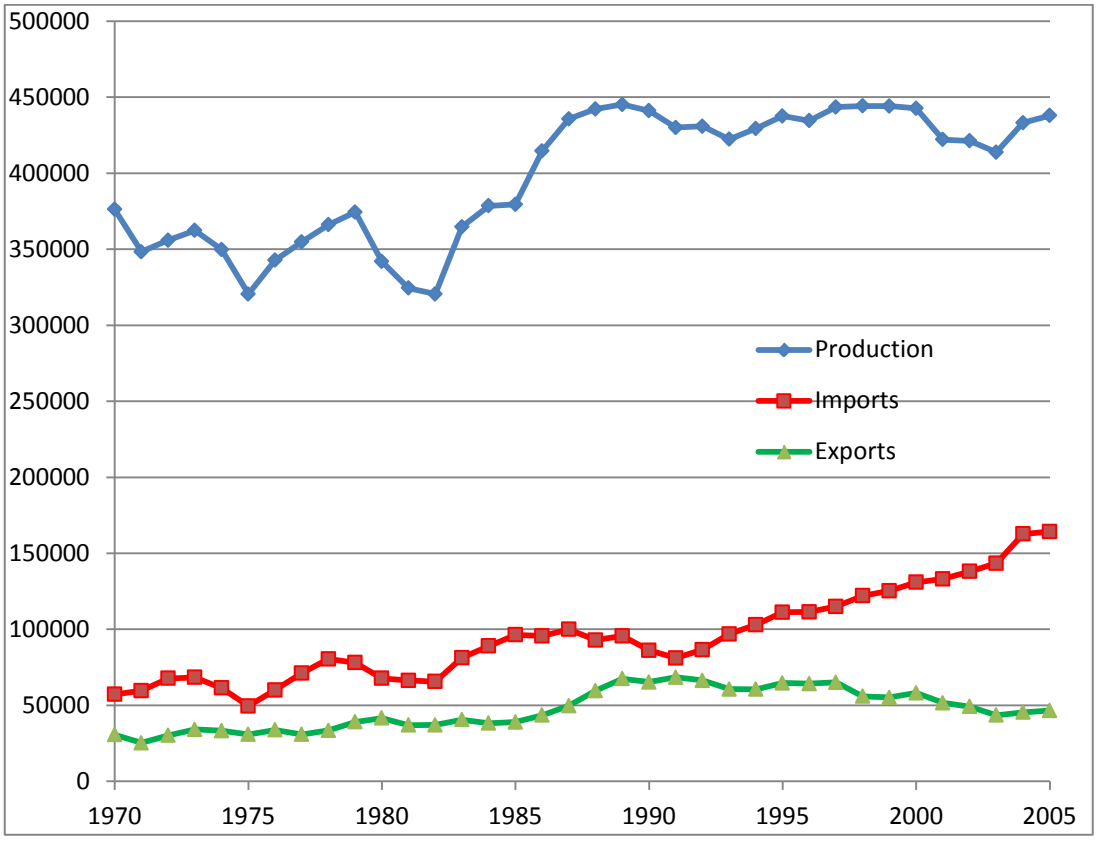
Table 2. *Forest Volume (million m³ overbark), from Global Forest Resources Assessment 2010 – Country Report – United States of America; Table 6.2.3*

FAO FRA category	**Year**		
	1900	**2000**	**2010**
Total Growing Stock	**38,832**	**40,993**	**47,088**
Coniferous	*28,258*	*27,050*	*34,282*
Broadleaf	*10,574*	*13,943*	*12,805*
Commercial species	**34,855**	**37,546**	**43,092**

Table 3. *Growing stock of the 10 most common species.*

Rank	**Species**	**Year**		
		1900	**2000**	**2005**
1st	*Pseudotsuga menziesii*	*4,523*	*4,775*	*5,296*
2nd	*Pinus taeda*	*2,875*	*2,869*	*2,817*
3rd	*Pinus ponderosa*	*1,865*	*1,969*	*1,899*
4th	*Tsuga heterophylla*	*1,540*	*1,626*	*1,564*
5th	*Pinus contorta*	*1,327*	*1,400*	*1,433*
6th	*Acer rubrum*	*1,127*	*1,312*	*1,614*
7th	*Quercus alba*	*1,059*	*1,118*	*1,234*
8th	*Liriodendron tulipifera,*	*851*	*898*	*1,043*
9th	*Quercus rubra*	*848*	*895*	*884*
10th	*Acer saccharum*	*769*	*812*	*1,147*
Remaining		**22,048**	**23,317**	**25,109**
Total		**38,832**	**40,993**	**44,040**

Figure 7. *Production, Imports and Exports of US round wood products, units = 1,000 m3 (from: Howard 2007, Table 5b).*



Chapter 1 – The Current State of Forest Genetic Resources

The United States continues to benefit from a large and diverse inventory of forests distributed across the Nation. Total U.S. forest area in 2010, as defined in the National Report on Sustainable Forests—2010, amounts to 304 million hectares, or about one-third of the Nation's total land area. Since the beginning of the past century, the size of this inventory has been relatively stable, and the forests it represents remain largely intact. The forest area's stability during the past century is the partial result of stable ownership patterns and land-use designations. A more important factor in maintaining overall forest area in America, however, is the fact that throughout the past century, losses of forest land in some areas (particularly those adjacent to growing urban areas) have been offset by gains in others (abandoned agricultural lands returning to forest, for example).

Although the size of forest area may be relatively stable, other indicators paint a more troubling picture about forest sustainability. Forest fragmentation, invasive alien species, native pathogens and insects, and climate change are all putting stress on the nation's ecosystems, putting genetic resources at risk. Numerous programs and agencies are striving to maintain healthy resilient forests, but despite management, some species and populations are in danger because of these increased stresses.

Forest fragmentation – Common knowledge and anecdotal evidence strongly suggests that the area of forests impacted by fragmentation has been increasing at a steady rate. Impacted areas include lands on the fringes of major population centers and in rural areas where growth in smaller centers and in the number of second homes continues to drive development and thereby fragmentation. This conclusion is supported by the information on the impacts of housing development on forest area.

Climate change is altering the physical and biological environments across the nation. There are many unknowns, but we can generally expect a warmer climate with more extreme climate events. As the environment changes, species interactions will change as species and populations migrate, expand or contract, and as species interactions (e.g., host-pathogen, plants-pollinators, etc.) are altered. Ecosystem composition will change as some species/populations adapt to their new settings and others migrate to where they are better-adapted. Some species may become extinct and some populations may become extirpated if they cannot adapt or migrate fast enough to a suitable habitat.

Wildland fires are increasing in size and intensity due to changing weather patterns and a history of fire suppression in ecosystems that are fire dependent. As a result, the need for restoration planting stock is also increasing. However, very few of the non-timber native plant species have locally-adapted, genetically-appropriate seed sources readily available, although native plant development programs are underway.

Insect populations in the US, Alaska and Canada are increasing to unprecedented densities as a result of longer growing seasons and warmer winters. The changing climate is increasing insect populations as longer, warmer growing seasons permit more annual insect generations, and warmer winters permit insects to expand upward in elevation and north of their historic ranges. Likewise, warmer climates can also create more favorable conditions for fungal diseases.

Globalization, the increased movement of organisms, has and will continue to bring new diseases, insects and invasive plants into the country. These "invasive alien species" continue to put forest and range species at risk, either through new diseases and insects, or through aggressive competitors which are displacing native species from our landscapes. The combined effects of climate change and increased pest and pathogen pressure has already negatively impacted the health, productivity and sustainability of the nation's forests and rangelands, and impacts are expected to increase over time.

Aukema et al. (2010) have summarized the accumulation of forest pests in the contiguous 48 states. More than 450 nonindigenous insects and at least 16 pathogens have colonized forest and urban trees since European settlement. Approximately 2.5 established nonindigenous forest insects per year were detected in the United States between 1860 and 2006. At least 60 of these insects and all 16 of the reported pathogens have caused notable damage to trees.

Mortality caused by insects and diseases was nearly 4.8 million hectares in 2008, up from 3.6 million hectares in 2000. Most of this mortality was caused by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins), an indigenous insect that has considerably expanded its activity and range due to warmer winters and longer growing seasons associated with climate change (USDA 2010).

This country report broadly describes the general condition of forest tree genetic resources and documents many of the *in situ* (on site) and *ex situ* (off site) efforts underway in the US to conserve these genetic resources.

Intraspecific genetic variation

Because of the wide ranges of many of the keystone forest species, intraspecific variation is typically found in every species since different environment conditions have applied different selection pressures over time. This leads to local adaptation that has been recognized for many decades, a primary example being the classic work of Clausen, Keck and Hiesey (1940). The basis for this consensus of local adaptation comes from a wealth of reciprocal transplant studies, representing all kingdoms of life, that provide strong evidence of adaptation to local environments in resident populations (Table 4; also see Antonovics and Primack 1982; Xie and Ying 1995; Linhart and Grant 1996; O'Brien and Krauss 2010; Hereford 2009; Johnson et al. 2010). While not all reciprocal transplant studies[1] show a home site advantage, many do.

Long-term provenance trials test different provenance collections over a variety of planting locations, and are analogous to reciprocal transplant studies in many ways and, in addition to documenting intra-species variation, can provide reliable information for determining the limits of seed movement and discern which seed sources suitable for planting locations because they evaluate seed sources over a long period of time. Numerous studies have been reported, with many dating back more than 50 years (see Munger and Morris 1937; Squillace and Silen 1962; Wakeley 1944). The wealth of provenance trials have demonstrated intraspecific variation for practically all timber species.

[1] Reciprocal transplant studies are where populations from different locations are planted together in each of the "home" locations to evaluate performance in the home ranges of those populations being tested.

Table 4. *Evidence from reciprocal transplant studies showing local sources as optimal or near-optimal (from Johnson et al. 2010). Additional studies are summarized in Hereford (2009).*

FAMILY	GENUS (common name)	SPECIES (reference)
Betulaceae	*Alnus* (alder)	*A. rubra* (Hamann and others, 2000)
Cupressaceae	*Chamaecyparis* (false-cedar)	*C. thyoides* (Mylecraine and others, 2005)
Fagaceae	*Quercus* (oak)	*Q. rubra* (Sork and others 1993)
Pinaceae	*Abies* (fir)	*A. grandis* (Xie and Ying 1993);
	Pinus (pine)	*P. contorta* (Ying & Hunt 1987; Ying & Liang 1994; Xie & Ying 1995; Wu & Ying 2004); *P. lambertiana* (Harry and others, 1983*); P. ponderosa* (Squillace & Silen 1962; Wright, 2007)*; P. taeda* (Frank 1951; Wakely 1944)

Genecology studies have been used as a method of mapping genetic variation across the landscape, predominantly in the Northwest. These are short-term, common-garden studies in nursery environments. The goal of these studies is to examine the variation of adaptive traits across the landscape. Adaptive traits are those related to traits such as growth rate, phenology, form, cold and drought tolerance. These traits provide measurable quantitative benefits to a plant in its native environment. Because the seed sources are all grown in a common environment, any difference among them is due to their genetic composition (and possibly epigenetic effects). If the genetic variation is correlated with physiographic or climatic variables of the seed-source locations, it provides evidence that the trait has responded to selection pressure and may be of adaptive importance. Over the past thirty years short-term studies have become the research tool of choice for mapping provenance variation in Northwest conifers. Variation patterns are not consistent among species, among regions, nor among traits. Although Northwest conifers all display clinal variation in all or part of their ranges, the amount and patterns of variation differs for each species. Similarly, the "distance" of separation needed to detect seed source differences differs for diverse of groups conifers sampled in the same region (Table 5, Rehfeldt 1994b). In this case "distance" is defined geographically (meters along an elevational gradient) and climatically (the associated change in number of frost-free days along the same gradient). In the example in Table 5, Rehfeldt (1994) describes Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*) as specialists because their populations appear to be adapted to relatively narrow niches. The opposite is true for two generalist species, western redcedar (*Thuja plicata*) and western white pine (*Pinus monticola*). Similarly, in the Southeast, geographic variation is more complex for loblolly pine (*Pinus taeda*) than for the other southern pines (Schmidtling 2001). Much of the genetic

Table 5. *Species differences in amount of environmental difference needed to show a genetic difference (from Rehfeldt,. 1994).*

Species	Elev. difference to find genetic difference	Frost-free days to find genetic difference	Evolutionary mode
Douglas-fir	200 m	18	Specialist
Lodgepole pine (*Pinus contorta* Dougl. ex Loud. (Pinaceae))	220 m	20	Specialist
Engelmann spruce (*Picea engelmannii* Parry ex Engelm. (Pinaceae))	370 m	33	Intermediate
Ponderosa pine (*Pinus ponderosa* P.& C. Lawson (Pinaceae))	420 m	38	Intermediate
Western larch (*Larix occidentalis* Nutt. (Pinaceae))	450 m	40	Intermediate
Western redcedar (*Thuja plicata* Donn ex D. Don (Pinaceae))	600 m	54	Generalist
Western white pine (*Pinus monticola* Dougl. ex D. Don (Pinaceae))	none	90	Generalist

Variation studies that have gone into determining seed transfer zones for the Southeast and Northwest are summarized in Schmidtling 2001, Randall 1996, and Randall and Berrang 2002.

