Tree Planters' Notes

United States Department of Agriculture
Forest Service

Fall 2012
Volume 55, No. 2

***Tree Planters' Notes* (TPN) is dedicated to technology transfer and publication of information relating to nursery production and outplanting of trees and shrubs for reforestation, restoration, and conservation.**

TPN is sponsored by the Cooperative Forestry Staff of the U.S. Department of Agriculture (USDA), Forest Service, State and Private Forestry Deputy Area, in Washington, DC. The Secretary of Agriculture has determined that the publication of this periodical is necessary in the transaction of public business required by law of this Department.

Editor: Diane L. Haase

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Printed on recycled paper.

Fall 2012

Dear TPN Reader

This Fall 2012 issue of *Tree Planters' Notes* (TPN) is packed with interesting and useful articles, including profiles of tree planting activities in three more States (New York, Nebraska, and Virginia); summaries of research and management activities underway in response to white pine blister rust and emerald ash borer; the effects of soil additives, root, dips, tree shelters, and wick irrigation on subsequent outplanting performance; and the laws governing reforestation on Federal lands.

The TPN subscription database has now been completely overhauled. Subscribers were required to renew their subscriptions, even though TPN remains a free publication of the Forest Service. If you received a postcard notifying you that your subscription expired, or if you would like to submit a new subscription, you can do so online at http://www.RNGR.net/subscribe. Electronic subscriptions are available for our readers who wish to be notified via e-mail when TPN has been posted to the RNGR Web site.

All previous issues of TPN (dating back to 1950) are available online at http://www.RNGR.net/publications/tpn. Please notify me if you notice any errors or omissions, and I will make every effort to correct them. In fact, Justin Davis contacted me this summer, seeking a copy of an article that his grandfather had published in the May 1971 issue of TPN entitled "Forecasting Weather Favorable for Fusiform Rust In-fection." For some reason, out of the hundreds of TPN articles that have been scanned and posted to the RNGR Web site, this one had been overlooked. I contacted my colleague George Hernandez, and he found a hard copy of it immediately. In less than 24 hours, we e-mailed a scanned version to Davis and posted the missing article to the Web site. In an August 18 e-mail, Davis wrote, "I got to present this information to my grandpa today and he was thrilled! His 89th birthday is next Sunday—and I think your help has made him just that much happier."

As always, I encourage you to submit your articles for publication to *Tree Planters' Notes* and to notify me with your suggestions for future articles or authors. Several interesting articles are already in the works for 2013. Until then, happy planting!

Diane L. Haase

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Forestry and Tree Planting in New York State

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Abstract

The New York State tree nursery system was founded in 1902, making it the oldest State-run tree nursery in the United States (Solan 2003). Throughout the decades, the New York State tree nursery has evolved to meet the changing needs of tree planting in New York State. From the first small nurseries in the Adirondacks, the nursery system grew to multiple nurseries across the State that provide trees to fulfill local planting needs. Since the first years of planting trees, when the State's land was barely 20 percent forested, through the huge reforestation programs in the 1930s and to the rising demand for native species in the 21st century, the nursery has grown the trees that have helped transform the State. Today, nearly 63 percent of the State is forested (figure 1) (NYS DEC 2010). As the effects of climate change become increasingly apparent, however, the need for trees and shrubs for replacement and mitigation will undoubtedly grow.

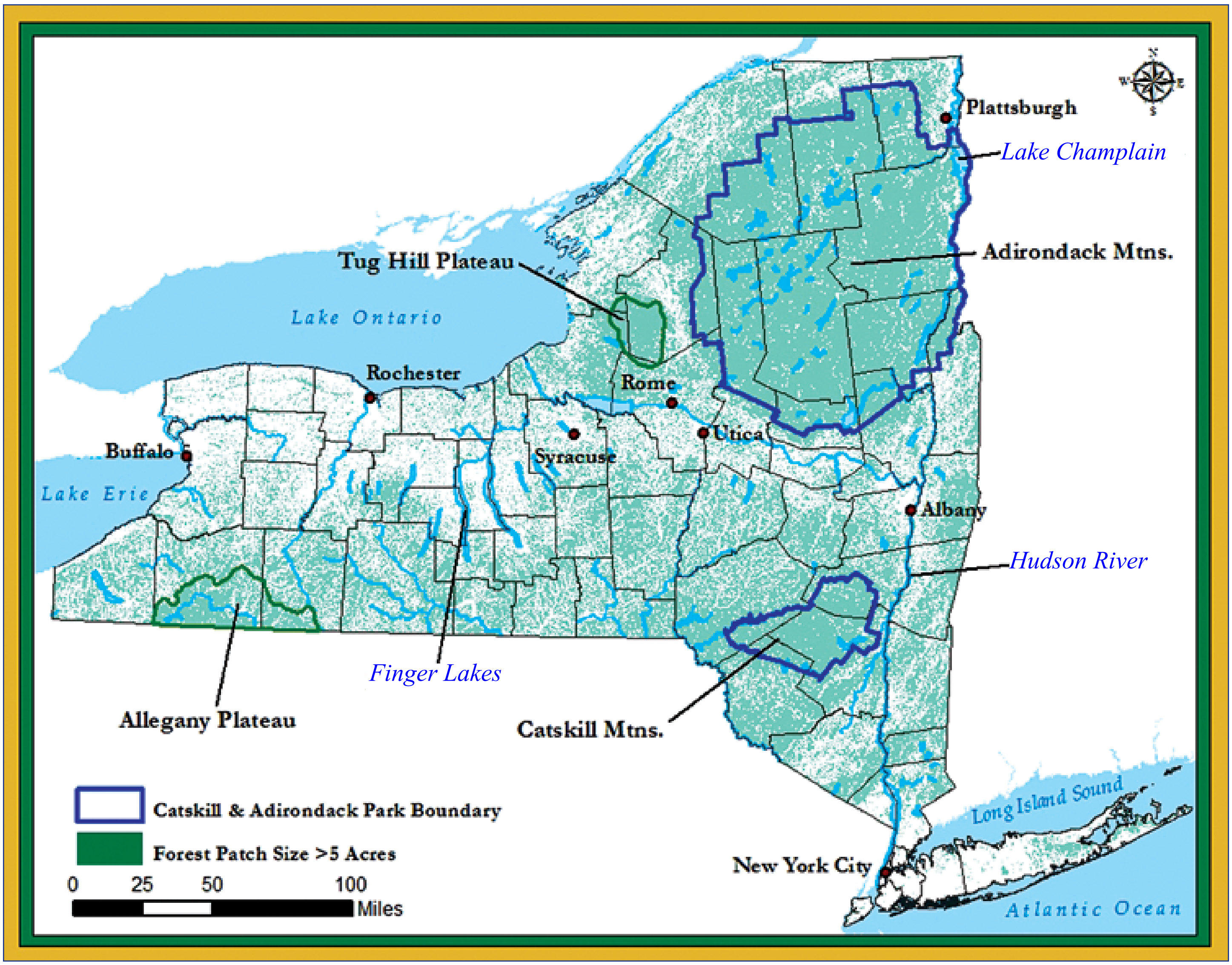

Figure 1. Forested areas in New York State. (Map source: New York State Department of Environmental Conservation [NYS DEC], 2010).

Introduction

New York's forests (figure 1) deliver the ecosystem services our society depends on daily, such as clean air, clean water, flood control, erosion control, carbon sequestration, natural cooling, drought mitigation, aquifer recharge, and a steady source of fresh oxygen from plant photosynthesis. They also produce a wealth of forest products, provide a place for outdoor recreation, and support associated economies.

New York has a long history of responding to challenges regarding the State's important forest resources, from the Forest Preservation Act of 1885 to the 2009 revision of the State's Open Space Conservation Plan (OSP) (NYS DEC 2010). As scientists learn more about the effects of global climate change, it becomes increasingly clear that healthy forests are essential to the Nation's future. The challenge is to keep the forests healthy and vigorous in the face of climate change, exurban sprawl, pests, diseases, and invasive species. By improving sustainable forest management practices, we can keep New York's forests as forests and keep them working for the future of the State and its residents.

Brief Overview of New York State's History, Politics, and Economy Regarding Forest Management

Early Deforestation

New York was one of the first States to have permanent European settlements, beginning in the 1600s with New York City and the Dutch communities along the Hudson River. At the time of European contact, the State was mostly forest. Native Americans had been using fire to manage forests, to encourage early succession communities for game, to maintain open ridge areas for blueberries, and to clear openings for agriculture. Until the opening of the first Erie Canal section from Rome to Utica in 1819, development of much of the State had been limited. The subsequent canal network was surprisingly extensive, considering the rugged topography of much of the State, and opened up vast areas of forested land for logging and agriculture (Verschoor 2006).

Serious deforestation started with the Industrial Revolution, which brought railroads, large-scale industry, and widespread use of steam engines. Logging became almost ruthlessly efficient, and large areas of the Adirondacks and other areas were heavily cut. Some industries were extremely dependent on forest products, notably the numerous tanneries, which used the high tannin bark of hemlocks; this use led to an almost complete removal of this species, especially in the Catskills (Kudish 2000).

By the 1880s, less than 20 percent of New York State was forested, and the remaining uncut forests in the Catskills and Adirondacks were being logged at a fast pace. In 1885, New York created the Forest Preserve Act to protect State-owned lands in the Catskills and Adirondacks from further exploitation (NYS DEC 2010). This act was strengthened in 1894 by an amendment to the New York State Constitution:

> The lands of the State, now owned or hereafter acquired, constituting the forest preserve as now fixed by law, shall be forever kept as wild forest lands. They shall not be leased, sold or exchanged, or be taken by any corporation, public or private, nor shall the timber thereon be sold, removed or destroyed.

The Forest Preserve began with 681,000 acres (275,600 hectares) in the Adirondacks and 34,000 acres (13,760 hectares) in the Catskills. Today there are more than 2.6 million forested acres (1.05 million forested hectares) in the Adirondacks and more than 300,000 acres (121,400 hectares) in the Catskills, held as forever wild lands for New Yorkers. The Forest Preserve is the largest State-designated wilderness in the country and the largest wilderness area east of the Mississippi River (figure 2).

In the 1930s, years of drought resulted in the national climate crisis known as the Dust Bowl—which coincided with the Great Depression. Even in New York, farms failed from drought and millions of agricultural acres were abandoned. Some of this land was in such poor condition that nothing could grow on it.

Bringing Forests Back

Forests in all the Northeastern States were disappearing quickly by the end of the 19th century, but New York was the first State to take measures to reverse this trend toward total forest destruction. In 1901, the Forest, Fish and Game Commission planted the first tree plantation on State land in the Catskills to replace trees that had been burned. Because no North American sources for seedlings were available in large quantities, it was necessary to import seedlings from the huge tree nurseries in Europe. Europeans had long practiced sustainable forestry, growing many tree species, including North American trees such as eastern white pine (*Pinus strobus* L.) and red pine (*P. resinosa* Ait.), in tightly managed tree plantations, where seedlings were planted to replace trees that had been cut. Millions of tree seedlings would be needed to even begin restoring the ravaged forests of New York. The United States needed to develop its own sources of seedlings, grown close to where they would be planted, and free of imported pests and diseases. Federal and State tree nurseries were the best way to supply millions of seedlings at reasonable cost.

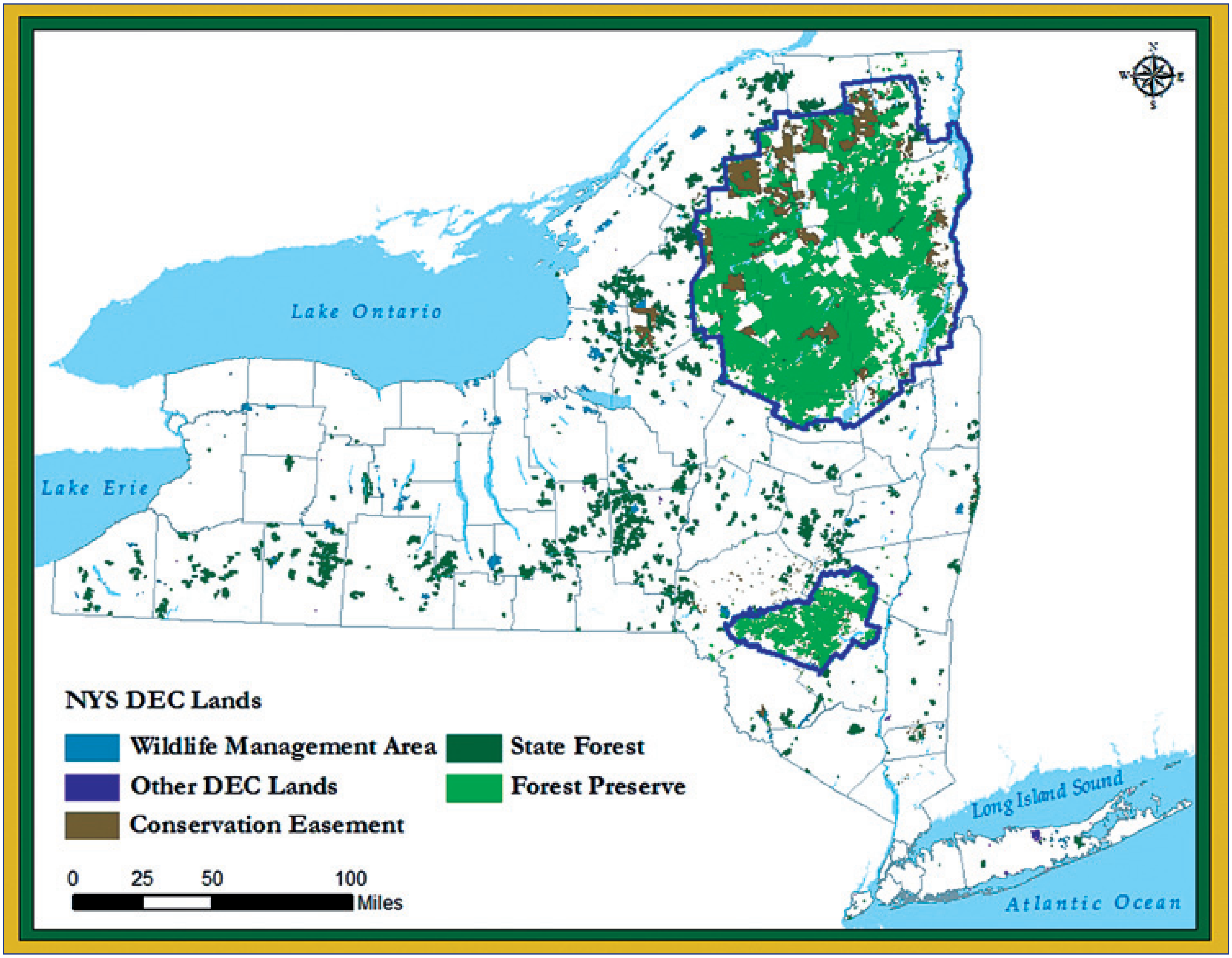

Figure 2. State land and conservation easements managed by the New York State Department of Environmental Conservation. (Map source: NYS DEC, 2012).

Much of the farmland in New York was on marginal land and, as better land became available out West, the agriculture industry began to decline in New York. When the Great Depression hit, many farmers could no longer make a living on their worn out, unproductive land (figure 3). The 1929 State Reforestation Act and the 1931 Hewitt Amendment authorized the Conservation Department to buy land for reforestation purposes (NYS DEC 2010, 2011). These lands were known as State reforestation areas and were the beginning of today's State Forest System in New York. Many of the early reforestation areas were established on some of the worst lands in the State. The Conservation Department began a massive tree-planting program to restore these lands for watershed protection, soil stabilization, flood prevention, and future timber production. Today, these areas are covered with healthy, well-managed State forests. (State Forests are still referred to as reforestation areas as originally defined in legislation.)

New York's Forest Practice Act (FPA) of 1946 recognized the importance and contributions of private forest lands. The FPA program was deemed vital to the interests of the people of New York State to ensure that the practice of forestry would be encouraged, that damage to the environment caused by unplanned and exploitive overcutting might be avoided, and that the industries of the State that are dependent on forest products might be stabilized as much as possible. The act provided free forestry assistance to private landowners. As late as 1970, 1 in 25 forest landowners received program technical assistance each year. Today, that number has declined to 1 in 300 because of decreases in program staffing and a sharp increase in the number of forest owners (NYS DEC 2010).

State funding for tree planting fell victim to the Depression, but the Federal Civilian Conservation Corps (CCC), founded by President Franklin D. Roosevelt in 1933, rescued the tree-planting program in New York. Millions of tree seedlings were planted on the barren soil of the new State reforestation areas, work that provided employment for thousands of young men. Roosevelt was especially interested in reforestation work, having planted his own estate with seedlings from the State tree nursery beginning in 1912. His trips to view CCC projects in New York typically included visits to reforestation areas (figure 4). Plantations consisted mainly of conifers. Hardwoods regenerated naturally but, at the time, were considered much less valuable than softwoods (figure 5).

Figure 3. The droughts that contributed to the 1930s Dust Bowl also affected the Northeastern United States; many farms on already marginal agricultural land turned to sand. (Photo from NYS DEC archives, date unknown).

Figure 4. Franklin Roosevelt visiting a New York State Reforestation Area, circa 1930. (Photo from New York State Museum).

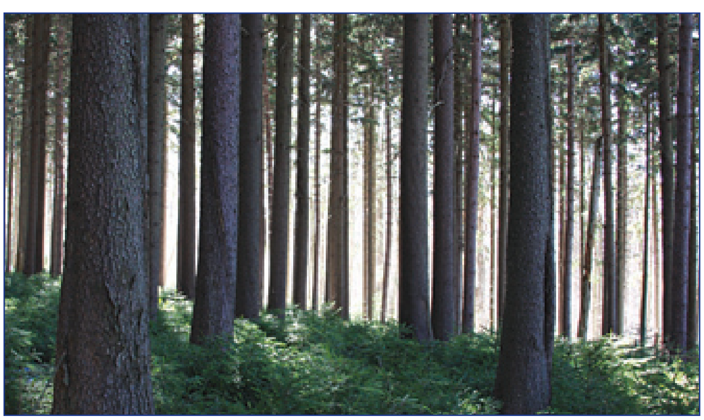

Figure 5. Norway spruce plantation in 2008. (Photo by Justin Perry, NYS DEC).

After World War II, a resurgence of tree planting occurred as more farmland fell vacant. Scientific game management led to the development of State-owned Wildlife Management Areas to provide optimal habitat for game species such as waterfowl and upland birds. The Park and Recreation Land Acquisition Act of 1960 and the Environmental Quality Bond Acts of 1972 and 1986, provided funds for the acquisition of additional State forest lands, including inholdings or parcels adjacent to existing State forests (NYS DEC 2011).

Creation of the Department of Environmental Conservation

In 1970, on the first Earth Day, the New York State Department of Environmental Conservation (DEC) was established. This new agency joined the mission of the old Conservation Department with the missions of State environmental quality bureaus that were part of the Department of Health. Today's DEC manages a variety of programs that protect air, land, and water resources, and the public lands and private forest landowner programs contribute mightily to this effort.

Topography and Climate of New York

The topography of New York reflects its complex geologic history. Nearly all of the State has been glaciated, and some areas are covered with thick glacial till and glacial lake sands and clay. Glacial deposits and soils are thin over the large areas of resistant bedrock, which control the topography.

Elevations range from sea level on the beaches of Long Island up to the 5,344 ft (1,683 m) summit of Mount Marcy in the Adirondack Mountains (figure 6). The Catskill Mountains, composed of resistant sedimentary sandstones and conglomerates, are located at the northeastern corner of the Appalachian plateau. The southernmost part of the State is Long Island, which was formed by a glacial terminal moraine. Most of the good farmland is along river valleys, the Great Lake plains, and the rolling hills of the Allegany Plateau (figure 1), where soils are deepest. These areas were cleared for agriculture relatively early in New York's history; some have been in cultivation since the 1600s.

New York has a humid continental climate with hot summers and cold winters. Much of the State is within U.S. Department of Agriculture (USDA) hardiness zone 5, dropping to zone 4 in the higher elevations and northern areas. The coldest areas are in the central Adirondack Mountains, which fall into zone 3a, with a minimum temperature of -30 to -40 °F (-34 to -40 °C). Water bodies have a considerable influence on New

Figure 6. Mount Joe in the Adirondack Forest Preserve. (Photo by James Sessions, NYS DEC, 2009).

York's climate and vegetation. The moderating effect of the Atlantic Ocean puts Long Island in USDA hardiness zone 7a. The Great Lakes have a strong influence on the climate of western New York, much of which is in zone 6, The Hudson River, the Finger Lakes, Lake Champlain, and the St. Lawrence River extend warmer climate zones into colder high-elevation areas. The 2012 USDA Hardiness Zone map shows a 5 degree Farenheit (2.8 degree Celsius) increase in average temperatures for the State since the last map was published in 1990. This increase has shifted the warmest areas of New York up to zone 7b and the coldest to zone 3b.