More recently there has been a surge in studies that examine variation in neutral molecular markers. A summary of isozyme studies in forest trees can be found in Hamrick et al. (1981).

In conclusion, there is evidence of some level of clinal and/or ecotypic variation in all forest tree species examined. Therefore, gene conservation activities must address within-species variation.

Forest Tree Species at Risk

Among forest-associated plant species in the United States, less than 1 percent have been determined to be presumed or possibly extinct (USDA 2011). However, at least 57 trees or trees/shrubs are officially listed as threatened or endangered (T&E) by the US Department of Interior Fish and Wildlife Service (Table 6). Most of these species are tropical: 35 from Hawaii (HI), 13 from Puerto Rico and/or the US Virgin Islands (all labeled PR in Table 6).

There are forest tree species not on the official T&E list that are suffering considerable mortality from indigenous and exotic diseases and insects; but they have not lost sufficient numbers of trees to be officially listed as threatened or endangered by the Fish and Wildlife Service. Some of these "not-listed" species, such as *Pinus albic*aulis (whitebark pine), are "candidate" species being considered for official listing as threatened or endangered. Tree species could be at higher risks than many plants because of the long time needed for most trees to reproduce. Species found on islands, "sky islands" / mountain tops and other specialized niches are especially of concern.

A more thorough listing the status of plants native to Canada and the United States is provided by NatureServe (http://www.natureserve.org/index.jsp). Plants in the NatureServe database are monitored by a network of state or provincial natural heritage programs, with the data maintained in a single database.

Table 6. *Tree or tree/shrub species officially listed as threatened or endangered in the U.S.*

Taxon	Fed. Status	States	Taxon	Fed. Status	States
Alectryon macrococcus	LE	HI	Pritchardia munroi	LE	HI
Caesalpinia kavaiensis	LE	HI	Pritchardia napaliensis	LE	HI
Chamaesyce celastroides	LE	HI	Pritchardia schattaueri	LE	HI
Clermontia pyrularia	LE	HI	Pritchardia viscosa	LE	HI
Colubrina oppositifolia	LE	HI	Xylosma crenata (crenatum)	LE	HI
Cyanea superba	LE	HI	Zanthoxylum dipetalum	LE	HI
Delissea undulata	LE	HI			
Eugenia koolauensis	LE	HI	Cercocarpus traskiae	LE	CA
Euphorbia haeleeleana	LE	HI	Cupressus abramsiana	LE	CA
Flueggea neowawraea	LE	HI	Cupressus goveniana	LT	CA
Gardenia brighamii	LE	HI	Fremontodendron mexicanum	LE	CA
Gardenia mannii	LE	HI	Pilosocereus robinii	LE	FL
Hesperomannia arbuscula	LE	HI	Pilosocereus robinii	LE	FL
Hibiscadelphus distans	LE	HI	Torreya taxifolia	LE	FL
Hibiscadelphus giffardianus	LE	HI	Lindera melissifolia	LE	FL, LA, GA
Hibiscadelphus hualalaiensis	LE	HI	Banara vanderbiltii	LE	PR
Hibiscadelphus woodii	LE	HI	Buxus vahlii	LE	PR
Hibiscus arnottianus	LE	HI	Calyptranthes thomasiana	LE	PR
Hibiscus brackenridgei	LE	HI	Calyptronoma rivalis	LT	PR
Hibiscus clayi	LE	HI	Cornutia obovata	LE	PR
Kokia cookei	LE	HI	Crescentia portoricensis	LE	PR
Kokia drynarioides	LE	HI	Goetzea elegans	LE	PR
Kokia kauaiensis	LE	HI	Ilex cookii	LE	PR
Munroidendron racemosum	LE	HI	Ilex sintenisii	LE	PR
Nothocestrum breviflorum	LE	HI	juglans jamaicensis	LE	PR
Nothocestrum peltatum	LE	HI	Solanum drymophilum	LE	PR
Pleomele hawaiiensis	LE	HI	Stahlia monosperma	LT	PR
Pritchardia affinis	LE	HI	Zanthoxylum thomasianum	LE	PR
Pritchardia aylmer-robinsonii	LE	HI	Betual uber	LT	VA

Chapter 2. The State of *in situ* Genetic Resources

This section describes efforts related to habitat conservation, with related benefits for the conservation of forest genetic resources. Specific breeding and restoration efforts are discussed in Chapter 3.

Forest Land Ownership

As previously stated, the inventory of forest land area has been relatively stable over the past century and the forests it represents remain largely intact with 44 percent of the forest land owned by Federal, State, and local governments (Figure 5). Because public lands typically strive to manage for native, locally-adapted forest species, these lands all provide some aspect of *in situ* conservation.

The availability of data, and types of management actions, often vary according to ownership and land class. The Forest Inventory and Analysis (FIA) data of the USDA Forest Service examines all forest lands and reports forest ownership by 3 regions, West, North and South (Figure 2). Land ownership differs widely by region; in the West 70 percent of the land is publicly owned, while in the east, 81 percent of the land is privately owned.

FIA further breaks forests into three land classes:

Forest land that is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timber land are capable of producing in excess of 1.4 cubic meters per hectare per year of industrial wood in natural stands.)

Reserved forest land is forest land withdrawn from timber utilization through statute, administrative regulation, or designation (this does not include all land in IUCN protection categories).

Other forest land is forest land other than timber land and reserved forest land. It includes available land that is incapable of producing annually at least 1.4 cubic meters per hectare of industrial wood under natural conditions because of adverse site conditions, such as sterile soils, dry climate, poor drainage, high elevation, steepness, or rockiness.

The percentage of each forest type in reserved land is shown in figures 8a & b. Western forest types have relatively large percentages located in reserves; this is a function of the West having 70 percent of forest land in public ownership, as compared to 19 percent in the east. This indicator currently addresses public protected forest areas, but millions of acres of private protected forests exist as well.

These private protected forests are primarily in various forms of conservation easements and fee simple holdings by nongovernmental organizations (NGOs). Conservation easements and related mechanisms by which private lands are assured some level of protection are growing in importance. Currently, the total area protected in this fashion is smaller relative to the area of publicly protected lands, but it is growing rapidly with the support of both public and private funding sources and will play a significant role in future forest policies both locally and nationally (USDA 2011). The National Land Trust Census in 2005 conservatively estimated 37 million acres of private land in protected status, largely by NGOs such as The Nature Conservancy, Ducks Unlimited, The Conservation Fund, and The Trust for Public Land.

Figure a. Percent of public forest land protected by cover type in the West, 2007.

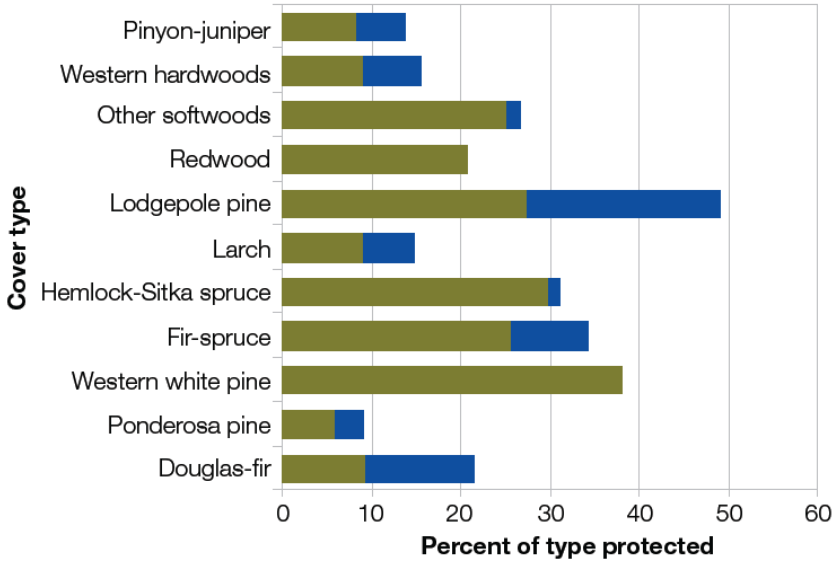
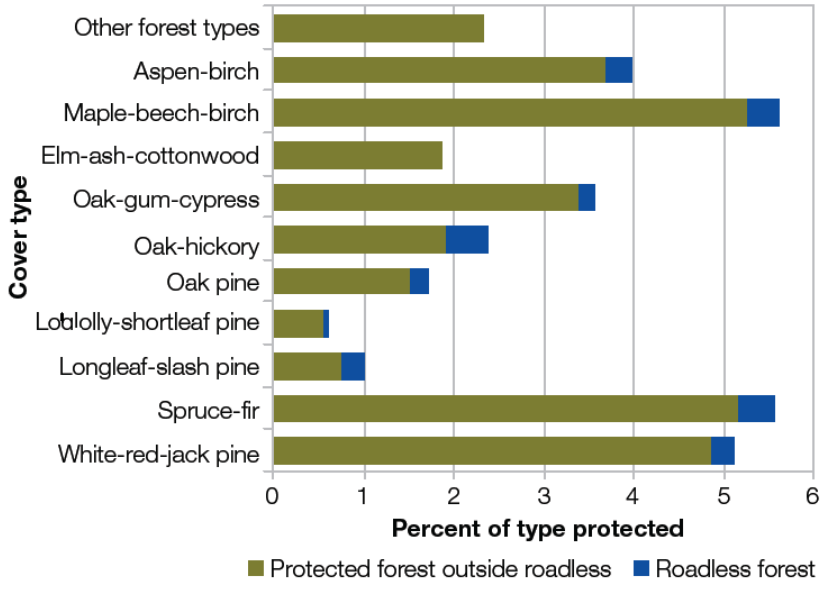


Figure b. Percent of public forest land protected by cover type in the East, 2007.



Overall data from the various sources, however, are inconsistent both spatially and as to how much of the areas are forested (USDA 2011).

The area of publicly protected forests has been stable for some time, but these forests are typically undergoing more stress than in the past. Levels of forest disturbance are rising, including a three-fold increase in insect-induced mortality since 2003 and increased wildland fire (USDA 2011). Changing weather patterns are altering host-pathogen relationships and exotic pests continue to be a problem. If left unmanaged, these forests protected from harvest, could be more "at-risk" than many actively-managed forests.

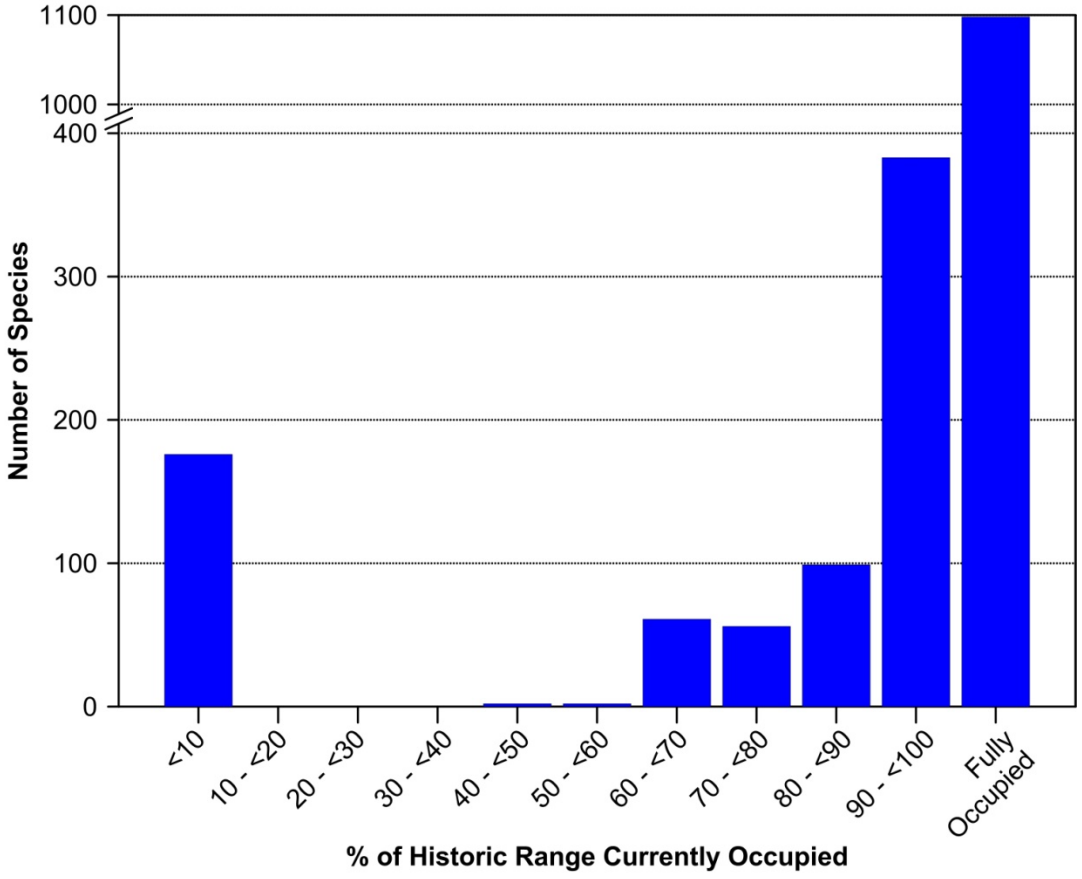
Range Contraction among Forest-Associated Vascular Plants

Species often occur as many genetically isolated (or nearly isolated) populations that serve different functional roles in different ecological systems. Conserving populations throughout a species' geographic range, including historically isolated lineages, will conserve geographic variation in the genome, permitting species to better address future environmental change (Moritz 2002), and to sustain the flow of benefits that humans derive from forest ecosystems (Hughes et al. 1997). Although the techniques for measuring genetic variation are well established (Hedrick and Miller 1992), it is not currently feasible to directly measure genetic variation throughout a species' range for even a small, well-selected subset of species. Because the number of genetically isolated populations is an increasing function of range size, shifts in geographic range size has been used as a surrogate measure of *in situ* genetic diversity (Hughes et al. 1997, Soulé and Mills 1998).