Ownership of Forest Land

Of New York's 30.2 million acres of land area (not including interior water bodies or submerged coastal areas), forest land covers 18.95 million acres (7.67 million hectares), or 63 percent. Of this land area, 14.4 million acres (5.8 million hectares), or 76 percent of New York's forest land area, is owned by approximately 687,000 private landowners. The State owns 3.7 million acres (1.5 million hectares) of forest land and owns conservation easements on an additional 900,000 acres (364,220 hectares) of forest land (figure 2).

Forest Types and Their Primary Plant Species

With its wide climate range and varied topography, New York has a rich diversity of forest types and tree species. The present forests in New York began developing after the last glacier started to retreat 15,000 years ago. Nearly all of New York State was scraped over by the glaciers and then covered with a layer of raw glacial debris. As the climate slowly warmed, plants began to migrate north to colonize the barren postglacial landscape. Spruce species were the first to arrive, followed by white pine, hemlock, oak, beech, and, finally, chestnut, which arrived 2,000 years ago.

Major forest-type groups and their respective percent of total forest have changed little in recent decades. New York forest land continues to be dominated by the northern hardwood forest type (maple/beech/birch) (56 percent), followed by the oak/hickory forest type (18 percent) (figure 7). More than 100 species of commercial and noncommercial trees populate New York's forests.

New York forests are mainly of natural origin, meaning they developed from seed dispersed by surrounding mature forest or from seed sources stored in the soil. Fewer than 1 million acres (404,690 hectares) of forest land developed from plantations planted by various landowners, mostly from the 1930s through the 1970s (figure 8). About 350,000 acres (141,640 hectares) of planted acres exist on approximately 750,000 acres (303,510 hectares) of State-owned forest management

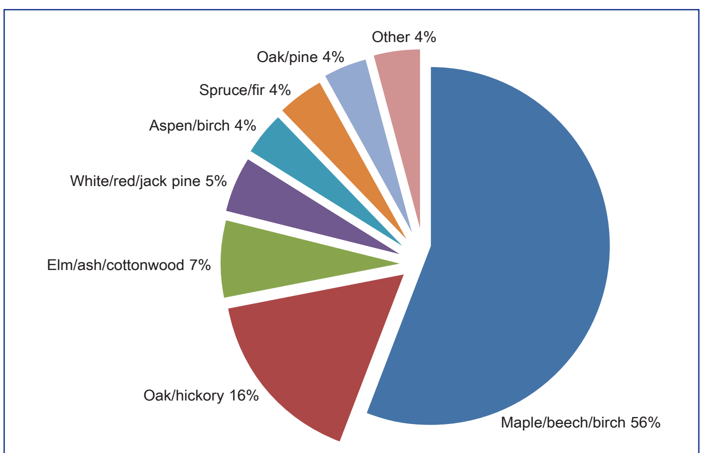

Figure 7. Area of forest land by forest type group. (Data source: NYS DEC, 2010).

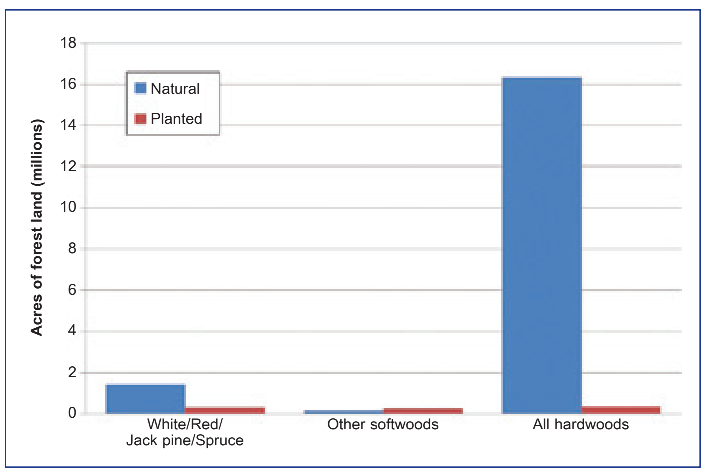

Figure 8. Area of forest land by stand origin. (Data source: NYS DEC, 2010).

land. The number of acres planted has waned substantially in recent decades, and some older plantations are being converted back to a natural forest condition.

Current Forest Restoration Projects

Current day restoration projects are primarily urban and community forestry and riparian buffer restoration projects. The term *urban forestry* still sounds contradictory to some people and yet, streets, parks, yards, and green spaces are where most New Yorkers are exposed to trees and their many benefits (figure 9). The number of community tree programs is increasing as the many benefits of trees are gaining recognition: physical and emotional health, storm water retention, more attractive places to live and visit, and energy savings for heating and cooling of buildings, to name a few (figure 10). The largest and most well-known urban forestry program is New York City's MillionTreesNYC campaign. Launched by the city's Parks Department and the New York Restoration Project, MillionTreesNYC is a collaboration of many partners, including community-based and nonprofit groups; city, State, and Federal agencies; corporations and small businesses; developers, architects, and landscape architects; private-property owners; and many New York residents. Hundreds of other municipalities, from large cities, to small villages, actively manage their community forests across the State.

Figure 9. As more people live in developed cities and communities, the urban forest and its benefits become more essential. (Photo by Mary Kramarchyk, NYS DEC, 2006).

Most communities buy trees directly from private nurseries. Some communities buy smaller, less expensive trees and grow them to the appropriate size for street planting. The State tree nursery works with some communities to provide seedlings that the community or a contracted private nursery grows to the appropriate size for street planting.

The storms and floods of 2011 reinforced one of the stated threats of global climate change—extreme weather events. Modeled after the successful Hudson River Estuary's Trees for Tribs program, New York State DEC's Trees for Tribs program engages volunteers in restoring thousands of feet of streamside buffer through tree planting using native bareroot stock from the State tree nursery (figure 11). The program provides landowners and local governments with low-cost or no-cost native planting materials and free technical assistance. Coordinating with local, Federal, and State agencies, Trees for Tribs focuses on comprehensive watershed restoration designed to protect the green infrastructure, which is the first line of defense against storm and flooding events; it also aims to protect property, water quality, fish, and wildlife. Trees for Tribs promotes best management practices for communities and encourages new programs, policies, and investments in tributary protection.

Figure 10. Street trees reduce heating and cooling costs in buildings and make communities more livable. (Photo by Mary Kramarchyk, NYS DEC, 2006).

Figure 11. The success of Trees for Tribs is the result of partnerships with communities, nonprofit organizations, businesses, private landowners, and volunteers. (Photo by James Clayton, NYS DEC, 2011).

Challenges Facing the State's Trees

Although fire was considered the greatest threat to New York forests 100 years ago, land development and forest pests and diseases are now the biggest threats. Large deer populations have had a major negative effect on forest regeneration and have opened up forest understory areas for colonization by many invasive plants. Climate change is expected to present new challenges and exacerbate threats from existing forest pests.

New York City, as a major port for international trade, has unfortunately been an entry point for many pests and diseases, leading to successive waves of tree species mortality. With the expansion of global trade beginning in the late 19th century, plants from Europe and Asia were imported in huge quantities without regulation or inspection. Chestnut blight was first discovered in 1904 on trees in the Bronx Zoo, followed by white pine blister rust in 1907, found on imported eastern white pine (*Pinus strobus* L.) seedlings. Dutch elm disease, gypsy moth, and a wide range of other pests and diseases continued to arrive in New York during the 20th century, despite the regulation of imported plants and wood products beginning in 1912, with the first Federal plant quarantine act.

Figure 12. Staff setting a sticky trap for emerald ash borer. (Photo from NYS DEC, 2010).

Hemlock wooly adelgid (*Adelges tsugae* Annand) has decimated eastern hemlock (*Tsuga canadensis* [L.] Carr.) populations in southeastern New York and continues to spread. Butternut canker (*Sirococcus clavigignenti-juglandacearum* Nair, Kostichka & Kuntz) has reduced butternut (*Juglands cinerea* L.) to a fraction of its former abundance. Asian longhorned beetle (*Anoplophora glabripennis* [Motschulski]) was discovered in New York City in 1996 and has already destroyed hundreds of trees, especially maples (*Acer* spp.), in the New York metropolitan area. Emerald ash borer (*Agrilus planipennis* Fairmaire), discovered in western New York in 2009, has already been found in numerous other locations throughout the State (figures 12 and 13).

Invasive plants are a major problem in many forests, especially those forests that are close to abundant seed sources, such as forests near urban and suburban areas. Some State forests in heavily populated counties, such as Putnam and Westchester, are heavily infested with invasive ornamental species, notably Japanese barberry (*Berberis thunbergii* DC.), honeysuckles (*Lonicera japonica* Thumb., *L. maackii* [Rupr.] Herder, *L. morrowii* A. Gray [incl. x *bella*]), Oriental bittersweet (*Celastrus orbiculatus* Thunb.), winged burning bush (*Euonymus alatus* [Thunb.] Sieb.), porcelain berry (*Ampelopsis brevipedunculata* [Maxim.] Trautv.), Norway maple (*Acer platanoides* L.), and an ever-increasing number of other invasive species favored by suburban residents.

To date, the effects of climate change in New York have primarily been warmer and shorter winters, along with more extreme precipitation events. The warmer winters are a growing problem for many aspects of forest management. Earlier springs may lengthen the growing season, but the phenology of many tree species is increasingly out of sync with the

Figure 13. Emerald ash borer larva. (Photo from NYS DEC, 2010).

weather. New York is the Nation's second largest producer of maple syrup, but early warm spring conditions can produce early bud break, which prematurely ends the tapping season.

Green Certification of State Forests

New York manages its State forests for a wide diversity of habitats and communities of varying ages and structural diversity, with the goal of having ideal conditions available on the landscape for every indigenous species. Modest planting occurs on State forests to fill gaps in the landscape. New York's State forests are green certified, which means they are managed sustainably (figure 14). The certification guidelines and efforts to fill gaps in the forest cover can come into conflict because green certification guidelines oppose planting in favor of natural regeneration. Sometimes natural regeneration will not result in the desired forest cover type.

The New York State Tree Nursery System

In the past 110 years, the New York State tree nursery system produced more than 1.7 billion seedlings. In the early years, most seedling production was conifer species used for reforestation, primarily eastern white pine (*Pinus strobus* L.), Norway spruce (*Picea abies* [L.] Karst), red pine (*Pinus resinosa* Ait.), Scotch pine (*Pinus sylvestris* L.), and white spruce (*Picea glauca* [Moench] Voss). These seedlings were usually planted in single-species plantations. At the time, conifers were preferred to hardwoods because they had a higher timber value. Conifers were also easier to grow in huge quantities and could better tolerate stressful planting conditions and poor soils.

Figure 14. Brookfield Woods in the green-certified Charles Baker State Forest. (Photo by Wells Horton, 2009).

Coping with the weather is the most difficult aspect of nursery management (figure 15). Irrigation can make up for the shortage of rainfall, but few effective practices prevent damage from too much heat, rain, wind, or snow. Frost heaving is another natural occurrence, which is difficult to control. These conditions can result in significant damage to a crop and little can be done to reduce the loss. This risk is why government agencies, rather than commercial nurseries, have been involved in raising seedlings to meet reforestation and conservation project needs.

Spring seedling harvest usually begins in early April when the ground thaws, but it can vary from year to year depending on weather conditions. A warm, early spring can mean early bud break, whereas a colder spring, when snow is still on the ground in April, sets back harvest and subsequent spring planting operations.

Over the years, the State nursery has developed many propagation techniques and invented specialized equipment, such

Figure 15. Ice storm at the State nursery, 2007. (Photo by James Clayton, NYS DEC).

as a tractor-mounted root pruner using discarded trimming knives from nearby paper mills. Another innovation, which nursery staff invented and built, was lightweight weeding carts, which are still used today (Evans and Swartz 1977).

The State Nursery Today

In 1970, all State nursery operations were consolidated to one location. The present State nursery, located in Saratoga Springs, NY, was started in 1911 on land that the State bought to protect the famous Saratoga mineral springs (figure 16). Today, the nursery has 250 acres split between two nearby parcels: the 150-acre (60.7-hectare) office site on Route 50 and the 100-acre (40.5-hectare) Route 9 production area, located within Saratoga State Park.

The Route 50 section contains the offices and operating facilities, along with storage buildings, garages, four greenhouses, 12 acres (4.9 hectares) of planting beds, seed production areas, and about 75 acres (30.4 hectares) of forest. The operating facilities include a production line for grading and packing seedlings, a cooler for seedling storage, and the largest and most completely equipped seed-processing plant in the Northeast. The seed plant building also houses a seed cooler for long-term seed storage. The Route 9 area mostly includes planting beds, with one corner dedicated to seed production and cutting stools. Huge white cedar hedges, which border the Route 9 site, have become something of a local landmark. In addition to maintaining the nursery land, the State maintains and uses more than 200 acres (81 hectares) of seed production areas and orchards, located on State forests across the State.

The State nursery produces more than 1.2 million bareroot and container (plug) seedlings for outplanting annually, including about 200,000 seedlings for planting on State forests. At any one time, more than 5 million seedlings, representing at least 50 species, are growing at the nursery (figure 17). Since 1985, the State nursery has filled more than 18,000 orders and provided more than 632,000 seedlings through the School Seedling Program, an education program in which schools receive free seedlings.

The State nursery also processes its own local New York source seed, propagates flowers for department campgrounds and DEC offices, assists many environmental groups and educational institutes with various stages of planting projects, and grows larger potted stock up to 6 ft (1.8 m) in height for DEC-sponsored special projects.

Over the years, the nursery has responded to changing needs of tree- and shrub-planting programs (Verschoor 2007). Although the current 63-percent forest coverage of New York may seem to limit future demands for historically large quantities of reforestation seedlings, the reality is that demand for maintaining forest regeneration is likely to increase by replacing trees killed by forest pests and diseases and replanting areas damaged by storms. In addition, the need for stream protection for water quality and flood mitigation has increased demand for riparian species, such as those planted in the successful Trees for Tribs programs. The expansion of green infrastructure using native plants is opening new areas of opportunity for the nursery to provide local source native plant material. The nursery is currently testing a number of native species for use in green roofs, green walls, and stormwater

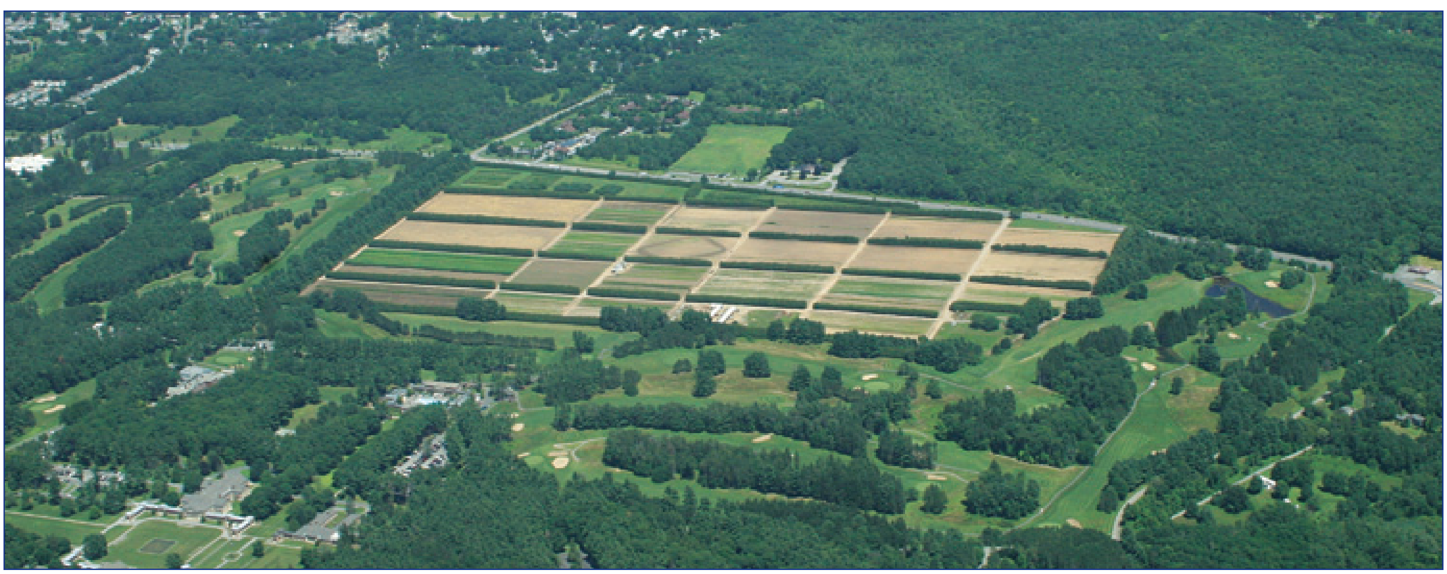

Figure 16. Aerial view of the State nursery in 2011. (Photo by Scott McDonnell, NYS DEC).

Figure 17. Red oak seedlings—one of many species produced at the State nursery. (Photo by Karin Verschoor, NYS DEC, 2006).

infrastructure. After these plants are proven effective, the hope is that commercial nurseries will make them more readily available. The nursery may be vital in introducing previously little known native plant material (for green infrastructure and landscape purposes) to the commercial market, which could significantly reduce the use of invasive plants.

Looking Forward

New York has an abundance of forests. In 2010, New York developed a Forest Action Plan that assessed the status of New York's forests and outlined strategies to address threats. The lack of forests may no longer be a primary concern, but no shortage of threats face New York's forests today. Protecting and improving the health of these forests has been, and continues to be, a multifaceted effort among government, landowners, and the general public. Collectively, these stakeholders are the guardians of New York forests and the many benefits they provide, such as clean air and water, wildlife habitat, a source of natural resources, and a vital component of livable communities.

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Nebraska: The Tree Planters' State

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Abstract

From the ponderosa pine forests of the Panhandle's Pine Ridge to the hardwood forests of the Missouri River bluffs, Nebraska is rich in tree and forest resources. Early settlers, however, encountered a land with few trees. Nebraskans have planted millions of trees since those early days, earning the nickname The Tree Planters' State in the late 1800s. Today, Nebraska has more than 3 million acres of treed land with 516 million trees that represent at least 39 species. Eastern redcedar (*Juniperus virginiana* L.) is the most abundant, followed by ponderosa pine (*Pinus ponderosa* Lawson and C. Lawson) and green ash (*Fraxinus pennsylvanica* Marsh.). Nebraska has more miles of river than any other State, and nearly two-thirds of its forest land is adjacent to streams and rivers. About 13.3 million trees can be found in Nebraska communities, but that is half of what was present 30 years ago. Several tree-planting programs are under way to reverse this decline. Trees have long been an important component of Nebraskan agriculture, and about 1 million conservation tree seedlings are distributed in the State annually.

Introduction

In the mid-1800s, when the first settlers ventured into the area that is now Nebraska, they encountered a land that was largely void of trees. Trees and forests existed along rivers and streams and in other areas that were protected from frequent prairie fires and were also present in the hills of the State's northwestern corner. Settlers quickly depleted these tree and forest resources. The relative scarcity of trees posed an enormous hardship for settlers—they lacked the materials needed to build homes, barns, wagons, and other everyday items. They adapted in several ways, one of which was to build their homes from Nebraska marble (prairie sod).

Pioneers adapted by planting trees to fulfill other basic needs. Nebraska became known as the Tree Planters' State because residents planted so many trees. When European settlement began, it is likely that trees covered less than 1 million acres, or less than 2 percent of Nebraska's land area. Today, Nebraska has about 3 million acres of land with trees and forests. The increase has occurred because wildfires have been suppressed, forests along rivers and streams have expanded, marginal croplands have been converted to pastures with trees, and because the people who live in Nebraska have planted trees.

Nebraskans have planted woodlots, orchards, firewood plantations, shelterbelts, wildlife habitat, and community forests. Despite a relatively low population, Nebraska is one of the top 10 States in the Nation in the number of communities designated as Tree City USA by the Arbor Day Foundation. In fact, the Arbor Day Foundation was established in Nebraska and has branches in Nebraska City on the eastern border, the Missouri River, and in Lincoln, Nebraska's capital.

Today, trees enhance living conditions on the Great Plains by providing shade, wood products, food, and beauty, and by protecting crops, reducing soil erosion, sheltering farmsteads and livestock, and providing wildlife habitat.

History

Archeologists estimate that humans arrived in Nebraska approximately 10,000 to 25,000 years ago. Before European settlers colonized the Midwest, Native Americans had inhabited the area for thousands of years. The Missouri, Omaha, Oto, and Ponca tribes farmed and hunted along rivers in Nebraska. The Pawnee tribe established agriculture-based settlements along the Platte and Loup Rivers. Wandering tribes, such as the Arapaho and Cheyenne, lived in western and central Nebraska.

In 1803, present-day Nebraska was sold to the United States as part of the Louisiana Purchase. Meriwether Lewis and William Clark were among the first Americans of European descent to visit Nebraska.

Nebraska's first recorded tree planting was by squatter G.B. Lore in 1853. Legal efforts soon followed to encourage more tree planting. Drawn by the promise of free land under the 1862 Homestead Act, many settlers traveled from the East to claim a new life on the Plains. Numerous "timber claims," many of which still exist, were planted by these early settlers to secure legal rights to their homesteaded lands. Early settlers often transported seeds or seedlings hundreds of miles to plant on barren homesteads to protect their homes and crops from the ever-present winds.

Arbor Day, which is celebrated in every State and many foreign countries, began in Nebraska in 1872. According to newspaper reports, Nebraskans planted more than 1 million trees on that one day.

Plantings increased under the Timber Culture Act of 1873, which offered free land to settlers if they planted trees as a part of their homestead (Schmidt and Wardle 1986). Remnants of these homestead plantings remain today throughout Nebraska.

Organized tree distribution began in Nebraska as far back as 1904, when Congressman Moses P. Kincaid introduced a bill (the Kincaid Act) that authorized free distribution of trees west of the 100th meridian. The plan included the western half of Nebraska, and records show that nearly 2 million trees were distributed from the Charles E. Bessey Nursery between 1912 and 1924.

In 1924, the Clarke-McNary Act authorized the U.S. Secretary of Agriculture to cooperate with States to procure, produce, and distribute tree seeds and seedlings to establish windbreaks, shelterbelts, and farm woodlots. More than 100 million Clarke-McNary tree and shrub seedlings were planted for conservation purposes in Nebraska.

The great drought in the 1930s stimulated creation of national programs to plant windbreaks across the Plains to slow the wind and reduce soil erosion. Thousands of miles of windbreaks were planted during this time.

Nebraska's State tree is the eastern cottonwood (*Populus deltoides* Bartram ex Marsh.). This historically significant species provided lumber to construct homes and barns, and to make other improvements. Distinctive trees also served as geographic markers for Native Americans and settlers traveling through the area. Cottonwood is still the primary tree species harvested in the State.

Trees and Nebraska's Economy

Nebraska's forest resources contribute significantly to the State's economy through the harvest and use of commodities, nonmarket environmental services, employment opportunities, and wealth creation. Nebraska's wood products manufacturing industry employs more than 2,300 workers with an output of more than $362 million (Walters and others 2012).

Nebraska's 57 mills processed 4.1 million cubic ft of industrial roundwood in 2006 (Walters and others 2012) (figure 1). More than 89 percent of the industrial roundwood processed by Nebraska mills was cut from Nebraska forests; cottonwood accounted for 83 percent of the total volume processed (Walters and others 2012). Nebraska sawmills processed 19.3 million board ft of saw logs in 2009, a decrease of 16 percent from 2006 (Walters and others 2012). In 2009, 5.6 million cubic ft of wood material was harvested from Nebraska's forests, of which 73 percent was used for primary wood products (Walters and others 2012).

Forest Ownership

Nebraska's forest land is distributed among private owners (85 percent) and public agencies (15 percent). Among private owners are families, corporations, tribes, and associations (figure 2). Although 74 percent of the family forest owners

Figure 1. Cottonwood (shown here), ponderosa pine, and eastern redcedar are the most frequently harvested trees in Nebraska. (Photo from Nebraska Forest Service [NFS], circa 2004).

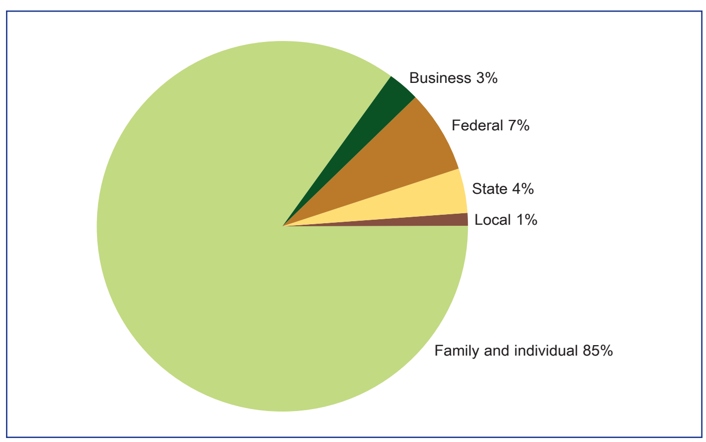

Figure 2. Distribution of Nebraska's forest land by ownership; approximately 85 percent (slightly more than 1 million acres) of Nebraska's forest land is privately owned. (Data source: Meneguzzo and others, 2005).

hold fewer than 10 acres of forest land each, 90 percent of the family forest land is in holdings of 10 acres or greater (Butler 2008).

Nebraska's Forests

Nebraska has 1.5 million acres (607,000 hectares) of forest land, an increase of 200,000 acres (81,000 hectares) since 2005, as defined through the Forest Inventory and Analysis program of the U.S. Department of Agriculture (USDA), Forest Service (figure 3). These forests contain nearly 394 million trees and are a unique mix of vegetation types, including central hardwood forests, ponderosa pine (*Pinus ponderosa* Lawson and C. Lawson) forests, and birch/aspen (*Betula Populus*) forests (Meneguzzo and others 2011). These forest types, combined with elm/ash/cottonwood (*Ulmus*/*Fraxinus*/*Populus*) riparian forests, mixed conifer forests, conservation tree plantings, and urban forests, create a highly diverse and unique array of tree and forest resources growing within an agricultural and range landscape.

In addition to forest land acres, Nebraska has an estimated 1.5 million acres (607,000 hectares) of rural nonforest land (defined as less than 1 acre, less than 120 ft wide, and less than 10-percent stocked), with approximately 119 million live trees across the State. Dominant species in these areas are eastern redcedar (*Juniperus virginiana* L.), Siberian elm (*Ulmus Pumila* L.), hackberry (*Celtis occidentalis* L.), red mulberry (*Morus rubra* L.), and ash *(Fraxinus* spp. L.).

Altogether, Nebraska has approximately 3 million acres (1.2 million hectares) of treed land, including forest land and nonforest land with trees, conservation plantings, and community forests (figure 4).

Coniferous Forests

Nebraska's coniferous forests are composed largely of three species: ponderosa pine, eastern redcedar, and Rocky Mountain juniper (*Juniperus scopulorum* Sarg.).

Ponderosa pine is found in the Pine Ridge, eastward along the Niobrara and Snake Rivers, and in other scattered pockets in western Nebraska, such as the Wildcat Hills south of Scottsbluff. North America's easternmost extensions of ponderosa pine occur in Nebraska, with potentially unique genetic adaptations that may be of value in a changing climate. Rocky Mountain juniper (in western Nebraska) and eastern redcedar (in central Nebraska) are common components of ponderosa pine forests.

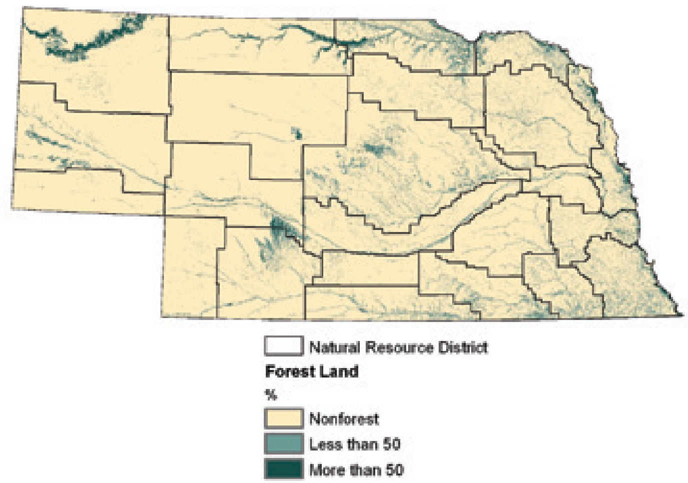

Figure 3. Nebraska's 1.5 million acres of forest land contain nearly 394 million trees. In addition, 1.5 million acres of nonforest land in the State have approximately 119 million trees, with the greatest tree density along the Missouri and Niobrara Rivers and in the Pine Ridge in the Nebraska Panhandle. (Map source: Meneguzzo and others, 2011).

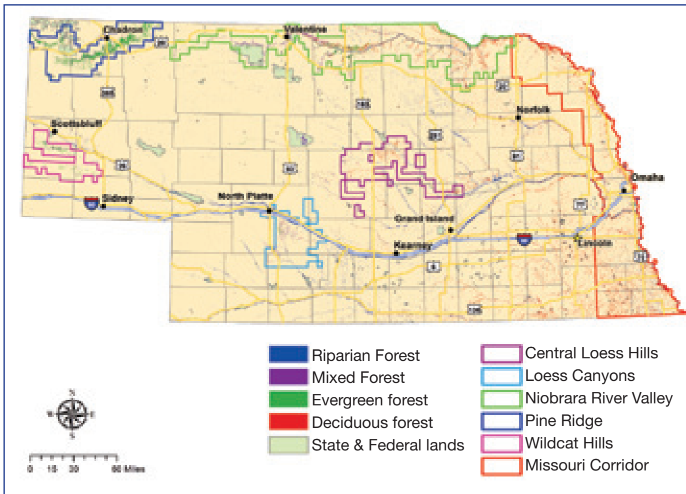

Figure 4. Nebraska's forests and woodland areas extend statewide, from the Pine Ridge in the Panhandle to the Missouri River, which forms the State's eastern border. (Map source: Joe Stansberry, NFS, 2012).

Eastern redcedar is abundant in Nebraska. It is the predominant species in some forested areas and is a common understory tree in conifer and mixed hardwood forests. Between 1994 and 2005, the area of timberland with eastern redcedar as a dominant species more than tripled to 172,000 acres (69,600 hectares) (Meneguzzo and others 2005).

Transitional Mixed Forests

Nebraska's transitional mixed forests are found along the Niobrara River in the northern part of the State and in the Central Loess Hills in central Nebraska. Six major ecosystems converge in the Niobrara River Valley: northern boreal forest, ponderosa pine forest, eastern deciduous forest, tallgrass prairie, mixed-grass prairie, and shortgrass prairie. More than 225,000 acres (91,050 hectares) of timberland are in the area, including 83,000 acres (33,600 hectares) of pine forest, 46,000 acres (18,600 hectares) of eastern redcedar, and 96,000 acres (38,850 hectares) of mixed forests (NLCD 2006)—making the Niobrara Valley unlike any other forested area in Nebraska (figure 5).

The Central Loess Hills are a patchwork of eastern redcedar forest, comprising isolated stands of relic ponderosa pines, mixed grass prairie, and cropland. Forest land in the hills includes deciduous, coniferous, mixed, and riparian forests.

Riparian Forests

Nebraska has more than 12,000 miles (19,300 km) of river, more than any other State. The riparian forests along the rivers provide critical habitat and travel corridors for wildlife and protect water by filtering sediment and agricultural runoff, moderating water temperature, stabilizing stream banks, slowing flooding, and contributing to recreational opportunities.

Composed primarily of ash, cottonwood, elm (*Ulmus* spp. L.), red mulberry, hackberry, boxelder (*Acer negundo* L.), sycamore (*Plantanus occidentalis* L.), willow (*Salix* spp. L.), black walnut (*Juglans nigra* L.), and increasingly redcedar, more than 824,000 acres (333,460 hectares) of riparian forests are located in Nebraska (NLCD 2006), a vital component of Nebraska's forest resources. Nearly two-thirds of Nebraska's forest land is adjacent to streams and rivers.

An additional 171,000 acres (69,200 hectares) of narrow, nonforest treed land are situated along riparian areas. These narrow but critically important water buffers separate the riparian and water resources from direct agricultural activities and are the first line of defense against sediment and contaminants entering the water. Nebraska has more than one-half of the total acreage of these nonforest, treed riparian areas across the four-State region of Nebraska, Kansas, North Dakota, and South Dakota. (NFS 2010a).

Community Forests

Nebraska has approximately 470,000 acres (190,200 hectares) of community forests (NFS 2010a). A large and diverse number of tree species are found in the community forests, with the typical forest resource dominated by hackberry, red mulberry, Siberian elm, juniper (*Juniperus* spp.), elm, ash, mixed hardwood, and evergreen species (figure 6). In Lincoln and Omaha, the State's two largest cities, the most common species are Siberian elm, hackberry, eastern redcedar, ash, red mulberry, Scotch pine (*Pinus sylvestris* L.), and mixed hardwood species.

In 2010, Nebraska Forest Service (NFS) inventories and calculations using UFORE (Urban Forest Effects Model) estimated that approximately 13.3 million trees were in Nebraska communities. Collectively, Nebraska's community forests have an average tree cover of 11.3 percent, with a total value of environmental, social, and economic benefits to the State of $9.7 billion.

State Forestry Agency and Properties

The NFS is part of the University of Nebraska system and is administratively located at the University's Institute of Agriculture and Natural Resources. NFS's mission is to provide

Figure 5. The Niobrara River Valley contains 83,000 acres of ponderosa pine, 46,000 acres of eastern redcedar, and 96,000 acres of mixed forests, making it unlike any other forested area in Nebraska. (Photo from NFS, circa 2009).

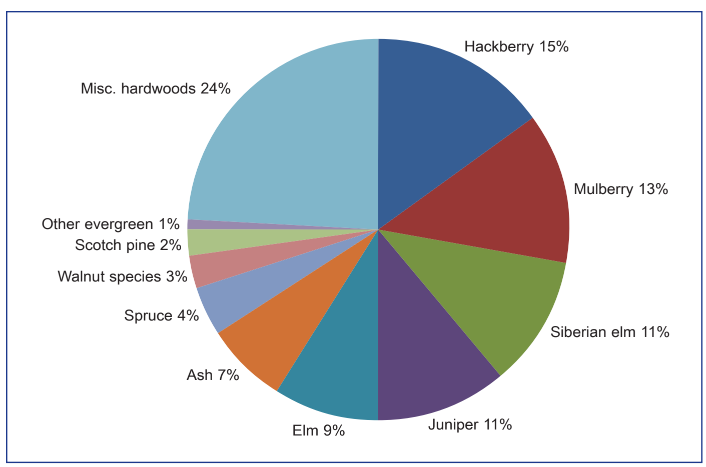

Figure 6. Statewide community forest species in Nebraska. A large and diverse number of tree species are found in Nebraska communities, with the typical forest resource being dominated by hackberry, red mulberry, Siberian elm, and juniper. (Data source: NFS, 2010c).

services and education to the people of Nebraska for the protection, use, and enhancement of the State's tree, forest, and other natural resources.

NFS provides education and services in four core areas: rural forestry, community forestry, forest health, and rural fire protection. The 45 NFS employees at 6 statewide district offices work with partners across the State and nationally to implement a diverse portfolio of programs to sustainably manage Nebraska's trees and forests, to connect people to trees and forests, and to engage them in environmental stewardship.

NFS owns three properties—Horning Farm State Demonstration Forest, Timmas Farm Ecological Forest Reserve (both located in southeast Nebraska), and Cedar Canyon State Demonstration Forest in southwest Nebraska.

The 240-acre (97.1-hectare) Horning Farm is a beautiful mosaic of grass fields, native forests, and former research tree plantations that is being transformed into a regional woodland owner education center. The center will serve forest landowners, acreage owners, and agricultural producers in a four-State area by demonstrating management practices, including high-value timber and specialty forest product production, oak (*Quercus* spp.) regeneration, wildlife habitat, and animal damage management. Portions of the property will be converted to oak savanna, as well as a commercially viable nut and woody floral agroforestry production system. The site also is testing new cultivars of highly productive, disease-resistant hybrid hazelnuts, an emerging perennial nut crop for food, animal feed, oils, and biofuel.

The newly acquired Timmas Farm is 120 acres (48.6 hectares) of natural forest land located in bluffs adjacent to the Missouri River. The farm will serve as a natural area and be used for horticultural research involving genetics and plant breeding programs at the University of Nebraska–Lincoln.

Cedar Canyon State Demonstration Forest, Nebraska's only State forest, is 640 acres (259 hectares) of western rangeland containing forested canyons and steep uplands with green ash, hackberry, cottonwood, and eastern redcedar trees, along with 100 acres (40.5 hectares) of cropland. The forestry objectives and demonstration interests at Cedar Canyon focus on management strategies for forested rangeland and the benefits of windbreaks on crop production and soil conservation.

Challenges to Nebraska's Trees and Forests

Nebraska's forests face wide-ranging threats—from wildland fire to destructive invasive insects and diseases to climate change and increasing urbanization.

Fire

Catastrophic wildland fire is perhaps the greatest threat to Nebraska's coniferous forests and is an emerging threat in riparian areas succeeding to Russian olive (*Elaeagnus angustifolia* L.) and eastern redcedar (which form a dense, fire-prone understory). Several trends combine to intensify the already severe conditions—increasing forest fuel loads, expansion of housing into wildland forest areas, increasing temperatures, drier conditions, and longer fire seasons.

For years, low-intensity wildfires burned across Nebraska's forest landscape, cleaning up the forest floor and removing much of the brush and litter than can fuel a fire. These fires were mostly surface fires and didn't spread into tree canopies. But in recent years, as more people move into rural, forested areas in western Nebraska, most fires have been suppressed and fuel loads have increased to unnatural levels. Debris has accumulated on forest floors, and brush and small-diameter trees have become established in forest understories, creating "ladder fuels" that serve as pathways for ground fires to become dangerous, highly destructive crown fires. The result has been high-intensity, stand-replacing fires in the Pine Ridge, with more than 126,000 acres (51,000 hectares) of forest (about 50 percent) converted to grassland since 1973.

The NFS has provided more than $4 million in cost-share funds to reduce fuel loads in the Pine Ridge. In 2009, NFS secured a $50,000 Arbor Day Foundation grant to plant 61,000 trees in Chadron after a fire that destroyed the native ponderosa pine forest near Chadron State College. Most of the trees were machine planted, but 35 Chadron community groups hand-planted about 12,000 trees in the effort. Participants said it was an important step in recovering from the devastating fire that took a heavy toll on the town.

Invasive Insects and Diseases

Nebraska's forests face a potential barrage of insect, disease and invasive and aggressive native plants that, if left unmanaged, will cause widespread damage to trees and forests.

EAB—Emerald ash borer (EAB) is a significant emerging threat to Nebraska's trees. Although EAB has not yet been found in the State, it is within 75 miles (121 km) of the border. When it arrives, EAB is expected to kill Nebraska's 42 million ash trees (about 20 percent of the trees in the State) and cost billions of dollars in removals and replantings.

Thousand Cankers Disease—Thousand cankers disease of black walnut has caused widespread tree mortality in Western States. The NFS is conducting street-side surveys in an effort to prevent introduction of thousand cankers. Outreach projects have been conducted within the State and more are underway with foresters from Colorado and Kansas. A statewide quarantine on walnut is in place.

A pest-detector program engages citizen volunteers and professionals in efforts to detect EAB and thousand cankers disease. Since its inception, trained volunteers have surveyed 363 sites in 35 counties. These surveys have greatly expanded the ability to monitor for pests while increasing awareness of the serious threats these pests pose to rural and community trees.

Pine Wilt—Pine wilt is causing Scotch pine, a popular tree for ornamental plantings, windbreaks, and Christmas tree farms, to disappear from Nebraska's landscape. The disease is common in the southeastern part of the State, but is spreading west and north.

Diplodia Blight and Mountain Pine Beetle—Two additional threats to pine in Nebraska are diplodia blight and mountain pine beetle. Diplodia blight has killed thousands of planted Austrian pine (*Pinus nigra* Arnold) and ponderosa pine trees in eastern Nebraska and native ponderosa pines in the Pine Ridge and Niobrara River Valley.

Small, scattered pockets of trees infested with mountain pine beetle are found in the Pine Ridge and Wildcat Hills in western Nebraska. Planted pines in windbreaks and communities also are affected. With more than 250,000 acres (101,200 hectares) of ponderosa pine in the State, mountain pine beetle poses a substantial and deadly threat to Nebraska's forests.

Invasive Plants and Aggressive Native Plants

Invasive plants and aggressive native plant species threaten to dramatically alter native ecosystems by outcompeting more desirable species. Purple loosestrife (*Lythrum salicaria* L.), saltcedar (*Tamarix ramosissima* Ledeb. and *T. parviflora* DC), and phragmites (*Phragmites australis* spp. Australis) all threaten the integrity of Nebraska riparian ecosystems.

Other invasive species that are becoming serious threats to the ecological stability of hardwood forests in eastern Nebraska are honeysuckle (*Lonicera* spp. L.), buckthorn (*Rhamnus* spp. L.), and Japanese barberry (*Berberis thunbergii* DC).

Of particular concern are Russian olive and eastern redcedar. Both are valued as conservation plantings, but they multiply profusely and can quickly overtake pastureland, forest land, and riparian areas.

To protect at-risk forests, NFS is using geospatial technology to identify areas that are overly dense with invasive and aggressive native species that would benefit from proactive management. Thus far, analyses have been conducted in the Niobrara Valley, Pine Ridge, and Platte River Valley.

Climate Change

With hot summers, cold winters, late spring and early fall freezes, fluctuating rainfall, frequent severe winds, and ice storms, Nebraska is a tough place for trees to survive. Scientists project that temperatures will continue to increase this century, with summer climate changes predicted to be larger than winter changes (Christensen and others 2007). The anticipated effects of climate change on trees in Nebraska are reduced productivity; greater risk of wildland fire; and irregular flows along riparian systems, which will alter water availability. These could lead to changes in agricultural systems, alteration of habitats, and proliferation of some invasive species. (Karl and others 2009).