We compiled estimates of the historic and current geographic range of species from NatureServe's Central Databases (NatureServe 2009) to obtain state-level occurrence and extirpation information for forest-associated vascular plants. Broad-scale distribution information was based on documented occurrence from the scientific literature, museum records, external databases, and consultations with species experts (NatureServe 2009). The percentage of the former range that is now occupied was calculated as: (area of current range / area of historic range) × 100. These data were also used to determine if range contraction has been concentrated in a particular geographic area. This was accomplished by mapping the number of species that have been extirpated from each state and identifying those states where the greatest number of state-level extirpations has taken place.

The geographic distributions of most forest-associated vascular plants have not been appreciably reduced. Geographic distribution data for 19,518 species show that 90.4 percent fully occupy their former range. Of the 1,877 species that have been extirpated from at least one state, 1,098 still occupy ≥ 90 percent of their former distribution. A total of 396 species (or 2.0 percent of all forest-associated vascular plants) now occupy < 80 percent of their historic distribution (Figure 9). The 2% figure is relatively low compared to those for freshwater fish (6.2 percent), birds (5.4 percent) and mammals (5.1 percent) (USDA 2011). Geographically, states that have lost the greatest number of forest-associated vascular plant species – areas where genetic diversity may be eroding – are concentrated in the mid-Atlantic region and into New England (Figure 10).

Figure 9. *The number of forest-associated vascular plants that currently occupy various percentages of their former geographic range given that it has been extirpated from at least one state.*



Chapter 3. The State of *ex situ* Genetic Resources

Ex situ forest tree genetic resources are predominately found in three (overlapping) categories: arboreta and botanic gardens, specific gene conservation programs, and restoration and breeding programs.

Arboreta and Botanic Gardens

Information from many US arboreta and botanic gardens is housed with Botanic Gardens Conservation International (U.S.). This organization works with over 80 partner gardens and conservation organizations on plant conservation programs. The BGCI U.S., in collaboration with the United States Botanic Garden and the Arnold Arboretum of Harvard University, recently produced a publication (Kramer et al. 2011) that consolidated a list of threatened plants in North America and compared it with seed banks and living collections information maintained in BGCI's PlantSearch database; which contains taxa-level information on plants maintained in collections at botanical institutions around the world. Results indicated that while some capacity for *ex situ* conservation is already in place, North America did not reach the 2010 Target 8 goal of the Global Strategy for Plant Conservation (GSPC); that goal being 60% of threatened plant species in accessible collections. Only 39% of the 9,496 North American threatened taxa are maintained in 230 germplasm or living plant collections in North America. However, 45% of these collections are known from only one location, raising significant concerns about their conservation application and long-term viability. BGCI U.S. is working with its member gardens and other partners, including the USDA Forest Service, to build the conservation value of living collections for threatened species that do not have storable seed. This includes conducting genetic studies and developing micropropagation and cryopreservation techniques for Red Listed oak species native to the United States.

The Kramer et al. (2011) report lists which taxa are in collections. One can also search for specific taxa in the BGCI data base (http://www.bgci.org/plant_search.php).

Gene Conservation Programs

There are a number of organizations that deal specifically with gene conservation, many of which are included in the BGCI collection. The following are singled out because of their specific purpose of gene conservation of native plants.

The **Center for Plant Conservation** coordinates collections of officially listed threatened and endangered plants (http://www.centerforplantconservation.org/). The Center is a network of 37 leading botanic institutions. Founded in 1984, the Center operates the only coordinated national program of *ex situ* conservation of rare plant material. This conservation collection ensures that material is available for restoration and recovery efforts for these species. Seventy seven (77) trees or tree/shrubs are part of the CPC collection and are listed in Table 7.

Table 7. *Threated or endangered trees with collections that are part of the Center for Plant Conservation.*

Taxon	CPC Garden	Global Rank	Fed. Status
Abies fraseri	The Arnold Arboretum of Harvard University	G2	SC
Acacia koaia	National Tropical Botanical Garden	G2	SC
Alectryon macrococcus var. auwahiensis	Amy B.H. Greenwell Ethnobotanical Garden	G1T1	LE
Betula murrayana	The Holden Arboretum	G1Q	LT
Banara vanderbiltii	Fairchild Tropical Botanic Garden	G1Q	SC
Brunfelsia densifolia	Fairchild Tropical Botanic Garden	G1	NL
Buxus vahlii	Fairchild Tropical Botanic Garden	G1	LE
Caesalpinia kavaiensis	National Tropical Botanical Garden	G1	LE
Calyptranthes peduncularis	Fairchild Tropical Botanic Garden	G1	SC
Calyptranthes thomasiana	Fairchild Tropical Botanic Garden	G1	LE
Calyptronoma rivalis	Fairchild Tropical Botanic Garden	G1G2	LT
Castanea pumila var. ozarkensis	Missouri Botanical Garden	G5T3	UR
Cercocarpus traskiae	Rancho Santa Ana Botanic Garden	G1	LE
Chamaesyce celastroides var. kaenana	Waimea Valley	G3T1	LE
Clermontia pyrularia	Amy B.H. Greenwell Ethnobotanical Garden	G1	LE
Colubrina oppositifolia	National Tropical Botanical Garden	G1	LE
Cornutia obovata	Fairchild Tropical Botanic Garden	G1	LE
Crataegus harbisonii	North Carolina Arboretum	G1	SC
Crescentia portoricensis	Fairchild Tropical Botanic Garden	G1	LE
Cupressus abramsiana	University of California Botanical Garden	G1	LE
Cyanea leptostegia	National Tropical Botanical Garden	G2	NL
Cyanea superba ssp. superba	Harold L. Lyon Arboretum	G1T1	LE
Delissea undulata ssp. undulata	Harold L. Lyon Arboretum	G1T1	LE
Erythrina eggersii	Fairchild Tropical Botanic Garden	G1	SC
Eugenia koolauensis	Waimea Valley	G1	LE
Euphorbia haeleeleana	National Tropical Botanical Garden	G1	LE
Flueggea neowawraea	National Tropical Botanical Garden	G1	LE
Forestiera segregata var. pinetorum	Fairchild Tropical Botanic Garden	G4T2	SC

Fremontodendron mexicanum	Rancho Santa Ana Botanic Garden	G2	LE
Gardenia brighamii	Waimea Valley	G1	LE
Gardenia mannii	Honolulu Botanical Gardens	G1	LE
Gaussia attenuata	Fairchild Tropical Botanic Garden	G1	NL
Goetzea elegans	Fairchild Tropical Botanic Garden	G1	LE
Heritiera longipetiolata	Waimea Valley	G1G3?Q	RT
Hesperomannia arbuscula	Harold L. Lyon Arboretum	G1	LE
Hibiscadelphus distans	National Tropical Botanical Garden	G1	LE
Hibiscadelphus giffardianus	National Tropical Botanical Garden	GHC	LE
Hibiscadelphus hualalaiensis	National Tropical Botanical Garden	GHC	LE
Hibiscadelphus woodii	National Tropical Botanical Garden	G1	LE
Hibiscus arnottianus ssp. immaculatus	National Tropical Botanical Garden	G3T1	LE
Hibiscus brackenridgei ssp. brackenridgei	Waimea Valley	G1T1	
Hibiscus brackenridgei ssp. mokuleianus	Waimea Valley	G1T1	LE
Hibiscus clayi	Waimea Valley	G1	LE
Ilex collina	The Arnold Arboretum of Harvard University	G3	RT
Kokia cookei	Waimea Valley	GXC	LE
Kokia drynarioides	Amy B.H. Greenwell Ethnobotanical Garden	G1	LE
Kokia kauaiensis	National Tropical Botanical Garden	G1	LE
Leitneria floridana	Mercer Arboretum and Botanic Gardens	G3	SC
Lindera melissifolia	Mercer Arboretum and Botanic Gardens	G2G3	LE
Magnolia pyramidata	The Arnold Arboretum of Harvard University	G4	NL
Munroidendron racemosum	National Tropical Botanical Garden	G1	LE
Nothocestrum breviflorum	Amy B.H. Greenwell Ethnobotanical Garden	G1	LE
Nothocestrum peltatum	National Tropical Botanical Garden	G1	LE
Opuntia basilaris var. treleasei	Regional Parks Botanic Garden	G5T2	SC
Pilosocereus robinii	Fairchild Tropical Botanic Garden	G1	LE
Pilosocereus robinii var. robinii	Desert Botanical Garden	G1T1Q	LE
Pleomele hawaiiensis	Amy B.H. Greenwell Ethnobotanical Garden	G1	LE
Polygala cowellii	Fairchild Tropical Botanic Garden	G1	RT
Pritchardia affinis	Amy B.H. Greenwell	GHC	LE

	Ethnobotanical Garden		
Pritchardia aylmer-robinsonii	National Tropical Botanical Garden	G1T1	LE
Pritchardia munroi	Waimea Valley	G1	LE
Pritchardia napaliensis	National Tropical Botanical Garden	G1T1	LE
Pritchardia schattaueri	Amy B.H. Greenwell Ethnobotanical Garden	G1	LE
Pritchardia viscosa	National Tropical Botanical Garden	G1	LE
Prunus alleghaniensis	North Carolina Arboretum	G4	SC
Prunus alleghaniensis var. davisii	The Holden Arboretum	G4T3Q	SC
Pseudophoenix sargentii	Fairchild Tropical Botanic Garden	G3G5	NL
Rhus kearneyi	Desert Botanical Garden	G4	RT
Sabal causiarum	Fairchild Tropical Botanic Garden	G1	NL
Solanum drymophilum	Fairchild Tropical Botanic Garden	G1	LE
Stahlia monosperma	Fairchild Tropical Botanic Garden	G1G3	LT
Tetraplasandra oahuensis	Waimea Valley	G3	NL
Torreya taxifolia	Atlanta Botanical Garden	G1	LE
Viburnum dentatum var. venosum	The New York Botanical Garden	G5T4T5	NL
Xylosma crenata (crenatum)	Harold L. Lyon Arboretum	G1	LE
Zanthoxylum dipetalum var. tomentosum	Amy B.H. Greenwell Ethnobotanical Garden	G2T1	LE
Zanthoxylum thomasianum	Fairchild Tropical Botanic Garden	G1	LE

The **U.S. National Plant Germplasm System** (NPGS) is a network of Federal, State, and private organizations and research units, coordinated by the U.S. Department of Agriculture, Agricultural Research Service (ARS). The national system of seed and clonal germplasm repositories is responsible for the collection, maintenance, evaluation, distribution, and preservation of economically important agronomic, horticultural, and industrial US crops. The National Center for Genetic Resources Preservation (NCGRP), a component of the NPGS, maintains long-term preservation of seed and vegetative tissue of using conventional and cryopreservation storage technologies. The Germplasm Resource Information Network (GRIN) is the centralized database for the NPGS (http://www.ars-grin.gov/npgs/index.html).

While the mission of the NPGS does not cover the preservation and maintenance of traditional forestry tree species, there is overlap with NPGS crops, such as fruit trees and woody landscape plants. The NPGS currently maintains approximately 548,000 accessions of 2,375 different genera. From a list of 109 genera taken from Little's Checklist of United States Trees (Little 1979), 95 genera are maintained in the NPGS represented by a total of 23,274 accessions (Table 8).