Deer

The Nebraska Game and Parks Commission estimates that Nebraska's whitetail deer population grew from 11,200 in 1959 to 288,000 in 2008, due largely to hunting restrictions. High deer populations are affecting forest regeneration. Trees protected either by thorns (honeylocust [*Gleditsia triacanthos* L.], Osage-orange [*Maclura pomifera* Raf. C.K. Schneid.], Russian olive) or an undesirable taste (cedar, Siberian elm), have become established in areas with large numbers of deer. Regeneration of other, more desirable species, is rare or absent in these areas.

Urbanization

In 2007, the U.S. Census Bureau estimated Nebraska's population to be slightly more than 1.75 million, making it the 38th largest State. More than one-half of Nebraska's people live in three eastern counties.

Long-term growth trends show increasing urban populations and continued decline in many rural counties in central and western Nebraska. Growing urban populations are creating the need for sustainable community forestry programs and implementation of green infrastructure into community planning practices. Declining rural populations are expected to lead to reduced budgets in rural communities, which could translate to cuts in local forestry programs.

Perception of the Value of Trees and Forests

In rural areas, increasing crop and agricultural land prices and drought negatively affect people's perception of the value of forest resources. As crop prices increase, conservation plantings (e.g., windbreaks and riparian buffers) often are removed to increase acres in crop production. Drought often leads to producers in stricken areas removing trees to eliminate the perceived competition for water between trees and crops.

Since 1984, the number of trees planted in conservation practices has declined from 3.5 million annually to slightly more than 1 million annually.

Charles E. Bessey Nursery

In 1902, the Charles E. Bessey Nursery was established in north central Nebraska as part of the Dismal River Forest Reserve to provide tree seedlings for the USDA Forest Service's Bessey Ranger District near Halsey. Named for Charles E. Bessey, a horticulture professor at the University of Nebraska whose vision of a forest growing in the Nebraska Sandhills prompted its creation, Charles E. Bessey is the longest continuously operating USDA Forest Service nursery in the Nation and is on the National Register of Historic Places. Until fire destroyed 40 percent of it in the mid-1960s, Nebraska had one of the largest planted forests in the country, some 32,000 acres (12,950 hectares) near Halsey. Charles E. Bessey Nursery and the forest surrounding it are part of the Nebraska National Forest.

Today, the Charles E. Bessey Nursery comprises 46 irrigated acres of bareroot crops and five greenhouses for container crops (figure 7). All of the Charles E. Bessey Nursery stock is used to supply USDA Forest Service forests, including Bighorn National Forest in Wyoming and Arapaho-Roosevelt National Forest in Colorado. Annual production at the Charles E. Bessey Nursery is 2.5 to 3.0 million seedlings, including conifers (spruces [*Picea* spp.], pines, redcedar, and Rocky Mountain juniper), broadleafs (maples [*Acer* spp.], oaks, black cherry [*Prunus serotina* Ehrh.], walnut, cottonwoods, hackberry, Harbin pear [*Pyrus ussuriensis* Maxim.], honeylocust, ash, lilac [*Syringa vulgaris* L.], crabapple [*Malus* spp.], and Kentucky coffeetree [*Gymnocladus dioicus* L.K. Koch]), and shrubs (American plum [*Prunus americana* Marsh.], chokecherry [*Prunus virginiana* L.], redosier dogwood [*Cornus stolonifera* Michx.], willow, viburnums [*Viburnum* spp.], black elderberry [*Sambucus nigra* L.], golden currant [*Ribes aureum* Pursh], sandcherry [*Prunus pumila* L.], serviceberry [*Amelanchier* spp.], sumac [*Rhus glabra* L.], and snowberry [*Symphoricarpos albus* (L.) S.F. Blake]).

Restoration and Tree Planting Programs

Conservation and Agroforestry Plantings

Trees have long been an important component of Nebraska agriculture. Windbreaks increase crop yields, reduce soil erosion, protect livestock from weather extremes, and protect rural homes (figure 8). Riparian forest buffers filter agricultural runoff and sediment, thereby protecting water quality. Farmers who incorporate conservation plantings into traditional row-crop systems benefit from increased crop yields and reduced soil erosion. Furthermore, conservation trees enhance the quality of life and add beauty and value to farm homes and the rural landscape.

Figure 7. Charles E. Bessey Nursery, the Nation's oldest Federal tree nursery, distributes about 3 million seedlings annually. (Photo from NFS, 2005).

Figure 8. Nebraska's 423,098 acres of windbreaks and planted riparian forests generate millions of dollars in economic benefits annually by fostering higher crop yields, improved vigor during spring calving, and reduced energy consumption on farms and acreages. (Photo by Dan Ogle, USDA Natural Resources Conservation Service [NRCS], 1992).

From 1926 through 2002, the NFS administered the State's conservation tree seedling distribution program (figure 9). Since 2002, seedling distribution has been coordinated by the Nebraska Association of Resources Districts with each Natural Resource District (NRD) administering its local tree program. Approximately 1 million conservation tree and shrub seedlings are distributed by Nebraska's 23 NRDs each year.

The Nebraska program is unique because no State or private nurseries provide conservation seedlings. The primary source of conservation seedlings for Nebraska is the USDA Forest Service's Charles E. Bessey Nursery.

The NFS's Rural Forestry (Forest Stewardship) Program plays a central role in helping landowners plant and manage trees for conservation purposes. Since 1991, NFS foresters have developed 936 forest stewardship plans placing 123,887 acres of private forest lands under management (NFS 2010b).

In 2010, NFS identified high-priority forest landscapes based on geospatial analyses, relevant and important nongeospatial data characterizing the value of the particular forest landscape, and the seriousness and complexity of issues affecting the area.

By identifying and then concentrating resources and programming in priority landscapes, NFS will help achieve landscape-level conservation, improving the natural resource base and the lives of people who depend on these resources. Geographic concentration helps to ensure that scarce resources are focused on targeted areas (figure 10).

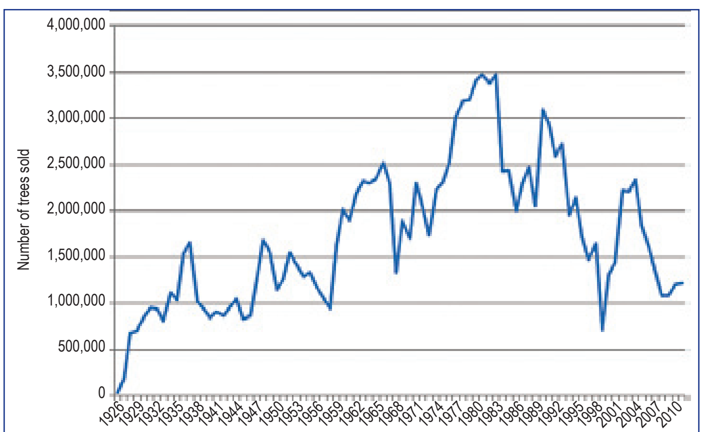

Figure 9. Number of trees sold annually through Nebraska's conservation tree seedling distribution program. Nearly three decades ago, the program sold 3.0 to 3.5 million trees annually for windbreaks, wildlife habitat, water-quality protection, and soil-erosion control. Since 2005, the number has dropped to about 1 million trees sold annually. (Data source: NRCS Progress Reporting System 2011, unpublished).

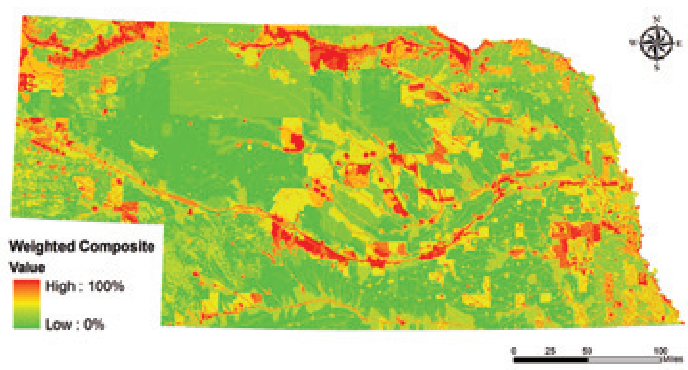

Figure 10. Nebraska Priority Forest Landscapes identified in 2010 for concentration of resources and programming to targeted areas. (Map source: NFS, 2010c).

ReTree Nebraska

Nebraska has lost nearly one-half of its community forests in the past three decades because of severe weather, drought, poor planting practices or species selection, insect and disease pests, and an aging tree population. To reverse this decline, NFS created ReTree Nebraska, a cooperative initiative to properly plant and maintain 1 million community trees by 2017 (figures 11 and 12). Raising awareness of the substantial value of trees and forests is an integral part of ReTree Nebraska's efforts. Nearly 300 volunteer ambassadors in 112 Nebraska communities work tirelessly to coordinate tree planting and educate citizens about the economic, environmental, social, psychological, and physical value of trees.

In collaboration with more than 20 participating nurseries across Nebraska, ReTree promotes the importance of diversity in the landscape by developing a list of underplanted species (figure 13). Among the current list, "12 for 2012," are baldcypress, (*Taxodium distichum* L. Rich.*)*, northern catalpa (*Catalpa speciosa* [Warder] Warder ex Engelm.), Kentucky

Figure 11. ReTree Nebraska is a 10-year initiative by the Nebraska Forest Service to plant 1 million trees across the State. The group in this photo, which includes Nebraska's First Lady Sally Ganem (right of the banner), planted a maple tree on the State Capitol grounds on Arbor Day 2012. (Photo from Nancy Evans, NFS, 2012).

Figure 12. This tree, planted in Gering, NE, on Arbor Day 2012, will be counted toward ReTree Nebraska's 1-million-tree goal. (Photo from NFS, 2012).

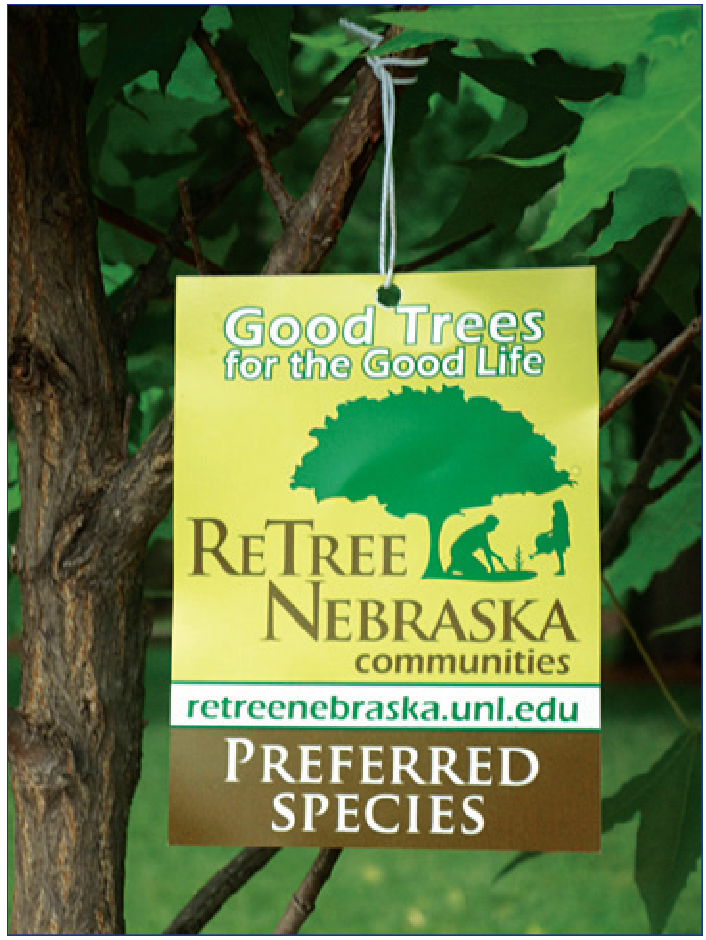

Figure 13. Tree species listed on ReTree Nebraska's "12 for 2012" recommended list of underplanted species are identified in nurseries by this hang tag. (Photo by Jessica Kelling, NFS, 2008).

coffeetree, chinkapin oak (*Quercus muehlenbergii* Engelm.), bur oak (*Q. macrocarpa* Michx.), English oak (*Q. robur* L.), Shantung maple (*Acer truncatum*), and Miyabe maple (*A. miyabei* Maxim.).

ReTree Nebraska Week is celebrated during the final full week of September to raise awareness of the opportunity to plant trees during the fall. Tree plantings and workshops are held statewide in conjunction with Nebraska Statewide Arboretum tours.

Greener Nebraska Towns

Started in 2011, the goal of Greener Nebraska Towns is to significantly improve the green infrastructure in communities across Nebraska. For the first phase, 8 communities were targeted to receive funding and technical assistance to plant 300 trees, implement waterwise landscaping, and conduct targeted education over the next 3 years.

Trees for Nebraska Towns

Trees for Nebraska Towns (TNT), funded by the Nebraska Environmental Trust, was developed to address tree loss; restore forest canopy; and improve overall health, sustainability, and species diversity of Nebraska's community trees. Coordinated by the NFS on behalf of the Nebraska Statewide Arboretum, it is part of ReTree Nebraska's efforts to plant 1 million trees in the State. In 2011, more than $250,000 was awarded to 36 projects in 25 communities. Over the past 5 years, TNT has awarded more than $1.1 million and planted more than 7,000 large-growing shade trees and appropriate companion plants across Nebraska.

Combined, these and other tree-planting programs result in 6,300 to 10,000 trees being planted in Nebraska's Tree City USA communities each year.

Community Enhancement Program

The Nebraska Community Enhancement Program (CEP), a collaborative program among NFS, the Nebraska Department of Transportation, and the Nebraska Statewide Arboretum, was a highly successful tree-planting program funded by Federal transportation dollars between 1994 and 2010, when it ended as a result of Federal program priority changes.

CEP funded more than 572 projects that resulted in thousands of trees being planted in 214 Nebraska communities. By planting large-maturing trees like oaks and elm hybrids and landscape accents of shrubs, perennials, and native grasses, the program made long-term effects on public property along transportation corridors including roadways, streets, parking lots, community entryways, and nonloop trails.

Cottonwood Restoration

NFS, along with The Nature Conservancy and other partners, is beginning work to restore cottonwood gallery forests along the Missouri River. Years of human alteration of the river have eliminated or degraded much of the cottonwood ecosystem, which at one time was the dominant species in the Missouri watershed. Existing cottonwood stands are largely over-mature and declining trees, and natural regeneration has essentially ceased.

NFS will restore 300 acres (120 hectares) of cottonwood forests as a demonstration project funded by the USDA Forest Service. The sites will showcase restoration methods and costs, economic analysis, and educational outreach for landowners and resource professionals. The hope is that this project will catalyze similar efforts on thousands of acres of cottonwood forests along the Missouri River.

Outlook

Nebraska has a rich tree-planting heritage, but the State's trees and forests are experiencing significant challenges—tree mortality is increasing as a result of disease and invasive pests, wildfires are increasing in size and severity, ecosystems are struggling to adapt to climate change, rural economies are declining, and forest land is being permanently converted to nonforest use.

An array of diverse agencies (among them NFS, the USDA Natural Resources Conservation Service, and Natural Resources Districts in Nebraska) are growing increasingly concerned about the continuing and accelerating losses of conservation trees and the relatively low level of tree planting. With a growing consortium of high-level support among key agencies, opportunities are emerging for multiagency collaborative action that would change public policies that support deforestation, design and launch public education programs focusing on the value and benefits of conservation plantings, and seek external dollars to support additional conservation tree planting.

Tree and forest advocates across Nebraska continue working to educate citizens about the economic, environmental, social, psychological, and physical value of trees to continue the State's tree-planting legacy for current and future generations.

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Forestry and Tree Planting in Virginia

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Abstract

Virginia (including the lower Chesapeake Bay) occupies 27.3 million acres (11 million hectares), 58 percent of which is forested (15.8 million acres or 6.4 million hectares). Most of the forest land is owned by more than 373,600 private individuals and families. The remaining 42 percent of the State is nonforest land, composed of agricultural and urban lands, as well as water. More than 75 percent of the State's forest land is stocked by hardwood forests. Regarding area of softwood forests, nearly two-thirds of stands are of planted origin. The most common plantation species by far is loblolly pine (*Pinus taeda* L.), while eastern white pine (*P. strobus* L.) makes up a distant second. Major forest types in Virginia are oak/hickory, loblolly and shortleaf pine, maple, beech, and birch. Annually, the two State nurseries plant, grow, and sell 25 million tree seedlings across 40 species. Most of the seedlings (23.5 million) are softwoods—primarily loblolly pine. Virginia has an active and vibrant tree research and improvement program that is highly appreciated by forest landowners.

Introduction

Virginia is rich in history. From its first permanent English settlement in 1607 to the present, forests have played a prominent role in the Commonwealth. Forests in early years were heavily used and exploited to make way for tobacco, corn, and cotton. Forests fueled the growth of Virginia with lumber, naval stores, and fuel for charcoal and iron furnaces. Although heavily used, Virginia's forests are resilient. Founding fathers George Washington and Thomas Jefferson both planted and cultivated trees in the State.

Efforts to restore forests began, in earnest, in 1914 with the creation of the Office of the State Forester and a mission to protect, conserve, and develop forests. The first tree nursery soon followed and was located in Charlottesville—land now occupied by the headquarters of the Virginia Department of Forestry (VDOF). Tree planting was a focus of the Civilian Conservation Corps during the Depression, and some of these tree plantations remain today. World War II called for wood and timber, and the postwar housing boom increased demand both for wood and paper. Forest industry and the then-Division of Forestry responded with the first large-scale reforestation efforts on cutover forest land in the 1950s. Heavy mechanical site preparation and later prescribed burning practices were developed and refined. Tree nurseries were developed and expanded, and by the 1960s, two State and two industry nurseries were operating.

Because of a concern over declining pine volumes in the State, the Virginia Reforestation of Timberlands program was created in 1970. This model program, funded from a self-imposed forest products tax by forest industry and matched by the General Assembly, greatly increased private lands reforestation. A third State nursery was added in the mid-1980s to meet seedling demands. Another surge in planting occurred in the late 1980s, due in part to the USDA Conservation Reserve Program, which focused on planting trees on highly erodible farm lands.

In 1988, reforestation peaked in Virginia when nearly 118,000 acres (47,750 hectares) were planted, the highest on record. In the past 20 years, planting has remained steady, with some peaks and valleys, often following the economy (figure 1). For more than 400 years, tree planting has been, and will continue to be, important for Virginia.

Virginia's Environment

Virginia's 42,774 square miles (110,780 square km) are divided into five physiographic provinces (figure 2): the Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau. Of this area, 58 percent (15.8 million acres/ 6.4 million hectares) is forested (figure 3) with a diversity of softwood and hardwood forests (table 1). The remaining 42 percent of the State is agricultural lands, urban areas, and water. Beginning on the Eastern Shore, where barrier islands and salt marshes are nearly at sea level, and traveling westward across rolling hills and moderate slopes, through valleys, and over rugged steep slopes, the diversity among the regions is evident.

Virginia's climate is equally diverse throughout its five climate regions (Hayden and Michaels 2000). The moisture of the Atlantic Ocean and Chesapeake Bay creates humid summer days, while the Blue Ridge and Appalachian mountain systems

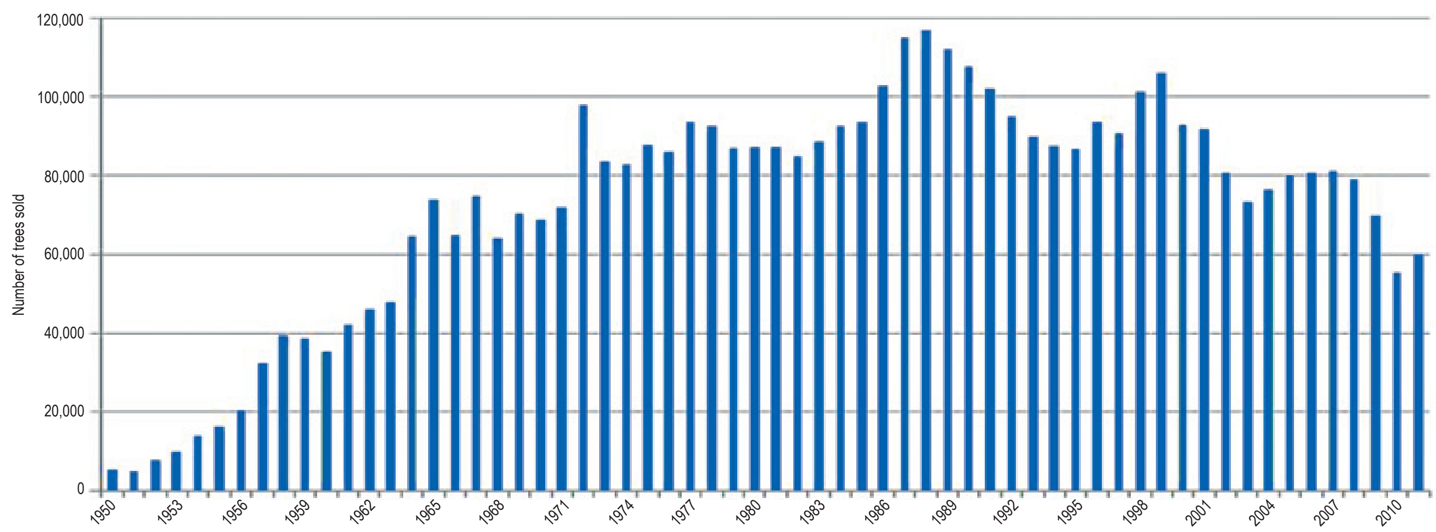

Figure 1. Virginia's historic tree-planting acres. (Data source: VDOF nurseries).