Table 8. *North American trees and tree/shrubs represented in the U.S. National Plant Germplasm System.*

GENUS	SPECIES		GENUS	SPECIES	
Abies	alba		Maclura	pomifera	
Acacia	modesta		Magnolia	champaca	
Acer	barbinerve		Malus	baccata	
Acoelorrhaphe	wrightii		Metopium	toxiferum	
Aesculus	chinensis		Morella	caroliniensis	
Alnus	cordata		Morus	alba	
Amelanchier	alnifolia		Nyssa	aquatica	
Arbutus	andrachne		Osmanthus	delavayi	
Betula	albosinensis		Ostrya	carpinifolia	
Bursera	simaruba		Oxydendrum	arboreum	
Calocedrus	macrolepis		Parkinsonia	aculeata	
Carpinus	betulus		Persea	americana	var. nubigena
Carya	aquatica		Picea	asperata	
Castanea	hybr.		Pinckneya	bracteata	
Catalpa	longissima		Pinus	caribaea	
Ceanothus	americanus		Pistacia	atlantica	subsp. mutica
Celtis	australis		Platanus	mexicana	
Cercis	canadensis	var. mexicana	Populus	alba	
Cercocarpus	breviflorus		Prunus	africana	
Chamaecyparis	thyoides		Pseudotsuga	menziesii	
Chilopsis	linearis	subsp. arcuata	Purshia	tridentata	
Cladrastis	kentukea		Quercus	spp.	
Cliftonia	monophylla		Rhamnus	alpina	subsp. fallax
Clusia	major		Rhododendron	alabamense	
Coccothrinax	argentata		Rhus	chinensis	
Cornus	mas		Roystonea	borinquena	
Corylus	americana		Sabal	causiarum	
Cotinus	coggygria		Salix	aegyptiaca	
Crataegus	azarolus		Sambucus	australis	

Cupressus	arizonica	var. glabra	Sapindus	saponaria	
Diospyros	kaki		Shepherdia	argentea	
Erythrina	corallodendrum		Sideroxylon	inerme	
Euonymus	alatus	var. apterus	Sorbus	alnifolia	
Fagus	sylvatica	subsp. orientalis	Stewartia	malacodendron	
Frangula	alnus		Styrax	americanus	
Franklinia	alatamaha		Taxodium	distichum	
Fraxinus	americana		Taxus	brevifolia	
Gymnocladus	chinensis		Thrinax	radiata	
Halesia	diptera	var. magniflora	Thuja	spp.	
Hamamelis	ovalis		Tilia	americana	var. americana
Ilex	cornuta		Torreya	jackii	
Illicium	anisatum		Tsuga	canadensis	
Juglans	cinerea		Ulmus	americana	
Juniperus	bermudiana		Viburnum	acerifolium	
Larix	gmelinii	var. olgensis	Washingtonia	robusta	
Leitneria	floridana		Zanthoxylum	americanum	
Leucaena	hybr.		Ziziphus	mauritiana	
Liquidambar	acalycina				

The **USDA Forest Service** supports a number of gene conservation programs that are often part of reforestation or forest tree breeding programs. All three deputy areas (National Forest System, Research & Development, State & Private Forestry) are involved in aspects of gene conservation. In addition to in-house efforts, State & Private Forestry funds Camcore to run a conservation program for *Tsuga canadensis* and *Tsuga caroliniana* (see http://www.camcore.org/projects/hemlock.php) and (*Chamaecyparis thyoides*). The National Forest System and State & Private Forestry supports Camcore to conserve *Pinus pungens* (http://www.camcore.org/projects/tableMountain.php).

Both the USDA Forest Service and the U.S. National Plant Germplasm System work together to collect and preserve eastern *Fraxinus* species (*Fraxinus americana*, *F. pennsylvanica*, *F. nigra*, *F. profunda*, and *F. quadrangulata*).

Other USDA Forest Service programs that emphasize gene conservation include the high elevation white pines of the West (*Pinus albicaulis* Engelm. , *Pinus aristata* Engelm., *Pinus longaeva* D.K. Bailey, *Pinus flexilis* James, and *Pinus balfouriana* Balf.), which includes reforestation collections and those specifically done for gene conservation. Just recently programs have been funded by State& Private Forestry for *Picea rubens*, *Picea breweriana*, *Pinus strobiformis*, and conservation plans are underway for west coast cypress species (*Cupressus bakeri, C. forbesii, C. macnabiana, C. nevadensis, C. sargentii,* and *C. stephensonii)*.

The **Institute of Forest Genetics,** a program of the USDA Forest Service Research and Development, has had an ongoing gene conservation program for decades. A list of their North American trees species in seed storage is shown in Table 9.

The **Seeds of Success** program is a national native seed collection program in the United States coordinated by the U.S. Department of Interior Bureau of Land Management (BLM) in conjunction with partners (http://www.nps.gov/plants/sos/index.htm). The goal of the program is to collect, conserve, and develop native plant materials for stabilizing, rehabilitating and restoring lands in the United States. While the scope of the program includes all plants, it is heavily focused on rangeland species. Over 13,000 native seed collections are in its national collection. Long-term seed storage is provided by the NCGRP.

Camcore (http://www.camcore.org/) is a non-profit, international program that works for the conservation of tropical and subtropical forest tree species. Although Camcore deals primarily with tropical and subtropical species, it is actively working with the USDA Forest Service to conserve eastern hemlocks (*Tsuga Canadensis* and *T. caroliniana*), table mountain pine (*Pinus pungens*), and Atlantic white cedar (*Chamaecyparis thyoides*).

The **North American Plant Collections Consortium** (NAPCC), a program of the American Association of Botanical Gardens and Arboreta (AABGA), is a network of botanical gardens and arboreta working to coordinate a continent-wide approach to plant germplasm preservation, and to promote high standards of plant collections management. Collection holders make germplasm available for taxonomic studies, evaluation, breeding, and other research (http://www.publicgardens.org/content/what-napcc).

Table 9. North American tree species in collections at the USDA Forest Service Institute of Forest Genetics.

Genus	Species	IUCN	total lots	From
Abies	amabilis	LC	6	Western US, CA
Abies	bracteata	LC	363	California
Abies	concolor	LC	288	Western US
Abies	magnifica	LC	95	Western US
Alnus	tenuitolia		1	Western US, CA
Aquilegia	formosa		1	Western US, CA
Asclepias	cordifolia		1	CA,OR, NV
Betula	occidentalis		1	Western US, CA
Calocedrus	decurrens	LC	227	CA,OR, NV
Chamaecyparis	lawsoniana	VU	24	CA, OR
Chamaecyparis	nootkatensis	LC	4	Western US, CA
Chamaecyparis	thyoides	LC	1	Eastern US
Clarkia	unguiculata		1	California
Pinus	albicaulis	VU	26	Western US, CA
Pinus	apacheca	LC	14	AZ, NM
Pinus	aristata	NT	9	CO, AZ, NM
Pinus	aristata [longeava]	VU	76	CA, NV, UT
Pinus	arizonica	LC	11	NM,AZ,TX
Pinus	armandi	LC	10	China
Pinus	Attenuata	LC	390	CA,OR
Pinus	ayacahuite	LC/NT	287	Central America/Mexico
Pinus	balfouriana	LC	49	California
Pinus	banksiana	LC	24	North Eastern US, CA
Pinus	caribaea	LC/VU	33	carabean
Pinus	cembroides	LC/VU	13	Mexico, TX, NM
Pinus	chiapensis	VU	2	Mexico
Pinus	clausa	NT	2	Southeastern US
Pinus	contorta	LC/NT	100	Western US, CA
Pinus	cooperi	LC	5	Mexico
Pinus	coulteri	LC	615	California
Pinus	culminicola	EN	1	Mexico
Pinus	douglasiana	LC	6	Mexico
Pinus	durangensis	LC	2	Mexico
Pinus	echinata	LC	54	Southeastern US
Pinus	edulis	LC	5	Southwestern US
Pinus	elliottii var. Densa	LC	18	Southeastern US
Pinus	flexilis	LC	155	Western US
Pinus	glabra	LC	2	Southeastern US

Pinus	greggii	NT	2	Mexico
Pinus	herrerae	LC	1	Mexico
Pinus	jeffreyi	LC	581	CA,OR, NV
Pinus	Jo [johannis]	Rare	2	Mexico
Pinus	lambertiana	LC	1586	CA, NV, OR,MX
Pinus	lawsoni	LC	6	Mexcio
Pinus	leiophylla	LC	6	NM, AZ, Mex
Pinus	longaeva	VU	33	CA/NV
Pinus	maximartinezii	EN	189	Mexico
Pinus	michoacana	LC	10	Mexico
Pinus	monophylla	LC	52	Western US, Mex
Pinus	montezumae	LC	51	Mexico
Pinus	monticola	LC	197	Western US, Canada
Pinus	muricata	NT	852	California
Pinus	murrayana	LC	439	Western US
Pinus	nelsoni	VU	1	Mexico
Pinus	occidentalis	NT	4	Haiti
Pinus	oocarpa	LC	8	Mexico, Central America
Pinus	patula	LC	36	Mexico
Pinus	pinceana	NT	260	Mexico
Pinus	ponderosa	LC	2071	Western US, CA
Pinus	pringlei	LC	1	Mexico
Pinus	pseudostrobus	LC	18	Mexico, Central America
Pinus	pungens	LC	15	Eastern US
Pinus	radiata	LC	967	California
Pinus	remorata (muricata var. remorata)	NT	11	California
Pinus	resinosa	LC	12	North Eastern US, CA
Pinus	rigida	LC	836	Eastern US
Pinus	rzedowskii	EN	1	Mexico
Pinus	sabineana	LC	582	California
Pinus	serotina	LC	2	Southeastern US
Pinus	strobiformis	LC	160	Sourthwestern US
Pinus	strobus	LC/VU	116	Eastern US
Pinus	tecunumanni	VU	5	Central America
Pinus	teocote	LC	6	Mexico
Pinus	torreyana	EN	188	
Pinus	virginiana	NT	23	Eastern US
Pinus	washoensis	LC	36	Western US, CA
Pseudotsuga	macrocarpa	NT	48	CA
Pseudotsuga	menziesii	LC	942	

Sequoia	sempervirens	VU	2	
Sequoiadendron	giganteum	VU	471	
Thuja	plicata	LC	4	Western US, CA
Tsuga	heterophylla	LC	1	Western US, CA
Tsuga	mertensiana	LC	3	Western US, CA

Breeding and Restoration Programs

Breeding and restoration programs can be some of the most effective gene conservation efforts available. They typically encompass aspects of both *in situ* and *ex situ* conservation since both planting and seed storage are involved. Most forest tree breeding and restoration programs utilize breeding zones or seed transfer zones that attempt to match seed sources to appropriate planting sites. These efforts help maintain aspects of the genetic structure found across the landscape. Non-private restoration and breeding programs are listed in Table 10. In total, restoration and breeding programs include over 100 species in the U.S.

Breeding programs may be the only hope to keep some species in the environment. Species under "threat" from diseases and pests may require increased resistance to maintain their place in the ecosystems they inhabit (or the new ones that could come along with climate change). For example, without the incorporation of disease resistance, neither American chestnut (*Castanea dentata*) nor American elm (*Ulmus americana*) can be expected to return to their dominant roles in the nation's forests. In addition, breeding programs, by default, have *ex situ* conservation plantings in their seed orchards, progeny tests in addition to any seed stores.

The USDA Forest Service has an extensive collection of seed for restoration purposes. This was summarized by Vicky Erickson for a gene conservation workshop in 2007; the document (FS_genetic_conservation_11_18.doc) can be found at http://www.fs.fed.us/r6/dorena/files/Genetic_Conservation/General_Info/. In total, there was 85,000 kg of tree seed from 56 tree species for restoration purposes. In addition, 84,621 family seed lots were in storage from a total of 44 tree species; although 94% of these collections were from 10 species (see below), and the top 3 species represented 74% of the total.

Species	Family seedlots		Species	Family Seedlots
Sugar pine	27,200		Lodgepole pine	3,254
Douglas fir	20,733		Eastern white pine	1,646
Ponderosa pine	~13,863		Noble fir	1,639
Western white pine	4,978		Whitebark pine	1,576
Western larch	4,419		White fir	648

Congress directed "*the Secretaries of Interior and Agriculture to report jointly to the Congress by December 31, 2001, with specific plans and recommendations to supply native plant materials for emergency stabilization and longer-term rehabilitation and restoration efforts*" (Fiscal Year 2002 Interior Appropriations House Report). BLM has taken the lead on this effort with the Native Plant Materials Development program (Seeds of Success program) and it is now being hailed as one of our best weapons in the climate change toolbox - esp. the preservation of native plant materials for long-term storage. The FWS National Wildlife Refuge System is currently using native plants for restoration purposes and could contribute enormously to national native genetic resource collections. Moreover, the Inventory and Monitoring program is initiating pilot projects on invasive species and threatened and endangered plants and animals on refuges: these surveys could provide distribution and coverage information for important tree species.

The U.S. Fish and Wildlife Service National Wildlife Refuge System (NWRS) manages over 150 million acres of land (http://www.fws.gov/refuges/) and, as such, plays an important role in providing *in-situ* conservation of the many native plant species located on these lands, including trees. The NWRS has significant restoration needs, especially following invasive species removals and wildfire, and has ongoing projects to restore, revegetate, reclaim, rehabilitate or improve portions of these habitats. In addition, NWRS lands contain many populations of desirable native species suitable for seed collection, propagation, and restoration projects (Tu, 2010). Refuges generally work locally or regionally to satisfy their native plant materials needs. Activities range from engaging in Memoranda of Understanding with native plant nurseries, working with friends groups that obtain native plant donations for restoration projects, and participating in large-scale cooperative multi-agency, state and private restoration collaborations. Sample tree restoration activities on Refuges include the Upper Ouachita National Wildlife Refuge Restoration project in Louisiana (http://www.conservationfund.org/louisiana/upper-ouachita-national-wildlife-refuge) and the Hawaiian Hakalau National Wildlife Refuge's Hakalau Forest Restoration (http://www.fws.gov/hakalauforest/management.html). In 2009, a pilot program begun in FWS Region 1 (Washington, Oregon, and Idaho) began exploring opportunities for NWRS to utilize volunteers to participate in the national Seeds of Success program (Tu, 2010). NWRS germplasm collections and contributions to long-term storage facilities, such as NCGRP, have not been analyzed on a national level.

Table 10. *Forest-tree breeding and restoration programs in the U.S.*

Scientific name	Common name	Organization	Home	Type
Abies magnifica var. shastensis	Shasta red fir	USFS Region 6	USFS Region 6	Restoration/Regeneration
Abies amabilis	Pacific silver fir	USFS Region 6	USFS Region 6	Restoration/Regeneration
Abies balsamea	Balsam fir	New Hampshire Dept of Resources and Economic Development	New Hampshire DREC	Breeding
Abies concolor	White fir	USFS Region 5	USFS Region 5	Breeding
Abies concolor	White fir	USFS Region 6	USFS Region 6	Restoration/Regeneration
Abies fraseri	Fraser fir	Christmas Tree Genetics Program	North Carolina State University	Breeding
Abies fraseri	Fraser fir	UT Tree Improvement Program	The University of Tennessee	Testing/conservation
Abies fraseri	Fraser fir	North Carolina Forest Service	Goldsboro Forestry Center	Breeding/Testing/Regeneration
Abies grandis	Grand fir	USFS Region 6	USFS Region 6	Restoration/Regeneration
Abies lasiocarpa	Subalpine fir	USFS Region 6	USFS Region 6	Restoration/Regeneration
Abies magnifica	Red fir	USFS Region 5	USFS Region 5	Restoration/Regeneration
Abies procera	Noble fir	USFS Region 6	USFS Region 6	Restoration/Regeneration
Acacia koa	Koa	Hardwood Tree Improvement and Regeneration Center	Purdue & USFS	Breeding
Acacia koaia	koaia	Hawaii Island Native Seed Bank Cooperative	The Hawai`i Forest Institute	Restoration/Regeneration
Acer saccharum	sugar maple	UT Tree Improvement Program	The University of Tennessee	Seed orchard
Acer saccharum	sugar maple	Cornell University	Cornell University	Breeding
Acer saccharum	Sugar maple	Indiana Department of Natural Resoutces	Indiana DNR	Breeding
Betula alleghaniensis	Yellow birch	USFS Region 9	USFS Region 9	Restoration/Regeneration
Calocedrus decurrens	incense cedar	USFS Region 5	USFS Region 5	Restoration/Regeneration
Calocedrus decurrens	Incense cedar	USFS Region 6	USFS Region 6	Restoration/Regeneration
Carya illinoiensis	pecan	UT Tree Improvement Program	The University of Tennessee	Seed orchard
Carya lacinosa	Shellbark hickory	Kentucky Division of Forestry	Kentucky DF	Restoration/Regeneration
Carya ovata	shagbark hickory	UT Tree Improvement Program	The University of Tennessee	Testing
Castanea dentata	American chestnut	Hardwood Tree Improvement and Regeneration Center	Purdue & USFS	Breeding
Castanea dentata	Chestnut	The American Chestnut Foundation & State Chapters	TACF	Breeding
Castanea dentata	American chestnut	USFS Region 8	USFS Region 8	Restoration/Regeneration
Castanea dentata	American chestnut	UT Tree Improvement Program	The University of Tennessee	Testing

Castanea dentata	American chestnut	Virginia DOF	Virginia DOF	Breeding/Restoration
Castanea dentate	American chestnut	New Jersey Forest Service	NJ Forest Service	Breeding
Castanea dentata	American Chestnut	West Virginia Division of Forestry	West Virginia DOF	Restoration/Regeneration
Castenea dentata	American Chestnut	Tennessee Division of Forestry	Tennessee Department of Agriculture	Preservation
Castenea spp.	Hybrid Chestnut	Tennessee Division of Forestry	Tennessee Department of Agriculture	Seed Production
Catalpa spp.	indian bean	US National Arboretum	USDA-ARS	Breeding
Cercis spp.	Redbud	US National Arboretum	USDA-ARS	Breeding
Chamaecyparis lawsoniana	Port-Orford-cedar	USFS Region 5	USFS Region 5	Breeding
Chamaecyparis lawsoniana	Port-Orford cedar	USFS Region 6	USFS Region 6	Breeding
Chamaecyparis thyoides	Atlantic white-cedar	Maryland Dept. of Natural Resources	Maryland DNR	Restoration/Regeneration
Chamaecyparis thyoides	Atlantic white-cedar	North Carolina Forest Service	Goldsboro Forestry Center	Testing/Restoration/Regeneration
Chamaecyparis thyoides	Atlantic white cedar	CAMCORE	Camcore - USFS S&PF	Conservation
Cupressus lusitanica	Alaska yellow cedar	USFS Region 6	USFS Region 6	Restoration/Regeneration
Cupressus spp.	Cypresses	USFS Region 5	USFS Region 5	Restoration/Regeneration
Diospyros virginiana	Persimmon	Tennessee Division of Forestry	Tennessee Department of Agriculture	Seed Production
Diospyrous virginiana	persimmon	UT Tree Improvement Program	The University of Tennessee	Testing
Dodonaea viscosa	aali'i	Hawaii Island Native Seed Bank Cooperative	The Hawai`i Forest Institute	Restoration/Regeneration
Eucalyptus benthamii		Arborgen	Arborgen	Breeding
Fagus grandifolia	American beech	USFS NRS - Delaware	USFS R&D	Breeding
Fraxinus americana	White ash	Indiana Department of Natural Resources	Indiana DNR	Breeding
Fraxinus americana	White ash	Pennsylvania Dept. of Conservation and Natural Resources	Pennsylvania DCNR	Breeding
Fraxinus pennsylvanica	Green ash	USFS NRS - Delaware	USFS R&D	Breeding
Fraxinus pennsylvanica	Green ash	Western Gulf Cooperative Tree Improvement Program	Texas A&M University	Tested orchard
Fraxinus spp.	Ash hybrids	USFS NRS - Delaware	USFS R&D	Breeding
Gleditsia triacanthos	honeylocust	UT Tree Improvement Program	The University of Tennessee	Testing (mapping population)
Gymnocladus dioicus	Kentucky Coffeetree	Kentucky Division of Forestry	Kentucky DF	Restoration/Regeneration
Ilex americana	American holly	UT Tree Improvement Program	The University of Tennessee	Seed orchard
Juglans cinerea	Butternut	Hardwood Tree Improvement and Regeneration Center	Purdue & USFS	Breeding
Juglans cinerea	Butternut	USFS Region 8	USFS Region 8	Restoration/Regeneration
Juglans cinerea	butternut	UT Tree Improvement Program	The University of Tennessee	Testing/conservation

Juglans cinerea	Butternut	Indiana Department of Natural Resources	Indiana DNR	Breeding
Juglans cinerea	Butternut	Iowa Department of Natural Resources	Iowa DNR	Breeding
Juglans cinerea	Butternut	New Jersey Forest Service	NJ Forest service	Breeding
Juglans cinerea	Butternut	Pennsylvania Dept. of Conservation and Natural Resources	Pennsylvania DCNR	Breeding
Juglans cinerea	Butternut	North Carolina Forest Service	Goldsboro Forestry Center	Testing/Regeneration
Juglans cineria	Butternut	Tennessee Division of Forestry	Tennessee Department of Agriculture	Preservation/Seed Production
Juglans nigra	Black walnut	Hardwood Tree Improvement and Regeneration Center	Purdue & USFS	Breeding
Juglans nigra	black walnut	UT Tree Improvement Program	The University of Tennessee	Testing
Juglans nigra	Black walnut	Illinois Department of Natural Resources	Illinois DNR	Breeding
Juglans nigra	Black walnut	Indiana Department of Natural Resources	Indiana DNR	Breeding
Juglans nigra	Black walnut	Iowa Department of Natural Resources	Iowa DNR	Breeding
Juglans nigra	Black walnut	University of Missouri	University of Missouri	Breeding
Juglans nigra	Black walnut	Wisconsin Department of Natural Resources	Wisconsin DNR	Breeding
Juglans nigra	Black Walnut	Tennessee Division of Forestry	Tennessee Department of Agriculture	Seed Production
Juglans nigra	Black Walnut	Kentucky Division of Forestry	Kentucky DF	Breeding
Kokia drynarioides	kokia	Hawaii Island Native Seed Bank Cooperative	The Hawai`i Forest Institute	Restoration/Regeneration
Larix decidua	European larch	New York State Dept. of Environmental Conservation	New York DEC	Breeding
Larix kaempferi	Japanese larch	Pennsylvania Dept. of Conservation and Natural Resources	Pennsylvania DCNR	Breeding
Larix kaempferi	Japanese larch	New York State Dept. of Environmental Conservation	New York DEC	Breeding
Larix laricina	Tamarck	Minnesota Tree Improvement Cooperative	University of Minnesota	Breeding
Larix laricina	Eastern larch	USFS Region 9	USFS Region 9	Restoration/Regeneration
Larix occidentalis	Western Larch	Inland Empire Tree Improvement Cooperative	University of Idaho	Breeding
Larix occidentalis	Western Larch	USFS Region 1	USFS Region 1	Breeding
Larix occidentalis	Western Larch	USFS Region 1	USFS Region 1	Restoration/Regeneration
Larix occidentalis	Western Larch	USFS Region 4	USFS Region 1	Restoration/Regeneration
Larix occidentalis	Western Larch	USFS Region 6	USFS Region 6	Breeding
Larix occidentalis	Western larch	USFS Region 6	USFS Region 6	Restoration/Regeneration
Larix occidentalis	Western redcedar	USFS Region 6	USFS Region 6	Restoration/Regeneration
Liquidambar styraciflua	Sweetgum	Western Gulf Cooperative Tree Improvement Program	Texas A&M University	Tested orchard
Liquidambar styraciflua	Sweetgum	Arborgen	Arborgen	Breeding