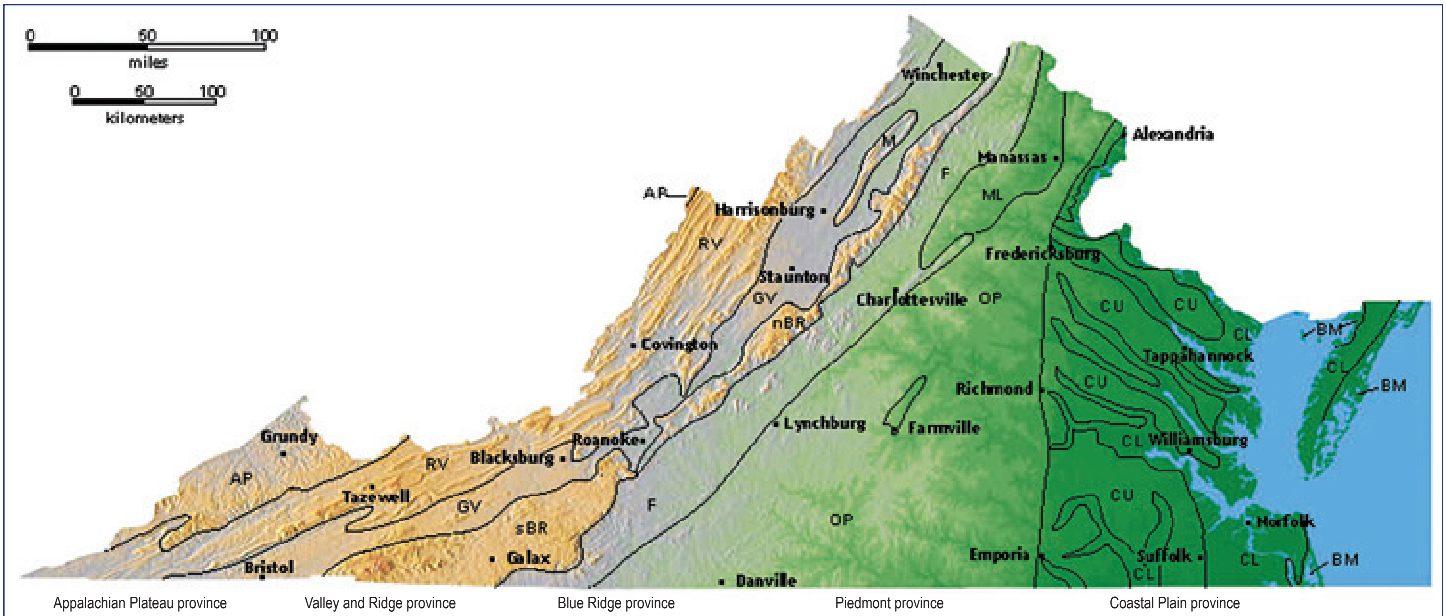

Figure 2. Virginia's five physiographic provinces: (1) Appalachian Plateau; (2) Valley and Ridge (includes Ridge and Valley subprovince [RV], Great Valley subprovince ([GV], and Massanutten Mountain [M]); (3) Blue Ridge (includes northern and southern subprovinces [nBR and sBR, respectively]); (4) Piedmont (includes Foothills subprovince [F], Mesozoic lowlands subprovince [ML], and Outer Piedmont subprovince [OP]); and (5) Coastal Plain (includes Upland subprovince [CU], Lowland subprovince [CL], and Barrier Islands and Salt Marshes [BM]). (Data source: Bailey, 1999).

provide cooler temperatures. The Northern Virginia Climate Region has the coolest average January temperatures of 19 to 42 °F (-7.2 to 5.6 °C), while the Piedmont Climate Region has the warmest average July temperatures of 68 to 88 °F (20 to 31 °C). Average annual rainfall is 42.2 in (107 cm), and snowfall amounts can vary from more than 50 in (127 cm) annually in the mountains to scattered flurries in the southeastern region. Severe weather in the form of a hurricane or tropical storm is somewhat common, averaging about one per year.

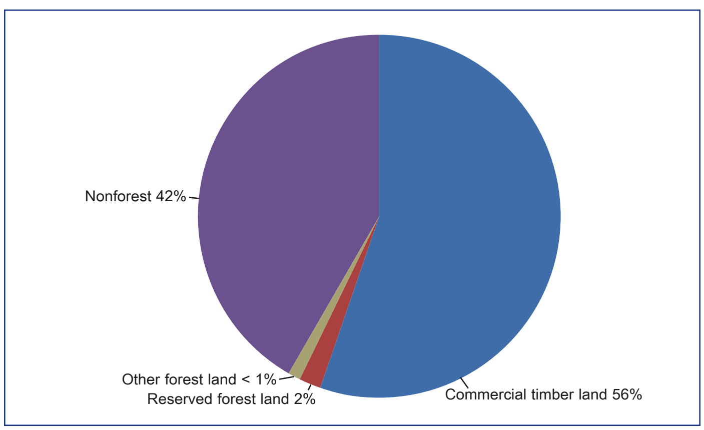

Figure 3. Land use in Virginia (total is 27.3 million acres/11 million hectares). (Data source: Miles, 2012).

Table 1. Softwood and hardwood forest types in Virginia.

Forest type	Acres *(Hectares)*			
	Coastal Plain	Piedmont	Mountains	Total
White/red/jack pine	—	16,504	156,951	173,455
	—	*(6,679)*	*(63,516)*	*(70,195)*
Spruce/fir	—	—	7,631	7,631
	—	—	*(3,088)*	*(3,088)*
Loblolly/shortleaf pine	1,378,391	1,351,327	147,760	2,877,478
	(557,815)	*(546,863)*	*(59,796)*	*(1,164,474)*
Other eastern softwoods	—	28,253	47,838	76,090
	—	*(11,434)*	*(19,359)*	*(30,793)*
Softwoods total	**1,378,391**	**1,396,084**	**360,180**	**3,134,654**
	(557,815)	*(564,975)*	*(145,760)*	*(1,268,549)*
Oak/pine	512,812	702,897	481,035	1,696,743
	(207,528)	*(284,452)*	*(194,668)*	*(686,648)*
Oak/hickory	1,309,546	3,863,035	4,553,656	9,726,237
	(529,954)	*(1,563,315)*	*(1,842,799)*	*(3,936,068)*
Oak/gum/cypress	345,066	31,377	5,326	381,769
	(139,643)	*(12,698)*	*(2,155)*	*(154,496)*
Elm/ash/cottonwood	113,685	231,003	49,731	394,419
	(46,007)	*(93,484)*	*(20,125)*	*(159,616)*
Maple/beech/birch	—	—	364,060	364,059
	—	—	*(147,330)*	*(147,329)*
Aspen/birch	—	1,638	2,634	4,272
	—	*(663)*	*(1,066)*	*(1,729)*
Other hardwoods	—	4,588	24,269	28,857
	—	*(1,857)*	*(9,821)*	*(11,678)*
Exotic hardwoods	1,673	24,338	15,161	41,173
	(677)	*(9,849)*	*(6,135)*	*(16,662)*
Hardwoods total	**2,282,782**	**4,858,876**	**5,495,872**	**12,637,529**
	(923,809)	*(1,966,317)*	*(2,224,100)*	*(5,114,227)*
Nonstocked	**22,800**	**44,653**	**28,263**	**95,716**
	(9,227)	*(18,070)*	*(11,438)*	*(38,735)*
Total	**3,683,973**	**6,299,613**	**5,884,313**	**15,867,900**
	(1,490,851)	*(2,549,363)*	*(2,381,297)*	*(6,421,511)*
Total %	**23%**	**40%**	**37%**	**100%**

Data source: USDA Forest Service Forest Inventory and Analysis, 2010.

Coastal Plain

The Coastal Plain accounts for approximately 30 percent of the State's land area and extends westward from the barrier islands and beaches along the Atlantic Ocean to the "fall line"—a geological fault that separates the Coastal Plain from the Piedmont. This region includes Virginia's section of the Chesapeake Bay—the largest estuary in the United States.

Most of the soils in this region are alluvial in origin, having been formed when the region was inundated by the ocean. Soils tend to have a high percentage of sand and can be droughty or poorly drained, depending on local topography.

In this region, 45 percent of the land is forested. Elevations range from sea level to approximately 250 ft (75 m) at the fall line. In this region, 37 percent of the area consists of softwood forest types, and the remaining 63 percent is hardwood forests (table 1). Loblolly pine (*Pinus taeda* L.) plantations make up most of the softwood area (figure 4). Diminished species in

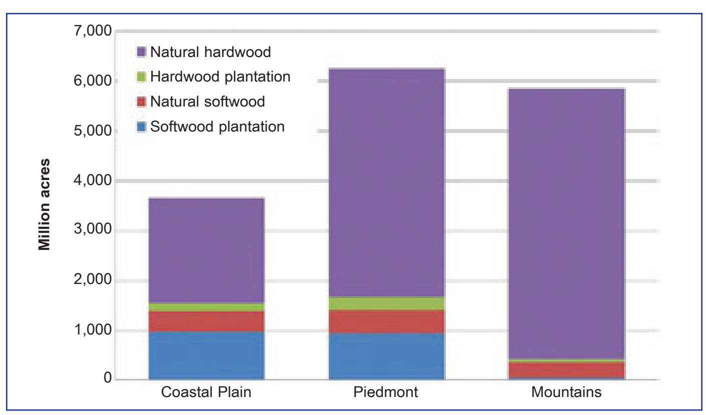

Figure 4. Stand origin for Virginia's forests. (Data source: Miles, 2012).

this area that are actively being restored include longleaf pine (*P. palustris* Mill.) and Atlantic white cedar (*Chamaecyparis thyoides* [L.] Britton, Sterns and Poggenb.).

Piedmont

The Piedmont region accounts for 37 percent of the State's land area and extends westward from the fall line and Coastal Plain to the Blue Ridge Mountains. This region consists mainly of rolling, well-drained foothills. Because of agricultural practices in the 18th and 19th centuries that caused erosion, much of the soil productivity has been lost.

The Piedmont physiographic region is 62 percent forested. Softwood forest types make up 22 percent of this area—primarily loblolly pine plantations and Virginia pine (*Pinus virginiana* Mill.) natural stands. The other 78 percent consists primarily of upland hardwoods (oak/hickory [*Quercus/Carya*] forest types). Diminished species include shortleaf pine (*P. echinata* Mill.) (table 1).

Mountains

The Mountains region accounts for 33 percent of the State's area and extends westward from the Piedmont to the West Virginia and Kentucky State boundaries. This area is composed of a number of subregions, including the Blue Ridge Mountains, Shenandoah Valley, Alleghany Highlands, Ridge and Valley, and Cumberland Plateau (Coalfields). This region has the highest point in the State, Mt. Rogers, which is at an elevation of 5,729 ft (1,746 m).

This region, which includes National Forest System lands, is 65 percent forested—94 percent of which is in hardwoods (table 1). At higher elevations, several forest types unique to Virginia occur, including spruce/fir (*Picea/Abies*) and maple/beech/birch (*Acer/Fagus/Betula*). Diminished species include eastern hemlock (*Tsuga canadensis* [L.] Carrière), Table Mountain pine (*Pinus pungens* Lamb.), and American chestnut (*Castanea dentata* [Marsh.] Borkh.).

Forest Land Ownership

Approximately 12.3 million acres (5 million hectares), or approximately 79 percent of Virginia's forest land, is owned by non-industrial private forest (NIPF) landowners (figure 5) (VDOF 2011). From 2001 to 2010, industrial landownership dropped from 6 percent (1 million acres [0.4 million hectares]) to 2 percent (0.26 million acres [0.11 million hectares]) (figure 5). This trend continues the long-term decline of the forest industry in Virginia. Much of the former industry lands have been purchased by Timberland Investment Management Organizations (TIMOs) and Real Estate Investment Trusts (REITs). This practice increased corporate non-industrial private forest lands from 12 percent (1.98 million acres [0.8 million hectares]) to 17 percent (2.68 million acres [1.08 million hectares]) of the total forest land area (figure 5).

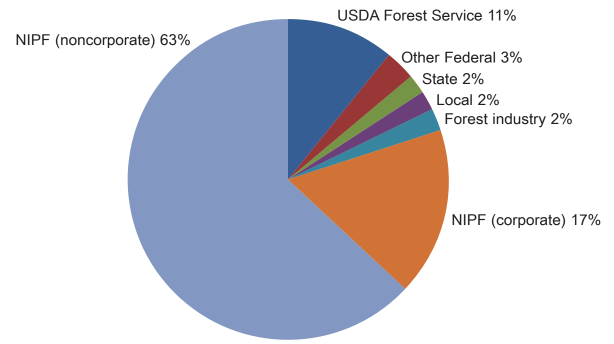

Figure 5. Forest ownership in Virginia in 2010. (Data source: Miles, 2012).

Challenges Facing Virginia's Forests

Insects and Diseases

East of the Blue Ridge Mountains, Virginia's most significant forest pest is the southern pine beetle (*Dendroctonus frontalis* Zimmerman), a native insect that primarily threatens mature plantations of loblolly, shortleaf, and Virginia pines throughout their respective ranges. Historically, outbreaks have occurred at 6- to 10-year intervals. More recently, major outbreaks have been less frequent, likely related to a multitude of factors, including improved silvicultural practices, a more fragmented landscape, and a rapid response to cutting out infested spots before they have a chance to grow and spread. Other bark beetles, such as various species of ips (*Ips* spp.) and the black turpentine beetle (*D. terebrans* Olivier), are less aggressive but can cause widespread, localized damage to pine stands under stress from drought or mechanical injury after logging.

Additional problems that periodically plague young pine plantations in the East include the pales weevil (*Hylobius pales* Herbst), Nantucket pine tip moth (*Rhyacionia frustrana* Scudder in Comstock 1880), and various species of sawflies (*Neodiprion* spp.). Root disease caused by anosum root rot (*Heterobasidion annosum* [Fr.] Bref.) is common on sandy, well-drained soils in the Coastal Plain. A more common root disease problem in the Piedmont is littleleaf disease, caused by *Phytophthora cinammomi* Rands. This pathogen is thought to be responsible for much of the decline and mortality of shortleaf pine during the past several decades, although it can be damaging to other pines and numerous hardwood species as well.

Among hardwoods, the most common native defoliator is the fall cankerworm (*Alsophila pometaria* [Harris]) followed by the spring cankerworm (*Peleacrita vernata* [Peck]), both of which can reach outbreak levels periodically throughout Virginia. Because defoliation occurs very early in the season, most trees typically recover from even severe defoliation. Cankerworms have a wide host range, but prefer oaks and maples. Other native insects can occasionally cause localized damage to hardwood forests, including the eastern tent caterpillar (*Malacasoma americanum* [F.]), fall webworm (*Hyphantrea cunea* [Drury]), locust leafminer (*Odontata dorsalis* [Thunb.]), tulip tree scale (*Toumeyella liriodendri* [Gmelin]), and variable oakleaf caterpillar (*Heterocampa manteo* [Doubleday]).

Over the past several decades, Virginia's forests have been plagued by the numerous nonnative invasive species, especially the gypsy moth (*Lymantria dispar* [L.]). Gypsy moths entered Virginia from the northeast in the late 1970s and have gradually spread south. Gypsy moths have had a profound effect on many parts of the landscape, especially in the oak-hickory forests in the mountain region. Oak decline is also widespread, in large part, due to aging forests that are exposed to a variety of abiotic stress factors as well as native insect and disease problems.

Other invasive insects include the hemlock woolly adelgid (*Adelges tsugae* Annand), a tiny sap-sucking insect, which kills eastern and Carolina hemlock (*Tsuga caroliniana* Engelm.). Although hemlock mortality is variable depending on tree age, site, elevation, and length of time since infestation, hemlock stands have declined significantly and the future remains uncertain.

A more recent exotic insect to Virginia's forests is the emerald ash borer (*Agrilus planipennis* Fairmaire), which was found in northern Virginia in 2008 and is killing every ash (*Fraxinus* spp.) tree in its path. Although insect biological controls have been released, it is unclear whether they will be able to slow or stop the EAB from decimating Virginia's ash resource. Nonnative diseases are also on the increase, including dogwood anthracnose (*Discula destructive* Redlin), butternut canker (*Sirococcus clavigignenti-julglandacearum* Nair, Kostichka, and Kuntz), beech bark disease (*Nectria coccinea* var. *faginata* Lohman, Watson, and Ayers) and, since 2011, thousand cankers disease (*Geosmithia morbida* Kolařík) of black walnut (*Juglans nigra* L.).

Urbanization

Urbanization is a major factor in forest land conversion as the rate of people moving from central cities to surrounding suburbs increases. Land for homes, businesses, shopping venues, schools, recreational areas, and other needs will continue to reduce our forest land acreage. During the past 10 years, Forest Inventory and Analysis (FIA) data indicated a 16,000-acre (6,475-hectare) average annual net loss of forest land in Virginia (Miles 2012).

Wildfire

The protection of lives, property and resources from wildfire is paramount and continues to be a foundational issue for VDOF. Virginia's leading cause of wildfire continues to be careless debris burning, accounting for nearly 40 percent of all wildfire causes. In a typical year, approximately 1,200 wildfires burn more than 10,000 acres (4,047 hectares). The human effect of these wildfires is increasing each year as the Wildland-Urban Interface increases at an alarming rate.

Each topographic region has unique fuel types and firefighting challenges.

Mountains: Fuels are mostly hardwoods with scattered areas of pine (pitch [*Pinus rigida* Mill.], Table Mountain, white, and Virginia). Hemlock and mountain laurel (*Kalmia latifolia* L.) contribute to the fuel loading.

Piedmont: The topography ranges from gently rolling hillsides to steep slopes. Gypsy moth and southern pine bark beetle outbreaks along with tornadoes, hurricanes, and ice storms during the past several years have added to the heavy fuel loading and significant snag hazard in some areas.

Coastal Plain: This area has one of the biggest challenges with communities being built in, or adjacent to, what was originally the main source of fiber for local pulp and saw mills. The loblolly pine plantations belonging to forest industry that originally covered thousands of acres are rapidly being developed and are now building homes and businesses along with growing trees.

Before the 20th century, fire occurred regularly in some parts of Virginia. Both Native Americans and settlers used fire to clear land and improve habitat for game. Consequently, many of Virginia's original native plants and animals were adapted to, or were even dependent on, fire. Early policies that required wildfires to be extinguished as rapidly as possible have contributed to declines in many of the State's fire-adapted species and natural communities.

Although the use of prescribed fire in resource management is regarded as an indispensable tool for land managers, Smokey Bear's message of preventing unwanted wildfire is still very important. In fact, Smokey understands the need for fire in the management and health of our forest ecosystems.

Conservation of Working Forest Land

In response to declining forest land in the State, the VDOF forest land conservation program was created to protect working forests from development by providing landowners with options for voluntary conservation. Because larger blocks of working forest provide the greatest range of benefits, the conservation program focuses on keeping the forest land intact and unfragmented, protecting the ability of landowners to manage their forest land for timber products and environmental benefits. The agency used geographic information systems analysis to rank all forest land in Virginia based on its contribution to water quality, wildlife habitat, production of forest products, and relative threat of conversion.

VDOF conservation easement deeds contain several elements that are specific to protecting working forests. These include specifying how and when stewardship plans are prepared and updated, location of homes to reduce effects on forest management, and restrictions on converting forests to cropland or pasture.

Demand for donated conservation easements is strong in Virginia because of a generous State tax credit program. The State provides tax credits that are equal to 40 percent of the value of the donated easement and can be sold to other taxpayers. This enables landowners to generate cash for their donations. These credits are also available to landowners who donate land for conservation.

Other than the State tax credit, Virginia has no dedicated funding source for land conservation. As a result, additions to Virginia's State forest system have resulted from private land donations, grant funds, or special allocations of State funds. The VDOF protects about 68,000 acres (27,519 hectares) on 22 State forests.

Tree Production in Virginia

Virginia State Nurseries

VDOF manages two State nurseries within Virginia. The hardwood nursery, known as the Augusta Forestry Center, is located in Crimora, VA, about 20 miles (32 km) west of Charlottesville. Each year the Augusta nursery grows 1.2 million hardwood seedlings across 25 native Virginia species and 1.5 million conifer seedlings (figure 6). The center is also actively involved in helping to restore the American chestnut in Virginia. Seed collected by the American Chestnut Foundation is planted on the nursery for research purposes. The Augusta nursery is also the location of the shipping and packing operation. Each year, seedlings are shipped all over the State via United Parcel Service to Virginia landowners.