Liquidambar styraciflua	Sweetgum	Indiana Department of Natural Resources	Indiana DNR	Breeding
Liquidambar styraciflua	Sweetgum	North Carolina Forest Service	Goldsboro Forestry Center	Breeding/Testing
Liriodendron tulipifera	yellow-poplar	UT Tree Improvement Program	The University of Tennessee	Testing/seed orchard
Liriodendron tulipifera	Yellow poplar	Western Gulf Cooperative Tree Improvement Program	Texas A&M University	Tested orchard
Liriodendron tulipifera	yellow-poplar	Indiana Department of Natural Resources	Indiana DNR	Breeding
Liriodendron tulipifera	Yellow-Poplar	Tennessee Division of Forestry	Tennessee Department of Agriculture	Breeding/Seed Production
Nyssa spp.	Tupelo	US National Arboretum	USDA-ARS	Breeding
Picea abies	Norway spruce	Pennsylvania Dept. of Conservation and Natural Resources	Pennsylvania DCNR	Breeding
Picea abies	Norway spruce	New York State Dept. of Environmental Conservation	New York DEC	Breeding
Picea breweriana	Brewer's spruce	USFS Region 5	USFS Region 5	Restoration/Regeneration
Picea breweriana	Brewer's spruce	USFS Region 6	USFS Region 6	Restoration/Regeneration
Picea engelmannii	Engelmann Spruce	USFS Region 1	USFS Region 1	Restoration/Regeneration
Picea engelmannii	Engelmann Spruce	USFS Region 2	USFS Region 1	Restoration/Regeneration
Picea engelmannii	Engelmann Spruce	USFS Region 3	USFS Region 1	Restoration/Regeneration
Picea engelmannii	Engelmann Spruce	USFS Region 4	USFS Region 1	Restoration/Regeneration
Picea engelmannii	Engelmann Spruce	USFS Region 6	USFS Region 6	Restoration/Regeneration
Picea glauca	White spruce	New York State Dept. of Environmental Conservation	New York DEC	Breeding
Picea glauca	White spruce	Wisconsin Department of Natural Resources	Wisconsin DNR	Breeding
Picea glauca	White spruce	Minnesota Tree Improvement Cooperative	University of Minnesota	Breeding
Picea glauca	White spruce	USFS Region 9	USFS Region 9	Restoration/Regeneration
Picea mariana	Black spruce	Minnesota Tree Improvement Cooperative	University of Minnesota	Breeding
Picea mariana	Black spruce	USFS Region 9	USFS Region 9	Restoration/Regeneration
Picea pungens	Blue spruce	USFS Region 2	USFS Region 1	Restoration/Regeneration
Picea pungens	Blue spruce	USFS Region 3	USFS Region 1	Restoration/Regeneration
Picea pungens	Blue spruce	USFS Region 4	USFS Region 1	Restoration/Regeneration
Picea rubens	Red spruce	CAMCORE	Camcore - USFS S&PF	Conservation
Pinus albicaulis	Whitebark pine	USFS Region 1	USFS Region 1	Breeding
Pinus albicaulis	Whitebark pine	USFS Region 1	USFS Region 1	Restoration/Regeneration
Pinus albicaulis	Whitebark pine	USFS Region 2	USFS Region 1	Breeding
Pinus albicaulis	Whitebark pine	USFS Region 2	USFS Region 1	Restoration/Regeneration
Pinus albicaulis	Whitebark pine	USFS Region 4	USFS Region 1	Breeding

Pinus albicaulis	Whitebark pine	USFS Region 4	USFS Region 1	Restoration/Regeneration
Pinus albicaulis	Whitebark pine	USFS Region 5	USFS Region 5	Restoration/Regeneration
Pinus albicaulis	Whitebark pine	USFS Region 6	USFS Region 6	Restoration/Regeneration
Pinus aristata	Rocky Mountain bristlecone pine	USFS Region 2	USFS Region 1	Restoration/Regeneration
Pinus aristata	Rocky Mountain bristlecone pine	USFS Region 3	USFS Region 1	Restoration/Regeneration
Pinus attenuata	Knobcone pine	USFS Region 6	USFS Region 6	Restoration/Regeneration
Pinus balfouriana	Foxtail pine	USFS Region 5	USFS Region 5	Restoration/Regeneration
Pinus banksiana	Jack Pine	Minnesota Tree Improvement Cooperative	University of Minnesota	Breeding
Pinus banksiana	Jack Pine	USFS Region 9	USFS Region 9	Restoration/Regeneration
Pinus banksiana	Jack pine	Michigan Department of Natural Resources/ MSU	Michigan State University	Breeding
Pinus banksiana	Jack Pine	Wisconsin Department of Natural Resources	Wisconsin DNR	Breeding
Pinus contorta	Lodgepole pine	Inland Empire Tree Improvement Cooperative	University of Idaho	Breeding
Pinus contorta	Lodgepole pine	USFS Region 1	USFS Region 1	Restoration/Regeneration
Pinus contorta	Lodgepole pine	USFS Region 2	USFS Region 1	Restoration/Regeneration
Pinus contorta	Lodgepole pine	USFS Region 3	USFS Region 1	Restoration/Regeneration
Pinus contorta	Lodgepole pine	USFS Region 4	USFS Region 1	Restoration/Regeneration
Pinus contorta	Lodgepole pine	USFS Region 6	USFS Region 6	Breeding
Pinus coulteri	Coulter pine	USFS Region 5	USFS Region 5	Restoration/Regeneration
Pinus echinata	Shortleaf pine	USFS Region 9	USFS Region 9	Restoration/Regeneration
Pinus echinata	Shortleaf pine	USFS Region 8	USFS Region 8	Restoration/Regeneration
Pinus echinata	Shortleaf pine	Kentucky Division of Forestry	Kentucky DF	Breeding
Pinus echinata	Shortleaf pine	Missouri Dept. of Conservation/University of Missouri	Missouri DOC	Breeding
Pinus echinata	Shortleaf pine	New Jersey Forest Service	NJ Forest service	Breeding
Pinus echinata	Shortleaf pine	North Carolina Forest Service	Goldsboro Forestry Center	Testing/Restoration/Regeneration
Pinus Echinata	Shortleaf pine	Virginia DOF	Virginia DOF	Breeding/Restoration
Pinus echinata	Shortleaf Pine	Tennessee Division of Forestry	Tennessee Department of Agriculture	Seed Production
Pinus elliottii	Slash pine	Southern Institute of Forest Genetics	USFS SRS	Breeding
Pinus elliottii	Slash pine	The Cooperative Forest Genetics Research Program	University of Florida	Breeding
Pinus elliottii	Slash pine	USFS Region 8	USFS Region 8	Restoration/Regeneration
Pinus elliottii	Slash pine	Western Gulf Cooperative Tree Improvement Program	Texas A&M University	Breeding

Pinus elliottii	Slash pine	Arborgen	Arborgen	Breeding
Pinus elliottii	Slash pine	Weyerhaeuser	Weyerhaeuser	Breeding
Pinus flexilis	Limber pine	USFS Region 1	USFS Region 1	Restoration/Regeneration
Pinus flexilis	Limber pine	USFS Region 2	USFS Region 1	Restoration/Regeneration
Pinus flexilis	Limber pine	USFS Region 3	USFS Region 1	Restoration/Regeneration
Pinus flexilis	Limber pine	USFS Region 4	USFS Region 1	Restoration/Regeneration
Pinus flexilis	Limber pine	USFS Region 5	USFS Region 5	Restoration/Regeneration
Pinus jeffreyi	Jeffrey pine	USFS Region 5	USFS Region 5	Restoration/Regeneration
Pinus lambertiana	Sugar pine	USFS Region 5	USFS Region 5	Breeding
Pinus lambertiana	Sugar pine	USFS Region 6	USFS Region 6	Breeding
Pinus lambertiana	Sugar pine	USFS Region 6	USFS Region 6	Restoration/Regeneration
Pinus longaeva	Great Basin bristlecone pine	USFS Region 4	USFS Region 1	Restoration/Regeneration
Pinus longaeva	Great Basin bristlecone pine	USFS Region 5	USFS Region 5	Restoration/Regeneration
Pinus monticola	Western white pine	Inland Empire Tree Improvement Cooperative	University of Idaho	Breeding
Pinus monticola	Western white pine	USFS Region 1	USFS Region 1	Breeding
Pinus monticola	Western white pine	USFS Region 1	USFS Region 1	Restoration/Regeneration
Pinus monticola	Western white pine	USFS Region 6	USFS Region 6	Breeding
Pinus monticola	Western white pine	USFS Region 6	USFS Region 6	Restoration/Regeneration
Pinus palustris	Longleaf pine	NCSU Cooperative Tree Improvement Program	North Carolina State University	Breeding
Pinus palustris	Longleaf pine	Southern Institute of Forest Genetics	USFS SRS	Breeding
Pinus palustris	Longleaf pine	The Cooperative Forest Genetics Research Program	University of Florida	Breeding
Pinus palustris	Longleaf pine	USFS Region 8	USFS Region 8	Restoration/Regeneration
Pinus palustris	Longleaf pine	Western Gulf Cooperative Tree Improvement Program	Texas A&M University	Tested orchard
Pinus palustris	Longleaf pine	North Carolina Forest Service	Goldsboro Forestry Center	Breeding/Testing/Restoration/Regeneration
Pinus palustris	Longleaf pine	Virginia DOF	Virginia DOF	Restoration
Pinus ponderosa	Ponderosa Pine	Inland Empire Tree Improvement Cooperative	University of Idaho	Breeding
Pinus ponderosa	Ponderosa Pine	North Sierra Tree Improvement Association		Breeding
Pinus ponderosa	Ponderosa Pine	USFS Region 1	USFS Region 1	Breeding
Pinus ponderosa	Ponderosa Pine	USFS Region 1	USFS Region 1	Restoration/Regeneration
Pinus ponderosa	Ponderosa Pine	USFS Region 2	USFS Region 1	Restoration/Regeneration

Pinus ponderosa	Ponderosa Pine	USFS Region 3	USFS Region 1	Restoration/Regeneration
Pinus ponderosa	Ponderosa Pine	USFS Region 4	USFS Region 1	Breeding
Pinus ponderosa	Ponderosa Pine	USFS Region 4	USFS Region 1	Restoration/Regeneration
Pinus ponderosa	Ponderosa Pine	USFS Region 5	USFS Region 5	Breeding
Pinus ponderosa	Ponderosa Pine	USFS Region 6	USFS Region 6	Breeding
Pinus pungens	Table mountain pine	CAMCORE	Camcore - USFS S&PF	Conservation
Pinus pungens	Table mountain pine	USFS Region 8	USFS Region 8	Restoration/Regeneration
Pinus resinosa	Red pine	Minnesota Tree Improvement Cooperative	University of Minnesota	Breeding
Pinus resinosa	Red pine	Michigan Department of Natural Resources/ MSU	Michigan State University	Breeding
Pinus resinosa	Red pine	Wisconsin Department of Natural Resources	Wisconsin DNR	Breeding
Pinus rigida	Pitch Pine	USFS Region 8	USFS Region 8	Restoration/Regeneration
Pinus rigida	Pitch pine	New Jersey Forest Service	NJ Forest service	Breeding
Pinus rigida	Pitch pine	Pennsylvania Dept. of Conservation and Natural Resources	Pennsylvania DCNR	Breeding
Pinus rigida x taeda	Pitch x Loblolly hybrid	New Jersey Forest Service	NJ Forest service	Breeding
Pinus rigida x taeda	Pitch x Loblolly hybrid	Pennsylvania Dept. of Conservation and Natural Resources	Pennsylvania DCNR	Breeding
Pinus sabiniana	Gray pine	USFS Region 5	USFS Region 5	Restoration/Regeneration
Pinus serotina	Pond Pine	North Carolina Forest Service	Goldsboro Forestry Center	Breeding/Regeneration
Pinus strobiformis	Southwestern white pine	USFS Region 1	USFS Region 1	Restoration/Regeneration
Pinus strobiformis	Southwestern white pine	USFS Region 2	USFS Region 1	Restoration/Regeneration
Pinus strobiformis	Southwestern white pine	USFS Region 3	USFS Region 1	Restoration/Regeneration
Pinus strobiformis	Southwestern white pine	USFS Region 4	USFS Region 1	Restoration/Regeneration
Pinus strobus	Eastern white pine	Christmas Tree Genetics Program	North Carolina State University	Breeding
Pinus strobus	White pine	Minnesota Tree Improvement Cooperative	University of Minnesota	Breeding
Pinus strobus	Eastern white pine	USFS Region 9	USFS Region 9	Restoration/Regeneration
Pinus strobus	eastern hemlock	UT Tree Improvement Program	The University of Tennessee	Testing/seed orchard
Pinus strobus	Eastern white pine	Kentucky Division of Forestry	Kentucky DF	Breeding
Pinus strobus	Eastern white pine	Maryland Dept. of Natural Resources	Maryland DNR	Breeding
Pinus strobus	Eastern white pine	New Hampshire Dept. of Resources and Economic Development	New Hampshire DREC	Breeding
Pinus strobus	Eastern white pine	New York State Dept. of Environmental Conservation	New York DEC	Breeding
Pinus strobus	Eastern White pine	West Virginia Division of Forestry	West Virginia DOF	Breeding