Garland Gray Forestry Center is located in Courtland, VA, approximately 25 miles (40 km) southeast of Petersburg. This nursery was built in 1984 specifically for growing loblolly pine (figure 7). The nursery's soil and environmental conditions are perfect for the species, and 20 million loblolly pine seedlings are grown there each year. Since Virginia's forest land base is shrinking, high-quality seedlings are needed to ensure superior performance and adaptability across Virginia's landscape. Virginia seedlings have been tested in the State for

Figure 6. Workers lift red osier dogwood seedlings at the Augusta Forestry Center. (Photo from VDOF, 2007).

Figure 7. Loblolly pine seedling beds at the Garland Gray Forestry Center. (Photo from VDOF, 2010).

performance and, most importantly, cold hardiness. Since Virginia is in the northernmost range of loblolly pine, any seedling planted here has to be adapted to cold weather. The Garland Gray Nursery ensures seedlings meet the cold hardiness criteria needed for specific outplanting sites. Through the use of cultural practices such as root pruning, seedling survival is also enhanced, especially in years where drought is an issue.

Most recently, the Virginia nurseries have contracted to have new inventory management software developed. The new software will use cutting-edge technology so that the business can adapt to the changing environment. Online ordering has now become a normal aspect of any operation that has to sustain itself. Although an online store is currently being used, the new online store will be more enhanced, will allow for more detail, and will be able to accept online orders from tax-exempt customers. This will allow for more transactions by credit, which is another must have for any current business. Nearly two-thirds of the nursery inventory is sold to contractors planting on behalf of the landowners. With this shift in sales, new technology must be in place to track credit accounts and bulk customer activity. This new software will help enhance our service to our customers and Virginia landowners.

Tree Improvement Program

VDOF has supported an active tree improvement research program for more than 50 years. In that time, we have achieved substantial gains in the health and productivity of Virginia's loblolly pine forests and in the potential growth and form of the loblolly pine seedlings we produce. We estimate that every 1-percent gain in productivity as a result of tree improvement and selection has a $14.5 million effect on Virginia's economy each year. Since we are now providing seedlings with as much as a 62-percent gain in productivity, the financial effect on our State is clearly substantial.

Tree improvement research is based on a simple premise: select individual trees with the most desirable traits (such as growth rate, straightness, wood quality, branching characteristics, or disease resistance) and then use their flowers, pollen, and seed for breeding future generations of nursery stock (figure 8). Before tree improvement, loblolly seeds were collected from unimproved, natural stands—mostly from trees felled during logging operations.

Because Virginia lies at the northern limit of loblolly pine's natural range, Virginia's selections are especially valuable to our forest landowners. Numerous selections from farther south showed good early growth in tests only to suffer high damage or mortality when exposed to their first cold temperatures, snow, or ice events. In addition, the graders who have made selections in Virginia have rigorously focused on tree form, so our selections have a unique combination of rapid growth and excellent straightness and branching characteristics.

Diminished Species Restoration

VDOF monitors the status of numerous currently or potentially diminished tree species, such as Atlantic white cedar, eastern hemlock, butternut (*Juglans cinerea* L.), ash, walnut, and others. Depending on the ecological or economic (or both) importance of the species and the opportunities for successful action, we then develop strategies and programs, such as grafting (figure 9), for restoration. Our three current programs relate to American chestnut, longleaf pine, and shortleaf pine.

Figure 8. Controlled pollination of loblolly pine at the New Kent Forestry Center. (Photo from VDOF, 2009).

Figure 9. Pine-grafting by hand is one strategy for restoring diminished species. (Photo from VDOF, 2006).

American Chestnut

In 1969, Dr. and Mrs. Arthur Valk of Wilmington, DE, deeded 420 acres (170 hectares) of land in Nelson County, VA, to the VDOF to be used for American chestnut research. The tract was named the Lesesne State Forest after Mrs. Valk's father, Archibald Marian Lesesne DuPont. Research there focuses on hybridization with other blight-resistant chestnut species (in cooperation with the American Chestnut Foundation) and breeding of survivors and hypovirulence (both in cooperation with Dr. Gary Griffin with the American Chestnut Cooperators' Foundation).

Two orchards have been established: one is a pure American chestnut orchard grafted from surviving trees throughout Virginia and the other is a hybrid orchard of American chestnut and Chinese chestnut (*Castanea mollissima* Blume) established in cooperation with, and using seedlings from, the Connecticut Agricultural Experiment Station.

Today, we have a number of 15/16th (93.75 percent American chestnut; 6.25 percent Chinese chestnut) American chestnut seedlings from this work, and we continue to develop more. The 15/16th trees will be crossed with other 15/16th trees. A small percentage of their offspring should be chestnut blight resistant with the phenotype of the pure American chestnut tree. This cross could be 10 to 20 years away at the current rate the VDOF program is progressing. VDOF does not currently sell any hybrid or native American chestnut seeds or seedlings; all progeny from these efforts are used for further research and demonstration. If the American chestnut research is ultimately successful, VDOF could begin selling these seedlings and restore this tree to its native habitat.

Longleaf Pine

Native longleaf pine has almost completely disappeared from the Virginia landscape. When Virginia was first settled by Europeans, the lands mainly south of the James River were covered by 1.0 to 1.5 million acres (between 405,000 and 607,000 hectares) of longleaf pine forests at the limit of the species' northern range. Those forest ecosystems were very diverse biologically and served as valuable sources of naval stores (tar and pitch) for use in ship building, open range for livestock, and high-quality timber. But changing land-use practices such as fire exclusion, land clearing, feral pig grazing, and replacement by other pine species in reforestation programs, caused the longleaf forests of Virginia to decline and virtually disappear.

Although viable numbers of the species remain in portions of its native range to the south, only a few hundred mature longleaf trees currently remain in Virginia. We are actively involved in the identification, protection, and production of seed from that remaining genotype—activities that have become top priorities for our restoration effort.

Shortleaf Pine

Shortleaf pine has the widest range of any pine in the Southeastern United States, and occurs statewide in Virginia except on the Eastern Shore. It has long been a major forest component for much of Virginia. Before European settlement, Virginia's forests were significantly affected by the use of fire by Native Americans. Shortleaf pine's moderately thick bark and ability to resprout after top-kill allowed it to survive in this landscape. The land clearing, disturbance, and land abandonment regime associated with settlement was also favorable for shortleaf pine establishment.

In the decades before 1940, subsistence and tobacco-based agriculture in Virginia were still common. In the decades after 1940, however, Virginia saw increases in industrial development, movement away from subsistence farms, population shifts to urban/suburban areas, development of industrial forestry based on loblolly pine, and great reduction in acres burned by wildfire. Because of these factors, natural shortleaf pine regeneration declined.

In many areas across Virginia, shortleaf pine now occurs only as an occasional remnant tree in older stands or along property lines and has little regeneration. A real danger exists that the species will be lost from the landscape in these areas. We grow, sell, and encourage the planting of shortleaf pine. Our intent is to maintain or re-establish this species in the landscape in its natural range as a viable silvicultural option to offer to landowners.

Tree Planting Programs

Loblolly pine is by far the most widely planted tree species within the Commonwealth of Virginia. Although the species is only planted east of the Blue Ridge Mountains, it still accounts for approximately 90 percent of the total acres reforested within the State annually. The species is highly adaptable to a variety of soil types—from highly infertile Piedmont clay to well-drained sandy loams in the Coastal Plain. With the eastern and south central parts of the State being located within the "wood basket" of the Southeast, many opportunities are available for forest landowners to profit from growing timber. Education has been the key to success regarding increased tree planting in Virginia. Programs developed by VDOF and workshops held by Virginia Cooperative

Extension have raised landowner awareness about the issues surrounding forestry and the need for sound forest management. Private landowners control approximately 80 percent of the State's forest land, making this an important focus area.

Several cost-share programs within the State offer open field planting for landowners who have lost production in their agricultural fields and wish to convert to forest land. Although we are losing 16,000 acres (6,475 hectares) of forest land per year to urbanization, as foresters we are still able to replace a fraction of this loss by using these opportunities. In 2011, approximately 2,000 acres (810 hectares) were planted in trees and converted from agriculture to forestry land use (IFRIS data). In addition, nearly 750 acres (305 hectares) of pasture land bordering streams were planted in various hardwood species. Most landowners converting land to forest use have chosen to plant loblolly pine. Although it is impossible to revert from development, anytime we can change a land use to forestry, we are improving our State as a whole by adding the much-needed benefits that forests provide.

Over the past 5 years, eastern white pine (figure 10) and hardwood planting has been in decline. White pine planting has been affected mostly by a decrease in demand for use as Christmas trees and for interior trim. The most highly prized Christmas tree is Fraser fir (*Abies fraseri* [Pursh] Poir.). These trees are grown in southwestern Virginia and transported all over the State for reasonable costs. Hardwood planting decline results from high planting costs and the nature of the species. The cost of planting hardwoods in Virginia can exceed $500 per acre, while the average cost of planting loblolly pine is around $75 per acre. Furthermore, rotation age of hardwood species is at least double that of an average loblolly pine stand. Of the Virginia landowners planting hardwoods, most are doing so for streamside buffers, field borders, and for wildlife habitat enhancement.

Figure 10. Collecting cones from white pine trees. (Photo from VDOF).

Growing trees is, by its very nature, a long-term investment for forest landowners, with its economic returns not being realized for many years. For this reason, cost-share assistance for reforestation is critically important to many landowners. These programs are summarized in the following sections.

State-Funded Programs

Virginia's Reforestation of Timberlands Program is the flagship cost-assistance program. Created in 1970 by the General Assembly, the program's purpose is pine reforestation. It is funded by a forest products tax of primary wood processors and State general funds. Site preparation, tree planting, and followup competition control are practices available through the program. Landowner reimbursement is based on a flat rate, averaging about one-third of the cost. To date, the program has assisted with planting or stand improvement for more than 41,000 projects on 1.5 million acres (607,402 hectares).

The Southern Pine Bark Beetle Prevention Program assists landowners with focused practices designed to foster healthy pine forests. Although administered by the VDOF, source funding comes from the U.S. Department of Agriculture (USDA), Forest Service, State and Private Forestry. The program assists private landowners with reforestation practices for beetle-resistant longleaf pine in southeastern Virginia as well as precommercial pine thinning and commercial pine thinning of smaller (less than 25 acres [10 hectares]) pine stands.

Federally Funded Programs

Virginia landowners benefit from numerous USDA programs, including the Environmental Quality Incentive Program (EQIP), administered by the Natural Resources Conservation Service, and the Conservation Reserve Program and Conservation Reserve Enhancement Program (CRP and CREP), offered through the Farm Service Agency.

Private and Regionally Specific Programs

Several private companies (Vaughan-Bassett Furniture, Plow and Hearth, Glatfelter Pulp Wood, and Belfort Furniture) recognize the benefit of trees in Virginia and have funded seedling programs. These companies partnered with VDOF to distribute pine or hardwood seedlings to landowners to improve the sustainability of Virginia's forests. In recent years, new opportunities for assistance have emerged. These have specific scope, purpose, and funding streams and provide assistance to landowners for traditional and new forestry practices. The Tomorrow Woods program, Forests for Southwest Virginia, and Forests to Faucets are examples of these partnerships.

The Future of Tree Planting in Virginia

Virginia nurseries have increased inventory and have experienced an increased demand for seedlings over the past 2 years (figure 11). If the past 5 years of economic conditions are an effective indicator of future sales, however, it appears we could be headed back down again because the future of planting is mostly correlated with the number of acres harvested annually. As long as timber is being removed from the landscape, tree planting will occur in rural Virginia. It appears that the state of the economy has had the opposite effect on forestry than most of us would have predicted.

Virginia Dominion Power has introduced several waste-wood-powered plants across Virginia. Because most of the fuel used at these plants is waste wood that would normally be left on the logging site, this additional revenue stream presents opportunities for forest landowners to increase their returns. The more options landowners have to make money, the more likely they are to continue with good forestry practices, such as tree planting.

USDA Forest Service programs have helped subsidize expensive wildlife management planting projects for Virginia landowners. Hardwood planting has the potential to increase

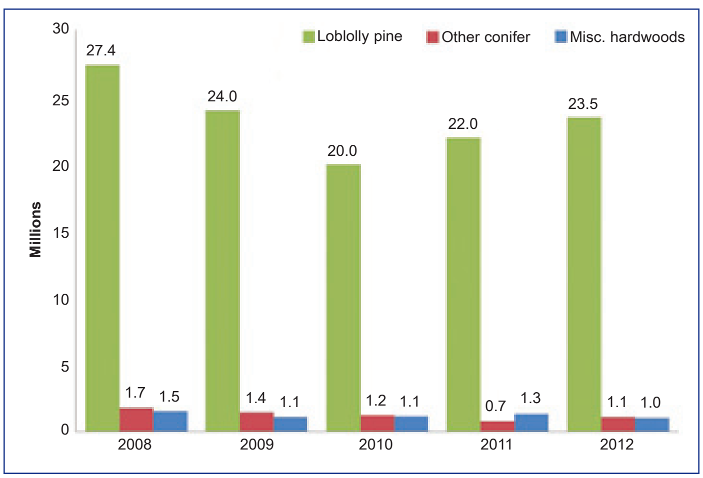

Figure 11. Virginia nursery seedling sales during the past 5 years. (Data source: VDOF, 2012).

over the next few years if these programs stay intact and are provided to the right audience. As with all forestry professionals, we must stay positive and react appropriately and aggressively to the changes around us.

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Acknowledgments

The author thanks Chris Asaro, Charlie Becker, Jerre Creighton, Dean Cumbia, Harvey Darden, Rob Farrell, Justin Funk, John Pemberton, Jim Pugh, and Paul Revell of the Virginia Department of Forestry for their contributions.

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The Use of Soil Additives and Root Dips on Noble Fir Christmas Trees

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Abstract

Three soil additive treatments and two root dips were applied to noble fir (*Abies procera* Rehd.) seedlings planted at three commercial Christmas tree plantations in Oregon. Survival was unaffected by any root treatment tested, although mortality was remarkably low for all treatments because of a mild summer in the region. The Rootex™ dip treatment resulted in modest increases in leader growth and stem diameter after 1 year of growth. Mycorrhizae colonization was low and no differences among treatments were noted. Seasonal growth and lammas growth was greater on one of the sites relative to the other two, which may be attributed to the use of milk carton enclosures around each seedling to prevent rabbit damage. The significant leader growth apparently provided from the enclosure deserves additional cost-benefit evaluation.

Introduction

Numerous materials can be added to the soil or drenched on tree roots during planting. Published trials on soil additives and root drenches reach back at least to 1950 and include hydrophilic gels, nutritional substances, fungicides, sodium alginate, seaweed products, insecticides, clays, vermiculites, auxins, and more (Sloan 1994). Generally, product claims focus on alleviation of plant water stress, root protection during planting, improved nutrient uptake, improved shoot or root growth, improved soil-water holding capacity, or some combination of the aforementioned. In general, results have been mixed and specific to site conditions, species planted, or seedling conditions such as root desiccation. Nonetheless, new products emerge, older formulations are changed or discontinued, and combinations of multiple products warrant continued testing.

Most conifer plantings that are used for Christmas tree production or forest regeneration do not receive supplemental watering after planting. Any boost in plant available water through the summer and fall is likely to improve establishment success (Talbert 2008) and minimize replanting expenses. Furthermore, any boost in initial plant growth could improve the time-to-market for Christmas tree producers. This study evaluated the effect of various commonly available additives and dips on growth and survival of noble fir (*Abies procera* Rehd.) field Christmas tree plantings.

Methods

Seedlings

Container noble fir seedlings (10 in^3 [164 cm^3]) were grown under operational conditions at the Kintigh Mountain Home Nursery (Springfield, OR). Seedlings were 2 years old and the seed source was from the Pacific Northwest Christmas Tree Association Hostetler seed orchard (Dallas, OR). The same seedling lot and stocktype were used at all test sites.

Sites

Three commercial Christmas tree test sites were selected in Oregon near the towns of Monroe, Banks, and Warren. All test sites were relatively flat, well drained, and were kept free of competing weeds for the duration of the study. Seedlings were hand planted into premarked planting spots using a 5.5 by 5.5 ft spacing (1.7 by 1.7 m).

The Monroe site (figure 1) was planted on March 9, 2011. This site had been planted in 2010 but because of rabbit damage to nearly all of the seedlings, the area was plowed and disked for replanting. To protect from rabbit feeding, planted seedlings at this site were enclosed in 1-quart milk cartons with open ends secured by two bamboo stakes shortly after planting (figure 2). The Banks site was a second rotation field and was planted on May 17, 2011. Site preparation included stump grinding, liming, and disking. At the Warren site, trees were interplanted on February 11, 2011 in a field where a few harvest-sized trees remained uncut. Two planting spaces were left unplanted where existing trees remained to avoid competition or shade.

Figure 1. Noble fir planting and layout of typical plot. (Photo by Chal Landgren, 2011).

Figure 2. Milk carton used for rabbit protection. (Photo by Chal Landgren, 2011).

Treatments

An untreated check, three additives, and two root dips comprised the six treatments (table 1). The additive products were distributed around the container seedling as each tree was planted. The root dip products were applied by immersing seedlings in the liquid mixture for 60 seconds and then keeping them in a planting bucket until planting within 1 hour.

Measurements

Seedling survival and morphology were measured in late September through October 2011 after the season's growth had ceased. Morphology measurements included total tree height, leader growth, stem diameter, and late-season lammas growth (yes = 1 or more buds had regrown; no = no buds had grown). In addition, tree color was evaluated using the Royal Horticultural Society (RHS) Colour Chart system (Royal Horticultural Society 2012). A scale ranging from 1 (yellow) to 5 (very dark green) has been used in evaluating Christmas tree colors in progeny and fertilizer tests for noble fir (Bondi 1993). Each tree was evaluated for color with the observer keeping the sun behind the color charts. For reference, a value of 3 = RHS color # 137A (Green), 4 = #135B (Dark Green), and 5 = # 189A (Dark Gray Green).

A subsample of three trees from each of the six treatments at each test site was excavated and delivered to PlantHealth LLC (Corvallis, OR), where they were evaluated for shoot and root mass (fresh weight) and scored for mychorrizal colonization (0 = no ectomycorrhizae; 1 = 1 to 10 percent ectomycorrhizae, 2 = 11 to 20 percent, and so on).

Table 1. Summary of treatments, product composition, application rates, and manufacturer.

Treatment	Product composition	Rate	Manufacturer
Control			
Soil additives			
Geohumus™ (Geo)	25 percent organic component is a cross-linked, partially neutralized polyacrylic and 75 percent mineral components a mixture of ground rock; minerals and washed sand in a granulate composition.	1 oz. (29.6 ml) per plant	Geohumus International GmbH, (Frankfurt, Germany)
BioTerra plus™ (Ecto)	(Ectomychorrizae mix) Active ingredients—*Pisolinthus tinctorius* (4,700,000 spores/gm), *Scleroderma sp.* (69,000 spores/gm), *Rhizopogon occidentalis* (85,000 spores/gm)	1 oz. (29.6 ml) per plant	Plant Health, LLC, (Corvallis, OR)
Geohumus™+ BioTerra plus™ (Geo+Ecto)	50/50 mix of both products	1 oz. (29.6 ml) per plant	
Root dips			
Zeba™	88 percent starch-g-poly (2-propenamide-co-2-propenolc acid) potassium salt	1.3 oz/4 gal water (36 g/15.1 water)	Absorbent Technologies (Beaverton, OR)
Rootex™	Ammoniacal N 7 percent, Available Phosphoric Acid (P_2O_5) 47 percent, Soluble Potash (K_2O) 6 percent, Inerts 40 percent,	1 lb/5 gal water (0.45 kg/18.9 l water)	Cosmocel (Monterrey, México)

Experimental Design and Statistical Analyses

All sites were planted in a randomized complete block design with five treatment replications. Each replication contained 10 trees randomly assigned to each of the 6 treatments for a total of 300 trees per site. Data were analyzed using SAS 9.2 (SAS Institute, Inc., Cary, NC). Duncan's Multiple Range Test was used to determine significant differences among means.

Results

Survival

Only 35 of the 900 noble fir seedlings (3.8 percent) died in 2011 across all sites. These were evenly divided among the sites and without any meaningful pattern among treatments. The 2011 growing season had good rainfall and was without any significant hot or dry period; in other words, a poor year to evaluate mortality. In a typical year, mortality of noble fir Christmas tree plantings averages 6 to 7 percent.

Morphology

Height and color had significant site-by-treatment interactions; stem diameter and leader length did not (table 2). The Rootex™ treatment resulted in trees with larger stem diameter and longer leaders than all other treatments across the three sites. In addition, the Rootex™, Geo, and Geo+Ecto treatments had larger stem diameters relative to untreated control seedlings across all sites (table 2).

Lammas growth varied among sites but differences were not related to treatment.

At the Monroe site where milk carton enclosures were used, trees were larger and had more lammas growth than those on the other two sites (table 3).

Average values of root and shoot mass and percent mycorrhizae colonization are summarized in table 4. With the limited number of plants, statistical evaluation is limited. It is clear, however, that ectomycorrhizal colonization after the first growing season was minimal.

Table 2. Average height, leader length, stem caliper, and color by site. Means followed by the same letter do not differ significantly at $\alpha \leq 0.05$.