Pinus strobus	Eastern white pine	Wisconsin Department of Natural Resources	Wisconsin DNR	Breeding
Pinus strobus	Eastern white pine	North Carolina Forest Service	Goldsboro Forestry Center	Breeding/Testing
Pinus strobus	White pine	Virginia DOF	Virginia DOF	Breeding
Pinus strobus	Eastern White Pine	Tennessee Division of Forestry	Tennessee Department of Agriculture	Breeding/Seed Production
Pinus sylvestris	Scots pine	New York State Dept. of Environmental Conservation	New York DEC	Breeding
Pinus taeda	Loblolly pine	NCSU Cooperative Tree Improvement Program	North Carolina State University	Breeding
Pinus taeda	Loblolly pine	Southern Institute of Forest Genetics	USFS SRS	Breeding
Pinus taeda	Loblolly pine	The Cooperative Forest Genetics Research Program	University of Florida	Breeding
Pinus taeda	Loblolly pine	USFS Region 8	USFS Region 8	Restoration/Regeneration
Pinus taeda	loblolly pine	UT Tree Improvement Program	The University of Tennessee	Seed orchard
Pinus taeda	Loblolly pine	Western Gulf Cooperative Tree Improvement Program	Texas A&M University	Breeding
Pinus taeda	Loblolly pine	Arborgen	Arborgen	Breeding
Pinus taeda	Loblolly pine	Weyerhaeuser	Weyerhaeuser	Breeding
Pinus taeda	Loblolly pine	Delaware Division of Forestry	Delaware DOF	Breeding
Pinus taeda	Loblolly pine	Kentucky Division of Forestry	Kentucky DF	Breeding
Pinus taeda	Loblolly pine	Maryland Dept. of Natural Resources	Maryland DNR	Breeding
Pinus taeda	Loblolly pine	North Carolina Forest Service	Goldsboro Forestry Center	Breeding/Testing
Pinus taeda	Loblolly Pine	Tennessee Division of Forestry	Tennessee Department of Agriculture	Breeding/Seed Production
Pinus virginiana	Virginia pine	Christmas Tree Genetics Program	North Carolina State University	Breeding
Pinus virginiana	Virginia pine	USFS Region 8	USFS Region 8	Restoration/Regeneration
Pinus virginiana	Virginia pine	UT Tree Improvement Program	The University of Tennessee	Seed orchard
Pinus virginiana	Virginia pine	Western Gulf Cooperative Tree Improvement Program	Texas A&M University	Tested orchard
Pinus virginiana	Virginia pine	North Carolina Forest Service	Goldsboro Forestry Center	Breeding/Testing
Pinus virginiana	Virginia Pine	Tennessee Division of Forestry	Tennessee Department of Agriculture	Seed Production
Pinus X spp.	Pine hybrids	Southern Institute of Forest Genetics	USFS SRS	Breeding
Pittosporum hosmeri	ho'awa	Hawaii Island Native Seed Bank Cooperative	The Hawai`i Forest Institute	Restoration/Regeneration
Platanus occidentalis	Sycamore	Western Gulf Cooperative Tree Improvement Program	Texas A&M University	Tested orchard
Platanus occidentalis	Sycamore	North Carolina Forest Service	Goldsboro Forestry Center	Breeding/Restoration/Regeneration
Populus deltoides	Eastern cottonwood	Arborgen	Arborgen	Breeding
Populus hybrid		Arborgen	Arborgen	Breeding

Populus spp.		GreenWood Resources	GreenWood Resources	Breeding
Prunus angustifolia	Chickasaw Plum	Tennessee Division of Forestry	Tennessee Department of Agriculture	Seed Production
Prunus serotina	Black cherry	Hardwood Tree Improvement and Regeneration Center	Purdue & USFS	Breeding
Prunus serotina	black cherry	UT Tree Improvement Program	The University of Tennessee	Seed orchard
Prunus serotina	Black cherry	Indiana Department of Natural Resources	Indiana DNR	Breeding
Prunus serotina	Black cherry	Pennsylvania Dept. of Conservation and Natural Resources	Pennsylvania DCNR	Breeding
Pseudotsuga macrocarpa	Bigcone Douglas-fir	USFS Region 5	USFS Region 5	Restoration/Regeneration
Pseudotsuga menziesii	Douglas-fir	Inland Empire Tree Improvement Cooperative	University of Idaho	Breeding
Pseudotsuga menziesii	Douglas-fir	North Sierra Tree Improvement Association		Breeding
Pseudotsuga menziesii	Douglas-fir	Northwest Tree Improvement Cooperative	Oregon State University	Breeding
Pseudotsuga menziesii	Douglas-fir	USFS Region 1	USFS Region 1	Restoration/Regeneration
Pseudotsuga menziesii	Douglas-fir	USFS Region 2	USFS Region 1	Restoration/Regeneration
Pseudotsuga menziesii	Douglas-fir	USFS Region 3	USFS Region 1	Restoration/Regeneration
Pseudotsuga menziesii	Douglas-fir	USFS Region 4	USFS Region 1	Restoration/Regeneration
Pseudotsuga menziesii	Douglas-fir	USFS Region 5	USFS Region 5	Breeding
Pseudotsuga menziesii	Douglas-fir	USFS Region 6	USFS Region 6	Breeding
Psuedotsuga menziesii	Douglas-fir	Weyerhaeuser	Weyerhaeuser	Breeding
Quercus accutissima	Sawtooth Oak	Tennessee Division of Forestry	Tennessee Department of Agriculture	Seed Production
Quercus acutissima	Sawtooth oak	Kentucky Division of Forestry	Kentucky DF	Breeding
Quercus acutissima	Sawtooth oak	Indiana Department of Natural Resources	Indiana DNR	Breeding
Quercus acutissima	Sawtooth oak	Maryland Dept. of Natural Resources	Maryland DNR	Breeding
Quercus alba	White oak	Hardwood Tree Improvement and Regeneration Center	Purdue & USFS	Breeding
Quercus alba	White oak	USFS Region 8	USFS Region 8	Restoration/Regeneration
Quercus alba	white oak	UT Tree Improvement Program	The University of Tennessee	Testing/Seed orchard/mapping population
Quercus alba	White oak	Illinois Department of Natural Resources	Illinois DNR	Breeding
Quercus alba	White oak	Indiana Department of Natural Resources	Indiana DNR	Breeding
Quercus alba	White oak	North Carolina Forest Service	Goldsboro Forestry Center	Testing
Quercus alba	White Oak	Tennessee Division of Forestry	Tennessee Department of Agriculture	Seed Production
Quercus bicolor	swamp white oak	UT Tree Improvement Program	The University of Tennessee	Conservation/seed orchard

Quercus bicolor	Swamp white oak	Illinois Department of Natural Resources	Illinois DNR	Breeding
Quercus bicolor	Swamp white oak	Indiana Department of Natural Resources	Indiana DNR	Breeding
Quercus falcata	southern red oak	UT Tree Improvement Program	The University of Tennessee	Testing
Quercus falcata	Southern Red Oak	Tennessee Division of Forestry	Tennessee Department of Agriculture	Seed Production
Quercus lyrata	overcup oak	UT Tree Improvement Program	The University of Tennessee	Testing
Quercus macrocarpa	bur oak	UT Tree Improvement Program	The University of Tennessee	Testing
Quercus macrocarpa	bur oak	Illinois Department of Natural Resources	Illinois DNR	Breeding
Quercus macrocarpa	Bur oak	Indiana Department of Natural Resources	Indiana DNR	Breeding
Quercus michauxii	swamp chestnut oak	UT Tree Improvement Program	The University of Tennessee	Testing
Quercus michauxii	Swamp chestnut oak	Kentucky Division of Forestry	Kentucky DF	Breeding
Quercus muehlenbergii	chinkapin oak	UT Tree Improvement Program	The University of Tennessee	Seed orchard
Quercus nigra	water oak	UT Tree Improvement Program	The University of Tennessee	Testing
Quercus nigra	Water/Willow oak	Western Gulf Cooperative Tree Improvement Program	Texas A&M University	Tested orchard
Quercus nuttalli	Nuttall Oak	Tennessee Division of Forestry	Tennessee Department of Agriculture	Seed Production
Quercus pagoda	cherrybark oak	UT Tree Improvement Program	The University of Tennessee	Testing
Quercus pagoda	Cherrybark oak	Western Gulf Cooperative Tree Improvement Program	Texas A&M University	Tested orchard
Quercus pagoda	Cherrybark oak	Indiana Department of Natural Resources	Indiana DNR	Breeding
Quercus pagoda	Cherrybark Oak	Tennessee Division of Forestry	Tennessee Department of Agriculture	Seed Production
Quercus phellos	willow oak	UT Tree Improvement Program	The University of Tennessee	Seed orchard
Quercus prinus	chestnut oak	UT Tree Improvement Program	The University of Tennessee	Testing
Quercus rubra	Northern red oak	Hardwood Tree Improvement and Regeneration Center	Purdue & USFS	Breeding
Quercus rubra	Northen red oak	USFS Region 8	USFS Region 8	Restoration/Regeneration
Quercus rubra	northern red oak	UT Tree Improvement Program	The University of Tennessee	Testing/Seed orchard/mapping population
Quercus rubra	Northern red oak	Illinois Department of Natural Resources	Illinois DNR	Breeding
Quercus rubra	Northern red oak	Indiana Department of Natural Resources	Indiana DNR	Breeding
Quercus rubra	Northern red oak	Pennsylvania Dept. of Conservation and Natural Resources	Pennsylvania DCNR	Breeding
Quercus rubra	Northern red oak	Wisconsin Department of Natural Resources	Wisconsin DNR	Breeding
Quercus rubra	Northern red oak	North Carolina Forest Service	Goldsboro Forestry Center	Breeding/Regeneration
Quercus rubra	Northern Red Oak	Tennessee Division of Forestry	Tennessee Department of Agriculture	Seed Production
Quercus shumardii	Shumard oak	UT Tree Improvement Program	The University of Tennessee	Testiing

Quercus stellata	post oak	UT Tree Improvement Program	The University of Tennessee	Testing
Quercus stellata var. margaretta	sand post oack	UT Tree Improvement Program	The University of Tennessee	Conservation
Quercus texana	Nuttall oak	Western Gulf Cooperative Tree Improvement Program	Texas A&M University	Tested orchard
Quercus velutina	black oak	UT Tree Improvement Program	The University of Tennessee	Testing
Robinia pseudoacacia	Black locust	Pennsylvania Dept. of Conservation and Natural Resources	Pennsylvania DCNR	Breeding
Sequoiadendron giganteum	Giant sequoia	USFS Region 5	USFS Region 5	Restoration/Regeneration
Sophora chrysophylla	mamane	Hawaii Island Native Seed Bank Cooperative	The Hawai`i Forest Institute	Restoration/Regeneration
Taxodium disticum	baldcypress	UT Tree Improvement Program	The University of Tennessee	Testing/seed orchard
Taxodium disticum var. ascendens	pondcypress	UT Tree Improvement Program	The University of Tennessee	Testing
Thuja occidentalis	Northern white-cedar	Indiana Department of Natural Resources	Indiana DNR	Breeding
Tsuga canadensis	Eastern hemlock	CAMCORE	Camcore - USFS S&PF	Conservation
Tsuga canadensis	eastern hemlock	UT Tree Improvement Program	The University of Tennessee	Testing
Tsuga caroliniana	Carolina hemlock	CAMCORE	Camcore - USFS S&PF	Conservation
Tsuga heterophylla	Western Hemlock	Northwest Tree Improvement Cooperative	Oregon State University	Breeding
Tsuga mertensiana	Mountain hemlock	USFS Region 5	USFS Region 5	Restoration/Regeneration
Tsuga mertensiana	Mountain hemlock	USFS Region 6	USFS Region 6	Restoration/Regeneration
Tsuga spp.	Hemlock	US National Arboretum	USDA-ARS	Breeding
Ulmus americana	American elm	USFS NRS - Delaware	USFS R&D	Breeding
Ulmus spp.	Elm	US National Arboretum	USDA-ARS	Breeding

Chapter 4. The State of Use and Sustainable Management of Forest Genetic Resources

Many timber species have some sort of breeding program in the US; typically these species are fast growing conifers, high value hardwoods, or fast growing hardwoods such as poplar.

Presently there are at least 150 "public" or cooperative breeding programs, representing over 70 species in the U.S. (Table 10). Many of these programs are part of the USDA Forest Service or are based at universities. The university-based programs tend to be cooperative breeding programs that are supported by government and industry partners, these include:

- NCSU Cooperative Tree Improvement Program (http://www.treeimprovement.org/)
- Western Gulf Forest Tree Improvement Program (http://txforestservice.tamu.edu/main/article.aspx?id=1687)
- Cooperative Forest Genetics Research Program (http://www.sfrc.ufl.edu/cfgrp/overview.shtml)
- Northwest Tree Improvement Cooperative (http://www.fsl.orst.edu/nwtic/)
- Inland Empire Tree Improvement Cooperative (http://www.cnr.uidaho.edu/ietic/)
- Minnesota Tree Improvement Cooperative (http://mtic.cfans.umn.edu/)
- University of Tennessee Tree Improvement Program (http://treeimprovement.utk.edu/home.htm)
- Hardwood Tree Improvement and Regeneration Center (http://www.htirc.org/)

There are also private companies that have forest tree breeding programs, including:

- Arborgen (http://www.arborgen.com/) primarily breeds *Pinus taeda, P. elliottii, Populus deltoids*, *Populus* hybrids, *Liquidambar styraciflua*, and *Eucalyptus.*
- GreenWood Resources (http://www.greenwoodresources.com/) breeds *Populus*
- Weyerhaeuser – (http://www.weyerhaeuser.com/) breeds *Pinus taeda, Pinus elliottii,* and *Psuedotsuga menziesii.*

Many of the companies involved with the university cooperatives have, in the past, run separate testing programs to step up gains from the cooperatives. This activity has declined with the advent of the vertically integrated companies spinning off their land holdings into Timber Investment Management Organizations (TIMOs) or Real Estate Investment Trusts (REITs) for tax reasons.