Treatment	Height in (cm)	Leader length in (cm)	Stem diameter mm	Color
Monroe site				
Control	15.3 (39.2) ab	7.4 (18.9) b	6.1 c	4.0 a
Geohumus	15.8 (40.4) a	7.6 (19.5) b	6.6 a	4.1 a
Ecto	15.1 (38.8) ab	7.4 (18.9) b	6.3 abc	3.9 c
Geo+Ecto	15.6 (40.1) a	7.8 (20.0) b	6.5 ab	4.0 a
Zeba	14.6 (37.4) b	7.3 (18.7) b	6.1 bc	3.8 a
Rootex	15.6 (39.9) a	8.9 (22.7) a	6.6 a	3.8 a
Banks site				
Control	10.5 (26.9) b	2.7 (6.9) c	5.2 bc	3.5 b
Geohumus	9.6 (24.6) d	3.2 (8.1) b	5.3 bc	4.5 a
Ecto	9.8 (25.1) cd	2.7 (6.9) c	5.0 c	3.4 b
Geo+Ecto	9.7 (24.9) cd	3.3 (8.5) b	5.5 b	4.1 a
Zeba	10.3 (26.5) bc	2.7 (7.0) bc	5.2 bc	3.3 b
Rootex	11.7 (29.9) a	4.5 (11.5) a	7.5 a	4.1 a
Warren site				
Control	12.1 (30.9) ab	2.3 (6.0) c	6.9 a	3.7 a
Geohumus	11.9 (30.4) ab	2.5 (6.5) bc	7.3 a	3.7 a
Ecto	11.4 (29.3) b	2.7 (6.8) bc	7.2 a	3.4 a
Geo+Ecto	11.7 (30.0) ab	2.8 (7.3) b	7.0 a	3.7 a
Zeba	11.2 (28.8) b	2.6 (6.6) bc	6.9 a	3.9 a
Rootex	12.4 (31.7) a	3.3 (8.5) a	7.2 a	3.5 a

Table 3. Average tree height, leader length, stem diameter, and lammas growth by site.

Site	Height in (cm)	Leader length in (cm)	Stem diameter mm	Number and (percent) trees with Lammas growth
Banks	10.4 (26.4)	3.2 (8.2)	5.4	3 (1%)
Warren	11.9 (30.2)	2.7 (7)	7.1	77 (26%)
Monroe	15.5 (39.3)	7.8 (19.8)	6.4	175 (59%)

Table 4. Average root and shoot mass (fresh weight) and ectomycorrhiza colonization for each treatment.

Treatments	Root mass	Shoot mass oz (g)	Percent ecto colonization rating
Control	0.51 (14.7)	0.80 (22.9)	0.7
Geohumus	0.76 (21.8)	1.00 (28.6)	0.3
Ecto	0.86 (24.8)	1.20 (35.4)	0.4
Geo+Ecto	0.66 (18.9)	0.99 (28.3)	0.1
Zeba	0.79 (22.7)	0.83 (23.7)	0.9
Rootex	1.20 (34.9)	1.10 (31.9)	0.3

Discussion

Soil Additives

Soil additives such as ectomycorrhiza have been shown to improve growth and survival in dry southern pine sites (Echols and others 1990) with inoculated seedlings. On the other hand, additions of *Pisolithius tinctorius* (one of the mycorrhizae in the BioTerra™ plus mix used in this study) on Douglas-fir on a harsh site did not improve seedling field performance (Pilz and Znerold 1986). Cordell (1996) showed both growth and survival benefits with mycorrhizae additions on reclaimed mine sites with acid soils (less than pH 3.0).

The use of Geohumus™ as an additive in conifer plantings in the field is recent. Drought protection has been reported for lettuce (Woodhouse and Johnson 1991) and hydrangea (Owen, pers. comm. 2012). In this study, no major response was evident relative to the untreated control seedlings. The combination of Geo+Ecto did show a modest leader growth improvement relative to the control. Ectomycorrhizae colonization after the first growing season was less than 1 percent, however, and does not appear to significantly influence growth of these container seedlings planted for Christmas trees.

Root Dips

Most root dip experiments suggest minimal (or variable) benefit to conifer seedling survival or growth during the first growing season (Sloan 1994). Landis (2006) noted that few if any studies had looked at container seedlings, and a study by Bates and others (2004) showed negative results when root dips were compared with a water dip alone on bareroot Christmas tree plantings. One noble fir trial (Owston and Stein 1972) showed some root dips reduced desiccation in roots exposed up to 40 minutes before planting. Few trials have evaluated noble fir growth in response to root dips on good sites in moist years. In this trial, the Rootex™ product did provide a benefit in terms of height growth, likely related to a mild fertilization effect rather than moisture conservation or root protection. On the other hand, seedlings treated with Zeba® root dip did not differ in morphology, survival, or color from the untreated control. In addition to adequate soil moisture on the site, planting practices that reduce root exposure from drying will minimize benefits from root dips designed to protect from desiccation. Furthermore, container seedlings are somewhat buffered from root drying by the container media.

Site Differences

Trees planted at the Monroe site were larger and had longer leader growth than those planted on the other two sites after the first year of field growth (table 3). This growth response is likely a "milk carton effect" because of all trees on the Monroe site being enclosed in open milk cartons to reduce rabbit damage (figure 2). Tree shelters, like Tubex™, have been shown to improve survival and growth on dry sites (Bainbridge 1994). The improvement is in addition to that attributed to reductions in browsing or other damages. Anthony (1982) suggested that open Vexar™ tubes provided growth improvements for ponderosa pine beyond simple browse protection from mule deer.

At the Monroe site, 59 percent of the trees exhibited lammas growth compared to 26 percent at Warren and 1 percent at Banks (table 3). Typically, lammas growth is caused by late season rainfall. Rain events were not monitored at individual sites during the study period but based on historical averages; the Monroe site is the driest of the three locations. An untested hypothesis explaining this increased lammas growth would suggest that the milk carton decreased moisture loss via shading. The Banks site was the final location planted, and it is possible that root development was delayed and lammas growth was minimal as a result. In harvest-age noble fir Christmas trees, lammas growth is undesirable along the leader because it tends to result in multiple tops. In seedlings, lammas growth can be beneficial if the growth is uniform because it essentially provides two growth periods in 1 year (though there is risk of damage to actively growing foliage in the event of an early fall freeze).

Milk cartons or similar enclosures may provide an inexpensive alternative to tubes, but the mechanism for this improvement is speculative and was an unexpected result of this study deserving additional exploration.

Foliar Color

Seedling color in this trial started and ended with trees showing good color regardless of treatment. A wide variety of color charts are available, but the RHS and Munsell systems are most common. Color translation tables between RHS and Munsell colors are available (Kelley 1965), and both systems allow for color comparison via the international CIE system.

Conclusion

The year 2011 was an excellent year for survival rates of noble fir container seedlings on three Oregon sites because of a mild, wet growing season. As a result, mortality was unaffected by treatments at the time of planting. It is unknown how these products would influence seedling field performance in a droughty year.

The Rootex™ treatment provided a modest growth improvement. In an operational Christmas tree planting, the addition of Rootex™ as a dip would be a low-cost treatment easily done during hand or machine planting. The value of an additional inch or so of leader growth, however, is debatable, unless the effect increases over time.

The ectomycorrhizae and Geohumus additions resulted in minimal root colonization and minimal growth improvement. The addition of these products at planting is time consuming compared with the root dips. As shown in this study, these soil additives are likely not needed on these productive sites during moist years.

The milk cartons cost roughly $0.08 each, plus each carton needs to be secured with two stakes. The time required to install and secure the carton is a little less than that needed to hand plant the tree itself. If this effort could consistently result in an additional 5 inches of tree growth, it is definitely a practice deserving further investigation.

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Acknowledgments

The author thanks the following individuals for their valuable assistance in this study: Dr. Wei Yang for data analysis; Robert Linderman, Stacy Reese, Plant Health LLC, Albany, OR.; Mark Russell, Geohumus; Steve Carlson, Zeba; Raul Moreno, OVS/Rootex; Testing Sites: Stroda Farms, Heritage Plantations, Landgren Tree Farm; and Judy Kowalski, North Willamette Research and Extension Center. Partial funding was provided by the Oregon Nursery Association and Oregon Department of Agriculture.

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Laws Affecting Reforestation on USDA Forest Service Lands

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Abstract

Many laws affect reforestation practices on U.S. Department of Agriculture (USDA), Forest Service lands. This article summarizes several acts that have had important influences on Federal reforestation. In particular, we delve into The Knutson-Vandenberg Act of 1930 and the National Forest Management Act of 1976, which have had the largest effect on reforestation of the national forests.

Introduction

Reforestation has a long and mixed history in the United States. At the beginning of the 20th century, States in the Great Lakes region experienced massive firestorms as wildfires raced through cutover and denuded areas. In the West, the great fires of 1910 that burned Wallace, ID, led to the famous incident in which Ed Pulaski (after whom the tool is named) saved his crew by forcing them into a mine shaft and holding them there at gunpoint to escape the flames (Pyne 2001). These events and subsequent episodes, such as the Tillamook Burn (a series of large fires in western Oregon from 1933 to 1951), tore through the West and seared themselves into the collective memory of the American public and underscored the need to reforest landscapes (Tillamook County Online 2012).

Capitalizing on this reforestation need and also to put large numbers of people to work, President Franklin Roosevelt created the Civilian Conservation Corps, which, among many other notable accomplishments such as construction of many of the grand lodges of our National Parks, planted hundreds of thousands of acres of trees.

The aforementioned factors and many others developed into a growing national environmental consciousness, which led to many Federal laws that directly and indirectly influence reforestation on Federal, and sometimes other, lands. In addition, many States, beginning with Oregon in 1971, have adopted forest practices acts that regulate activities on non-Federal lands.

In this article, we will briefly explore some of the relevant Federal laws that affect reforestation and delve more deeply into two key laws that have a profound effect on management of the national forests, primarily through funding and policy implications for reforestation.

Overview of Federal Laws Affecting Reforestation

Clarke-McNary Act of 1924

This act allowed the USDA to work with land-grant universities and other agencies to support and educate private landowners regarding reforestation efforts for "wood lots, shelter belts, wind breakers, and other valuable forest growth" (Title 16, United States Code [U.S.C.], Section 568) (figure 1). Among other things, this act also supported many graduate degrees in forestry to aid in the development of reforestation efforts nationwide.

The Knutson-Vandenberg Act of 1930

This act, known commonly as KV, authorized establishment of new USDA Forest Service nurseries and provided official

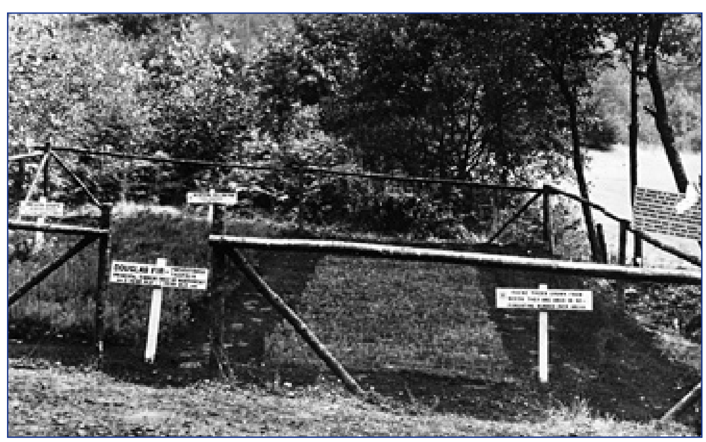

Figure 1. These informational signs at a demonstration nursery at Eagle Creek Campground show one of the many avenues the USDA Forest Service used to educate the public about reforestation. (Photo from USDA Forest Service archives, date unknown).

codification for existing USDA Forest Service nurseries (figure 2). In addition to nurseries, KV was designed to "do all other things needful in preparation for planting on National Forests" (16 U.S.C. 576). In particular, KV permits the collection of funds from USDA Forest Service projects, such as timber sales, to pay for reforestation and improvement of the sale area. Further exploration of KV occurs later in this article.

Anderson-Mansfield Reforestation and Revegetation Joint Resolution of 1949

This resolution declares that "denuded and unsatisfactorily stocked timberland…[or] seriously depleted rangelands… will not restock or revegetate satisfactorily or within a reasonable time except through reforestation and revegetation…." (16 U.S.C. 581j). The resolution set a 15-year timeframe to reforest these lands and also provided funds for acquisition of non-USDA Forest Service land to be used for nurseries. The ability to acquire non-USDA Forest Service land was significant because, up to that point, nurseries could be established only on land managed by the USDA Forest Service—and, depending on the location, that land was not necessarily ideal for nursery crop production. As a historical note, 1949 was also the year that Aldo Leopold's *Sand County Almanac* was published.

Granger-Thye Act of 1950

This act allowed donations from partners for reforestation and other types of work on non-Federal lands near a national forest. In addition, Granger-Thye made clear that USDA Forest Service nurseries may sell trees and seed to other Federal and public agencies, but they may not compete with private nurseries (figure 3).

Figure 2. This view of the Wind River nursery in Washington State shows the context of the nursery in relation to the Yacolt burn. (Photo from USDA Forest Service archives, circa 1930).

Multiple-Use Sustained-Yield Act of 1960

This act directed that many values be considered for use of National Forest System lands "so that they are utilized in the combination that will best meet the needs of the American people; making the most judicious use of the land…." (16 U.S.C. 531(a)). In addition, the act directed planning to determine the "high-level annual or regular periodic output of the various renewable resources of the National Forests without impairment of the productivity of the land" (16 U.S.C. 531(b)). This again highlighted the drive to provide ample resources for reforestation to ensure long-term yields without decreasing the forested landbase.

Endangered Species Act of 1973

The Endangered Species Act (ESA) directed all Federal agencies to "conserve endangered and threatened species" (16 U.S.C. 1531 Sec. 2(c)(1) and to protect their critical habitat. ESA had a large indirect effect on reforestation by dramatically altering the forest management approach and techniques in use in many areas of the country. A prime

This political cartoon from the Sacramento Bee *newspaper on April 4, 1941, shows that the government-private nursery competition issue is nothing new.*

Figure 3. There has always been a delicate balance in producing reforestation materials while not competing with private business. (From USDA Forest Service, 1997).

example of this effect is the large reduction in the use of regeneration harvest in the Pacific Northwest to conserve late seral habitat for the northern spotted owl (*Strix occidentalis caurina* [Merriam]). This reduction in regeneration harvest (which also resulted from many other legal, scientific, and social factors) resulted in a commensurate reduction in the near-term need for reforestation. In addition, potential listings under ESA for plant species such as whitebark pine (*Pinus albicaulis* Englem) can lead to special considerations for forest restoration programs and the methods used to collect, store, grow, and plant seeds and seedlings.

Forest and Rangeland Renewable Resources Planning Act of 1974

This act directed the USDA Forest Service to prepare and update a Renewable Resource Assessment, which evaluated the Nation's timber supply every 10 years. Furthermore, the act specified that, on national forest lands, the agency perform surveys of reforested areas the first and third years after planting. The act also set the requirement that timber harvest will occur only if the lands can be reforested within 5 years after harvest. Many of these requirements were updated, included, or superseded by the subsequent National Forest Management Act.

National Forest Management Act of 1976

The National Forest Management Act (NFMA) supplemented and amended the Forest and Rangeland Renewable Resources Act. NFMA applied to USDA Forest Service lands and continued to include requirements for first and third year reforestation surveys. It also continued to include the 5-year reforestation requirement. Furthermore, NFMA set out requirements to maintain lands in "appropriate forest cover" (16 U.S.C. 1606 Sec. 4 (d)(1)), to use "sound silvicultural practices" (16 U.S.C. 1606 Sec.6 (m)(1)), "to provide for a diversity of plant and animal communities" (16 U.S.C. 1604 Sec. 6 (g)(3)(B)), and to ensure that stands have generally reached "the culmination of mean annual increment" (16 U.S.C. 1606 Sec.6 (m)(1)) before regeneration harvest. These factors, among many, led to the current system of professional silviculturist certification within the USDA Forest Service. In addition, NFMA laid the groundwork for the creation of forest planning by requiring "one integrated plan for each unit of the National Forest System" (16 U.S.C. 1606 Sec.6 (f)(1)).

A Closer Look at the KV Act

KV has arguably had the largest direct effect on the reforesting of lands managed by the USDA Forest Service. Not only did KV officially authorize the establishment of the USDA Forest Service nursery system, which has supplied hundreds of millions of tree seedlings and other plant materials, KV also provided a funding vehicle to reforest and improve "the future productivity of the renewable resources of the forest land on [the] sale area…." (16 U.S.C. 576b Sec. 3 (a)(4)). The funding for KV comes from the sale of the timber (or other resource), and elements such as funding for essential reforestation (required stocking) can be included directly in the bid price for the sale in addition to a minimum of 50 cents per thousand board ft (MBF) to be returned to the National Treasury. This approach of requiring the bid price to cover essential reforestation ensures that adequate funds are available to reforest the harvested site. If additional KV funds are available, other enhancement projects can be conducted within the defined "sale area improvement" (SAI) plan. The SAI plan can encompass the harvest area and other area affected by the treatment (within ~0.25 mi [~400 m]). KV funds from one project may not be used to supplement another project, so each project must be self-sufficient.

NFMA, a Key Law Affecting Federal Reforestation

NFMA has guided many of the policies of the USDA Forest Service for nearly 40 years. It would probably be an overstatement to describe NFMA as the Magna Carta of USDA Forest Service activities, but it has certainly provided the foundation for many core elements of national forest management.

A primary effect of NFMA has been the creation of forest plans for all national forests. These plans guide nearly all activities, management, and use that occur on National Forest System lands. The plans determine "forest management systems, harvesting levels" (16 U.S.C. 1604 Sec. 6 (e)(2)), and coordinate "outdoor recreation, range, timber, watershed, wildlife and fish, and wilderness" (16 U.S.C. 1604 Sec. 6 (e)(1)) into a comprehensive management approach for a forest. The forest plan incorporates "public involvement" (16 U.S.C. 1604 Sec. 6 (f)(4)), "interdisciplinary review" (16 U.S.C. 1604 Sec. 6(g)(3)(F)(ii)), considers "economic and environmental aspects of various systems" (16 U.S.C. 1604 Sec. 6(g)(3)(A)), and must base decisions on the "suitability and capability of the specific land area to meet overall multiple-use objectives" (16 U.S.C. 1604 Sec. 6(g)(3)(B)).

NFMA's requirements also led to the system of certifying USDA Forest Service silviculturists. All vegetation management activities on USDA Forest Service lands must have a prescription that is reviewed and signed by a certified silviculturist. Silvicultural certification is a challenging process that requires several years of experience with reforestation, timber stand improvement, and timber harvest and planning activities. In addition, candidates for certification must successfully pass 12 weeks of graduate-level education in various ecosystems around the country. Finally, the candidate must prepare and successfully defend a detailed silvicultural prescription before a panel of experts. After certification, silviculturists must complete required levels of advanced continuing education every 4 years and receive the recommendations of both their forest supervisor and their forest silviculturist to be recertified.

Certified silviculturists have the training and expertise to help ensure that the agency meets many of the requirements of NFMA. In addition to the requirement to use "sound silvicultural practices" (16 U.S.C. 1604 Sec. 6 (m)(1)) and to "maintain appropriate forest cover" (16 U.S.C. 1604 Sec. 4 (d)(1)), NFMA requires the agency to "preserve the diversity of tree species" (16 U.S.C. 1604 Sec. 6 (g)(3)(B)). The act also makes clear that ecological, not economic, considerations will drive the selection of harvest methods. For instance, the USDA Forest Service must ensure that "the harvesting system to be used is not selected primarily because it will give the greatest dollar return or the greatest unit output of timber" (16 U.S.C. 1604 Sec. 6 (g)(3)(E)(iv)). Furthermore, regeneration harvest techniques such as clearcutting, seed tree cutting, and shelterwoods may be used only if they are "determined to be the optimum method…to meet the objectives and requirements of the relevant land management plan" (16 U.S.C. 1604 Sec. 6 (g)(3)(F)(i)). When these techniques are used, they must be "shaped and blended to the extent practicable with the natural terrain" (16 U.S.C. 1604 Sec. 6 (g)(3)(F)(iii)). Stands that are considered for regeneration harvest must have achieved, in general, culmination of mean annual increment (CMAI—that is, their biological rotation age as defined by their declining annual growth). NFMA provides exceptions to the CMAI rule to allow for "use of sound silvicultural practices, such as thinning or other stand improvement measures" (16 U.S.C. 1604 Sec. 6 (m)(1)) and for salvage relating to fire, windthrow, insects, and disease. NFMA also offers an exception to the CMAI requirement in consideration of multiple-use resources such as recreation and wildlife habitat.

NFMA has strong requirements that look ahead to the future productivity of a site, and focuses in particular on the ability to reforest an area. Timber may be harvested from national forests only if "there is an assurance that such lands can be adequately restocked within 5 years after harvest" (16 U.S.C. 1604 Sec. 6 (g)(3)(E)(ii)). The act goes further to ensure that the reforestation requirement is met by also requiring that treated lands "shall be examined after the first and third growing seasons and certified…as to stocking rate…Any lands not certified as satisfactory shall be…scheduled for prompt treatment" (16 U.S.C. 1601 Sec. 4 (d)(1)).