Practically all these breeding programs recognize the need to delineate breeding zones and typically have breeding populations for each zone or combination of zones. Effective population sizes of the cooperative breeding programs tend to be in the hundreds (Johnson et al. 2001), thus insuring that most of genetic variation is maintained; although rare low-frequency alleles could be lost. The numbers of clones used in seed orchards tend to be of sufficient size to maintain levels of genetic variation similar to native populations (Johnson & Lipow 2002).

The university-industry cooperatives all strive to increase growth rates and also look at health, disease resistance and wood quality. The federal programs stress adapted populations. For species that are under severe pressure from disease; disease resistance is the primary trait (e.g. chestnut, elm, and ash).

For nearly all these species, improved seed and the resulting seedlings are the means of propagation. Ornamental programs (e.g., those at the US National Arboretum) are the exception where clones are typically deployed. While there has been a movement to move to clonal forestry to increase gains, less than 5% of the growing stock is clonal propagules.

With the exception of some eucalyptus programs and hybrid back crossing programs, most U.S. breeding programs deal with native tree species.

Chapter 5: The State of National Programmes, Research, Education, Training and Legislation

National Programmes

There is no single national forest gene conservation program in the United States like that for agricultural crops (NPGS). However, there are federal programs that are national in scope (USDA Forest Service and Seeds of Success); as well as the Botanic Gardens Conservation International U.S. (described in Chapter 3).

Education and Training

At present, there are no U.S. universities programs in forest genetic resource management, per se, but a number of universities offer programs in forest genetics; these include:

North Carolina State University
Purdue University
Penn State University
Oregon State University
University of Florida
University of Minnesota

In addition, many universities offer training in botany, forestry, genetics, plant physiology, conservation biology, taxonomy, statistics, and other subjects related to the plant sciences are available at numerous institutions. Over 50 institutions of higher learning are accredited by the Society of American Foresters; these can be found at http://www.safnet.org/education/2012_accreditation_list.pdf.

Chapter 6: The State of Regional and International Collaboration

The Forest Genetic Resources Working Group (FGRWG) of the FAO North American Forestry Commission is a primary venue for the North American countries (Mexico, USA, and Canada) coordinate and communicate their forest gene conservation activities. In addition, scientists and administrators associated with the U.S., Canadian and Mexican plant genetic resources programs have a history of bilateral cooperation on virtually all aspects of genetic resources preservation and utilization. Individuals from these programs routinely communicate. Germplasm and data are freely exchanged among the countries.

In a broader context, the US has considerable collaborative efforts with plant material, especially those efforts that have connections to the agricultural and landscape horticultural fields and come under the USDA ARS National Plant Germplasm System. These collaborative efforts are thoroughly discussed in Country Report on the State of Plant Genetic Resources for Food and Agriculture: United States of America. The USDA Forest Service National Seed Laboratory (http://www.nsl.fs.fed.us/) in a key contact point for USDA Forest Service seed.

Chapter 7: Access to Forest Genetic Resources and Sharing of Benefits Arising from their Use to Food Security, Poverty Alleviation and Sustainable Development

Because the *ex situ* forest genetic resources are scattered among various programs, there is no single point within the US that directs exchange of germplasm. While much of the data on ex situ resources can be found in data repositories (Germplasm Resources Information Network (GRIN), and Botanic Gardens Conservation International – U.S.), the curators of the germplasm represent a wide variety of organizations. The two USDA agencies with primary responsibility for conserving forest genetic resources (Agricultural Research Service and Forest Service) have an open policy for sharing genetic resources. Likewise, the BLM's Seeds of Success Program's collections have a liberal sharing policy for a large portion of their collections since it is kept within the ARS National Plant Germplasm System.

Chapter 8: The Contribution of Forest Genetic Resource Management to Food security and Sustainable Development

The crucial role that plant genetic resources play in agricultural sustainability, food security, economic development and poverty alleviation has been well documented. Its importance will not diminish in the future and in all likelihood will increase (e.g., Day-Rubenstein et al. 2006). Genetic diversity must be preserved for current and future use, but simple preservation is not enough. If germplasm is not readily available for use, resources expended to preserve it will be wasted. Forest genetic resources are important sources for a number of food crops that include mast crops (e.g., *Carya* spp., *Castanea dentata*., *Juglans* spp. and *Pinus* spp.) and fruit trees (e.g. *Asimina triloba*, *Diospyros virginiana* and *Prunus* spp.), in addition to the many shrubs and herbs found in forests. Many of these crops are of special importance to the Native American population in the US.

Literature Cited

Antonovics J, Primack RB. 1982. Experimental ecological genetics in Plantago. VI: the demography of seedling transplants of P. lanceolata. Journal of Ecology 70:55–75.

Aukema JE, McCullough DG, Von Holle B, Liebhold AM, Britton K , Frankel SJ. 2010. Historical Accumulation of Nonindigenous Forest Pests in the Continental United States. BioScience 60 (11): 886-897.

Bailey RG. 1989. Explanatory supplement to ecoregions map of the continents. Environmental Conservation 16: 307-309. With separate map at 1:30,000,000.

Clausen J, Keck DD, Hiesey WM. 1940. Experimental studies on the nature of species. I. Effect of varied environments on western North American plants. Washington (DC): Carnegie Institution of Washington Publication 520.

Day-Rubenstein, K, Smale M, Widrlechner MP. 2006. Demand for genetic resources and the U.S. National Plant Germplasm System. Crop Sci. 46:1021-1031.

Eyre FH, ed. 1980. Forest cover types of the United States and Canada. Bethesda, MD: Society of American Foresters. 148 p. 1 map sheet.

Frank B. 1951. Southern pines from different geographic sources show different responses to low temperatures. Journal of Forestry 49:915–916.

Hamann A, Koshy MP, Namkoong G, Ying CC. 2000. Genotype×environment interactions in Alnus rubra: developing seed zones and seed-transfer guidelines with spatial statistics and GIS. Forest Ecology and Management 136:107–119.

Hamrick JL, Milton JB, Linhart YB. 1981. Levels of Genetic Variation in Trees: Influence of life history characteristics. In: MT Conkle, Technical coordinator. Proceeding of the symposium on isozymes of North American forest trees and insects, July 27, 1979. Berkeley , CA. Gen. Tech. Rep. PSW-GTR-48.

Hamrick JL, Godt MJW, Sherman-Broyles SL. 1992. Factors influencing levels of genetic diversity in woody plant species. New Forests 6: 95-124.

Harry DE, Jenkinson JL, Kinloch BB. 1983. Early growth of sugar pine from an elevational transect. Forest Science 29:660–669.

Hedrick PW, Miller PS. 1992. Conservation genetics: techniques and fundamentals. Ecological Applications. 2: 30-46.

Hereford J. 2009. A quantitative survey of local adaptation and fitness trade-offs. American Naturalist 173:579–588.

Howard JL. 2007. U.S. timber production, trade, consumption and price statistics 1965-2005. Research Paper FPL-RP-637. Madison, WI: US Department of Agriculture, Forest Service, Forest Products Lab. 91 p.

Hughes JB, Daily GC, Ehrlich PR. 1997. Population diversity: its extent and extinction. Science. 278: 689-692.

Johnson R, Lipow S. 2002. Compatibility of breeding for increased wood production and long-term sustainability: the genetic variation of seed orchard seed and associated risks. In: Proceedings from the Wood Compatibility Initiative Workshop, number 18. p 169-179.

Johnson R, St. Clair B, Lipow S. 2001. Genetic Conservation in Applied Tree Breeding Programs. In: Proceedings: ITTO Conference on in situ and ex situ conservation of commercial tropical trees. June 11-13, 2001. Yogyakarta, Indonesia.

Johnson R, Stritch L, Olwell L, Lambert S, Horning ME, Cronn R. 2010. What are the best seed sources for ecosystem restoration on BLM and USFS lands? Native Plants Journal 11(2):117–131.

Kramer A, Hird A, Shaw K, Dosmann M, Mims R. 2011. Conserving North America's Threatened Plants: Progress report on Target 8 of the Global Strategy for Plant Conservation. Botanic Gardens Conservation International U.S. http://www.bgci.org/usa/NACA2010report

Linhart YB, Grant MC. 1996. Evolutionary significance of local genetic differentiation in plants. Annual Review of Ecology and Systematics 27:237–277.

Little EL Jr. 1979. U.S.D.A. Agriculture Handbook 541. Forest Service, U.S.D.A., Washington, D.C. 375 p.

Moritz C. 2002. Strategies to protect biological diversity and the evolutionary processes that sustain it. Systematic Biology. 51: 238-254.

Munger TT, Morris WG. 1937. Growth of Douglas fir trees of known seed source. Washington (DC): United States Department of Agriculture. Technical Bulletin 537. 40 p.

Mylecraine KA, Kuser JE, Zimmermann GL, Smouse PE. 2005. Rangewide provenance variation in Atlantic white-cedar (Chamaecyparis thyoides): early survival and growth in New Jersey and North Carolina plantations. Forest Ecology and Management 216:91–104.

NatureServe. 2009. NatureServe Central Databases – 1/28/09. NatureServe, Arlington, VA. (Metadata on file with Curtis H. Flather, Rocky Mountain Research Station, Fort Collins, CO).

O'Brian EK, Krauss SL. 2010. Testing the Home-Site Advantage in Forest Trees on Disturbed and Undisturbed Sites. Restoration Ecology 18 (3):359–372.

Randall WK. 1996. Forest tree seed zones for western Oregon. Salem (OR): Oregon Department of Forestry.

Randall WK, Berrang P. 2002. Washington tree seed transfer zones. Olympia (WA): Washington Department of Natural Resources.

Rehfeldt GE. 1994. Evolutionary genetics, the biological species, and the ecology of interior cedar-hemlock forests. In: Proceedings of interior cedar-hemlock-white pine forests: ecology and management; 1993 Mar 2–4; Spokane, Washington. Pullman (WA): Washington State University. p 91–100.

Smith,W.B, tech. coord; Miles PD, data coord; Perry CH, map coord.; Pugh SA, Data CD coord. 2009. Forest Resources of the United States, 2007. Gen. Tech. Rep. WO-78. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 336 p.

Schmidtling RC. 2001. Southern pine seed sources. Ashville (NC): USDA Forest Service, Southern Forest Research Station. General Technical Report SRS-44.

Sork VL, Stowe KA, Hochwender C. 1993. Evidence for local adaptation in closely adjacent subpopulations of northern red oak (Quercus rubra L.) expressed as resistance to herbivores. American Naturalist 142:359–367.

Soulé ME, Mills LS. 1998. No need to isolate genetics. Science. 282: 1658-1659.

Squillace AE, Silen RR. 1962. Racial variation in ponderosa pine. Forest Science, Monograph 2.

Theobald DM. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. Ecology and Society. 10(1): 32.

Tu M. 2010. Assessment and Recommendations for Involving Volunteers in Native Seed Collection for Restoration Projects on National Wildlife Refuges – Pacific Region (Region 1). Report to the USFWS National Wildlife Refuge System, National Invasive Species Program. 51 pages with Appendices.

United States Department of Agriculture. 2010. Major Forest Insect and Disease Conditions in the United States: 2009 Update. G Man, complier. USDA Forest Service FS-952. July 2010.

United States Department of Agriculture. 2011. National Report on Sustainable Forests – 2010. USDA Forest Service FS-979. June 2011.

Wakely P. 1944. Geographic sources of loblolly pine. Journal of Forestry 42:23–32.

Wright JW. 2007. Local adaptation to serpentine soils in Pinus ponderosa. Plant and Soil 293:209–217.

Wu HX, Ying CC. 2004. Geographic pattern of local optimality in natural populations of lodgepole pine. Forest Ecology and Management 194:177–198.

Xie C-Y, Ying CC. 1993. Geographic variation of grand fir (Abies grandis) in the Pacific coast region. Canadian Journal of Forest Research 23:1065–1072.

Xie C-Y, Ying CC. 1995. Genetic architecture and adaptive landscape of interior lodgepole pine (Pinus contorta ssp. latifolia) in Canada. Canadian Journal of Forest Research 25:2010–2021.

Ying CC, Hunt RS. 1987. Stability of resistance among Pinus contorta provenances to Lophodermella concolor needle cast. Canadian Journal of Forest Research 17:1596–1601.

Ying CC, Liang Q. 1994. Geographic pattern of adaptive variation of lodgepole pine (Pinus contorta Dougl.) with the species' coastal range: field performance at age 20 years. Forest Ecology and Management 67:281–298.

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