Conclusion

Many laws, regulations, and policies influence reforestation and land management on the national forests. We have covered only a few important acts of Congress that have an effect on the reforestation of National Forest System lands. The primary laws that affect reforestation are The Knutson-Vandenberg Act of 1930 and the National Forest Management Act of 1976. The unique combination of KV's official authorization to operate USDA Forest Service nurseries to supply reforestation materials, KV's ability to ensure funding for essential reforestation, and NFMA's requirement to complete reforestation within 5 years has led to a strong reforestation ethic on National Forest System lands. It is clear that laws and policies change over time, but the forward thinking contained in these two acts has helped ensure that current and future generations are able to enjoy and benefit from our Nation's national forests.

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Hackberry: An Alternative to Ash Species in the Battle Against Emerald Ash Borer

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Abstract

Emerald ash borer (*Agrilus planipennis* Fairmaire) is a pest that is spreading across much of the Northeastern United States and parts of southeastern Canada. Scientists, foresters, and land managers are dealing with its devastating effect in a variety of ways. One simple and effective method for controlling the pest is to plant a diverse array of native tree species that are resistant or immune to attack from this pest. Northern hackberry (*Celtis occidentalis* L*)* is comparable with most, if not all, of these regions' native ash species and is, therefore, suggested as a suitable alternative for these species.

Background

Eastern North America contains a number of native and introduced ash species. Southern Ontario and much of the Great Lakes region are home to five of these species, including white ash (*Fraxinus americana* L), green/red ash (*F. pennsylvanica* Fern), black ash (*F. nigra* Marsh), blue ash (*F. quadrangulata* Michx), and pumpkin ash (*F. profunda* [Bush] Bush) (Smith 2004).

At least two of these species, white and green/red ash, are cornerstones of many rural and urban landscapes found throughout these regions. Since its discovery in the Detroit, MI/Windsor, ON, area in 2002, however, emerald ash borer (*Agrilus planiplennis* Fairemaire) (EAB) has destroyed millions of native ash trees across several States and two Canadian provinces (figure 1) (Michler and Ginzel 2010). In fact, the speed and thoroughness of the devastation have not only affected the appearance of these landscapes, but they threaten their health and function as well. Without an effective long-term solution, the nature and severity of this outbreak have created a sense of urgency among researchers, governments, and the public.

Despite the fact that no effective control of EAB has yet been found, researchers and land managers are investigating several promising approaches, including the following:

- Chemical controls using a number of novel insecticides (Herms and others 2009, BioForest Technologies 2011, McCullogh and others 2011).
- Biological controls using an array of fungi, nematodes, and parasitic insects (Hajek and Bauer 2009, USDA APHIS/ARS/FS 2012).
- Genetic manipulation using Asian and North American populations of EAB (Bray and others 2011).
- Germplasm conservation (Simpson 2010).
- Silvicultural controls using harvesting prescriptions (Gupta and Miedtke 2011, Williams and Schwan 2011), aftermath natural regeneration (Herms and others 2011), the development of EAB-resistant hybrids between native and exotic ash species (Koch and others 2011), and planting alternative tree species that are resistant or immune to EAB attack (Cregg and Schutzki 2006).

An Interim Solution

Given the importance of ash trees to the health and functionality of urban and forest landscapes and the very real threat facing these trees, it is important that prompt actions be taken in response to EAB. Failure to take action runs the risk of repeating past experiences, such as those that occurred as a result of chestnut blight, Dutch elm disease, and butternut canker. These epidemics have decimated populations of American chestnut (*Castanea dentata* [Marsh] Borkh), native elm species *(Ulmus americana* L*, U. thomasii* Sarg, and *U. rubra* Muhl), and butternut (*Juglans cinerea* L), respectively.

In light of recent decisions by many local governments to restrict or ban planting of ash species, one of the easiest and most effective actions that homeowners, landowners, and tree planting agencies can take is to plant a diverse array of trees, particularly species that are resistant to diseases and insect infestations like EAB. Although this tack may not affect the ultimate fate of native ash species, it will help to maintain the health and functionality of the associated landscapes. It may also buy some time until a more effective solution can be developed.

One of the many species that can assist in this endeavor is common, or northern, hackberry (*Celtis occidentalis* L).

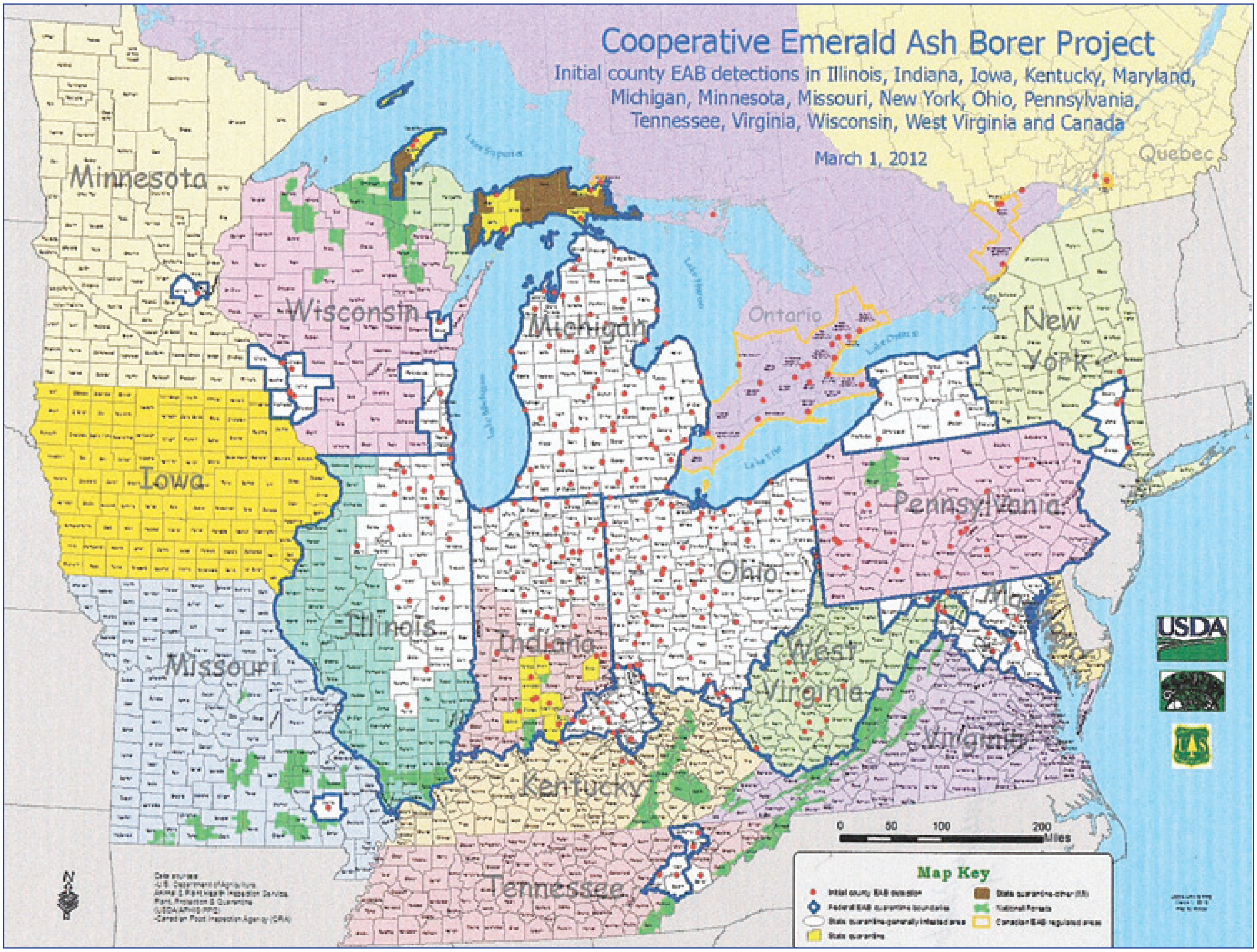

Figure 1. The spread of emerald ash borer across northeastern North America. (Map source: http://www.emeraldashborer.info, March 2012).

Species Description and Attributes

Northern hackberry is a relatively fast-growing and shade-tolerant member of the elm family (figure 2**)**. It is a native, deciduous tree that can live up to 200 years and grow to more than 65 ft (20 m) in height. Characteristically, it has an upright form with ascending branches, dark green foliage, and attractive bark. It produces regular crops of small cherry-like fruit that turn dark blue or purple when ripe.

Northern hackberry has a large geographic range, most of which is in the eastern part of the United States (figure 3). In southern Ontario, it is at the northern extremity of this range within the deciduous forest region (or Carolinian zone). Interestingly, some evidence shows that northern hackberry is a relatively recent and expanding arrival to this zone (Waldron 2003). Although northern hackberry in Ontario is found primarily in the deciduous forest region (seed zones 37 and 38, figure 4), several other local, but disjunct, populations are found throughout the central (seed zone 34) and eastern parts of southern Ontario (seed zone 36) and southeastern Quebec (Krajicek 1965). In addition, there is an isolated population at the southern end of Lake Manitoba (figure 3**).**

Given this wide distribution, northern hackberry is found on a broad range of sites and soils. It is typically a bottomland species, although it is also found on upland sites. It grows best on moist, limestone-based soils near stream banks and along flood plains (Krajicek and Williams 1990). It also exhibits considerable hardiness (USDA hardiness zones 2 through 9) under the wide variety of climatic conditions found throughout its range (Anderson and Tauer 1993, Gucker 2011).

As a result of this adaptability, considerable genetic variation exists within the species, including several ecotypes (Krajicek 1965), as evidenced by variation in its form, size, and ability to withstand drought, cold, and periodic flooding (Bagley 1979, Tober and others 2011). In addition, given the

Figure 2. Typical form of an open-grown northern hackberry. (Photo by Tim Mathers, Toronto Region Conservation Authority [TRCA], April 5, 2012).

reproductive compatibility between northern hackberry and sugarberry (*Celtis laevigata* Willd) and dwarf hackberry (*C. tenufolia* Nutt), evidence shows that introgression with these species is possible where their ranges overlap (Boonpragob 1972, Wagner 1974).

Uses

Northern hackberry has been used historically in a number of interesting ways. In the Midwest and Plains States of the United States, it has been used extensively for windbreaks and shelterbelts to control erosion and blowing snow. Its fast growth and deep root system are excellent for providing quick cover and stabilization of disturbed soils (Gucker 2011).

As a wildlife species, northern hackberry has been used successfully as a food source and for cover. The fruit is highly sought after by a number of bird and mammal species, and it provides habitat for a variety of game species.

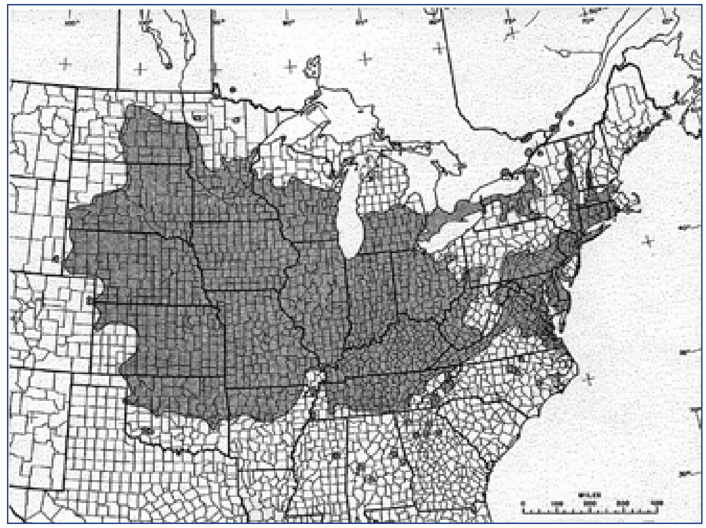

Figure 3. The native range of northern hackberry in North America. (Map source: Krajicek, 1965).

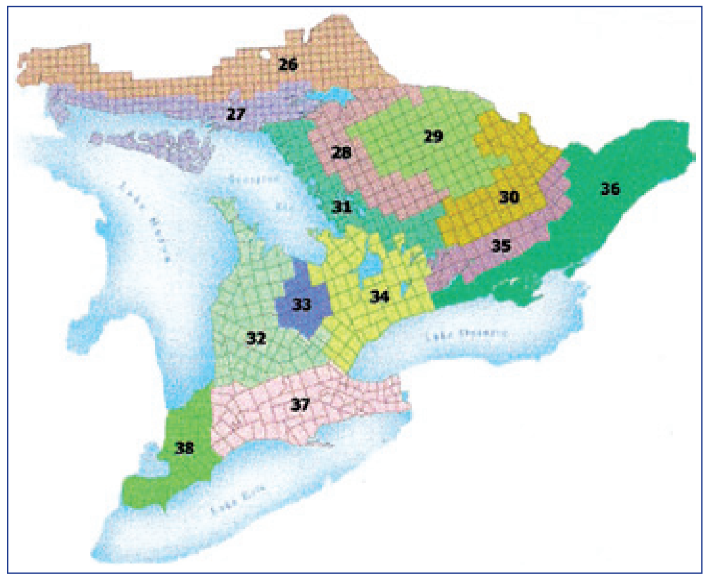

Figure 4. Seed zones for southern Ontario. (Data source: http://www.ontariosnaturalselections.org/ons8, July 21, 2012).

Northern hackberry has also been used for biomass production because of its fast growth, coppicing ability, and adaptability to a wide range of site conditions. In addition, it has been used for restoration and remedial work, particularly along watercourses and riparian zones, where fluctuating water levels and excessive competition can prove detrimental to other species.

In urban settings, northern hackberry is commonly used as a replacement for American elm in ornamental plantings and as a street tree. It functions well in these applications because of its hardiness, disease resistance (particularly to Dutch elm disease), transplantability, ease of propagation, and tolerance to shade, drought, soil compaction, and other urban environment stresses.

Limitations

Perhaps the greatest limitation to the use of northern hackberry is its susceptibility to a number of insect and fungal pests, including a variety of gall-making insects, leaf spot fungi, and witches' broom disease. Although many of these pests can make the tree look unattractive, their effects are more cosmetic than debilitating. In fact, with proper site, seed source, and/or cultivar selection, many of the unsightly effects of these pests can be overcome. The other difficulty with northern hackberry is its tendency to develop a low crown with poor branch structure (figure 5) which can lead to ice, snow, and wind damage. Fortunately, tree structure can be improved with corrective pruning, especially if it is undertaken within the first 5 to 7 years of the tree's life. Another option is to select seed sources from trees that exhibit good natural form and branch structure, or to select one of the several cultivars that have been developed for these and other traits, such as improved hardiness and greater pest resistance (Tober and others 2011).

Figure 5. Northern hackberry with branch structure needing corrective pruning. (Photo by Tim Mathers, TRCA, April 5, 2012).

Availability

Northern hackberry is available from a number of nurseries throughout southern Ontario and across the Eastern United States. Many commercial growers focus on larger caliper (machine-dug or container-grown) trees for the landscape and street tree markets. Other growers and forest and conservation nurseries produce smaller stock such as bareroot seedlings, transplants, whips (figure 6), or smaller container-grown seedlings for the restoration and reforestation markets.

Although no up-to-date production numbers exist, previous estimates indicated that production has been adequate for

Figure 6. Typical northern hackberry bareroot whip and container-grown planting stock. (Photo by Tim Mathers, TRCA, April 5, 2012).

market demands. For example, approximately 40,000 to 45,000 northern hackberry trees produced from 1995 to 2000 were able to satisfy southern Ontario market demands (Kessel 1994). With the liquidation of many existing ash inventories, however, (greater than 100,000 trees per year) anecdotal evidence indicates that, if northern hackberry is to be adopted as a substitute for EAB threatened ash species, production will need to increase accordingly (Swaile 2012). In fact, indications are that such increases are in progress, particularly for larger sized trees (for example, wire basket caliper and 2-, 5-, 7-, and 15-gallon container trees) (Llewellyn 2012).

If northern hackberry is to be a successful alternative to ash species, attention to seed sources and the origin of other types of propagating material will be critical (Anderson and Tauer 1993). To maintain species diversity and ecosystem health, it is important that plants be produced from locally adapted and identifiable sources of propagating material. This is particularly important in southern Ontario, where the scattered distribution of northern hackberry spans a variety of climate regimes, hardiness zones, and soil types. The Ontario Ministry of Natural Resources (OMNR) developed seed zones (OMNR 2011) (figure 4) for southern Ontario to assist in the collection and propagation of biologically appropriate seed and plant materials. In addition, cooperators from the Canadian Forest Service and the OMNR have developed a stock and seed transfer tool called Seedwhere (McKenney and others 1999, Nielsen 2003). This tool assists in making decisions regarding the appropriate movement of plant species from one seed zone to another. Both the seed zone map and Seedwhere have great value for current establishment of northern hackberry, as well as considerable potential in assisted migration efforts under various projected climate change scenarios (Pedlar and others 2011).

In addition, several hackberry cultivars have been developed for improved form and pest resistance, including Oahe, Magnifica, Prairie Pride, Chicagoland, and most recently, Prairie Harvest (Wennerberg 2004, Tober and others 2011). Most of these cultivars, however, have been developed from American propagating material for American conditions. This is not to say that these cultivars should not be used, where available, in southern Ontario. But, given the large geographic range of northern hackberry and the inherent variability in climate, soil, and site factors over its range, it is important to match conditions at the planting site with those of the seed sources, wherever possible (Anderson and Tauer 1993). Such an endeavor will not only help ensure greater survival and, therefore, better planting success, but it will also help maintain landscape diversity and functionality.

Final Thoughts

Because pests like emerald ash borer continue to spread across southern Ontario and the rest of eastern North America, they not only threaten the future of these areas' ash resource, but also negatively affect landscapes across these regions. To address this threat, governments, landowners, and environmental groups must develop workable and timely actions to deal with such threats. One of the most effective ways to accomplish this response is to plant a diversity of appropriate tree species. Such an activity is something that most people can and will embrace.

Although many species can be used as substitutes for ash, northern hackberry is a particularly suitable choice. Its compatibility with most, if not all, of southern Ontario's and eastern North America's ash species and its adaptability and availability to tree planters are seen as practical advantages for wider use.

Hopefully, with innovation and diligence, native ash species across their ranges can be restored and sustained. In the meantime, the time to plant more trees is now.

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Using Tree Shelters as Deep Containers

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Abstract

Tubex™ tree shelters worked well as containers for growing mesquite (*Prosopis glandulosa* Torr.) for a desert restoration site. The double-wall shelter resulted in increased growth in the container and development of a robust root system and shoot for planting on severe sites. With the tree shelter installed after planting, very little material remains to be returned to the nursery. Gravity wick irrigation worked well for these deep-rooted plants and appears to be a promising method for remote sites.

Introduction

Planting containerized stock is essential for successful revegetation or restoration of most dry sites (Bainbridge 2007). More than 25 years of desert restoration projects on a variety of very challenging sites have demonstrated the value of choosing a container that best meets the biological and bureaucratic requirements of the project while still resulting in high field survival at minimal cost. Choosing an appropriate container is one of the most important considerations of a successful planting program. Many projects and experiments have demonstrated that good seedling survival and growth can be expected from a wide range of container sizes, even in areas with annual precipitation of less than 3 in (76 mm) if plants are cultured appropriately, irrigated as needed, and protected from herbivory using cages and/or tree shelters.

Deep Containers for Improved Survival on Difficult Sites

Seedling survival on dry sites is dependent on the root system's ability to access soil moisture and generate new roots. The use of a deeper container can be helpful for increasing survival. I first read about deep containers in Smith (1950) and was interested in the possible application of these for my desert restoration work. To help assess their value, I undertook a series of root growth studies using desert-type soils in layflat polyethylene tubing set in steeply slanted gutter sections. These studies showed that aboveground shoot growth often lagged behind root growth, and that within a few weeks a root could reach 18 in (45.7 cm) or more in length (figure 1). It was also observed that virtually all of the containers in use disrupted taproot development. Subsequent field studies have shown that plants grown in deep containers with a high root:shoot ratio are desirable (Bainbridge 1987, 1994a; Bainbridge and others 1995). Deep planting is also very effective for establishing cuttings in the field (Dreesen and Fenchel 2008).

Although container type often refers simply to volume, shape is also important (Bainbridge 1994a). One of the most biologically important container dimensions is height (depth), because of its effect on the water-holding properties of the growing medium and root development of the seedling. The relation of width to height is the aspect ratio (W/H = AR). Aspect ratios of common containers range from 0.14 to 0.85. Growth media in deep containers with a low aspect ratio have different physical properties, water relations, and porosity than in traditional shallow containers with a high aspect ratio. Growing-medium components may need to be adjusted to compensate for these changes to optimize nutrient and water availability.

The best container to use depends on the planting season (although unpredictable rainfall can confound seasonal timing), the handling process, the species, and the project. One of the most important considerations is determining which container size and depth is most cost effective, with the lowest cost per surviving plant. The emphasis on deep rooting leads to preference for containers that are tall but narrow (Felker and others

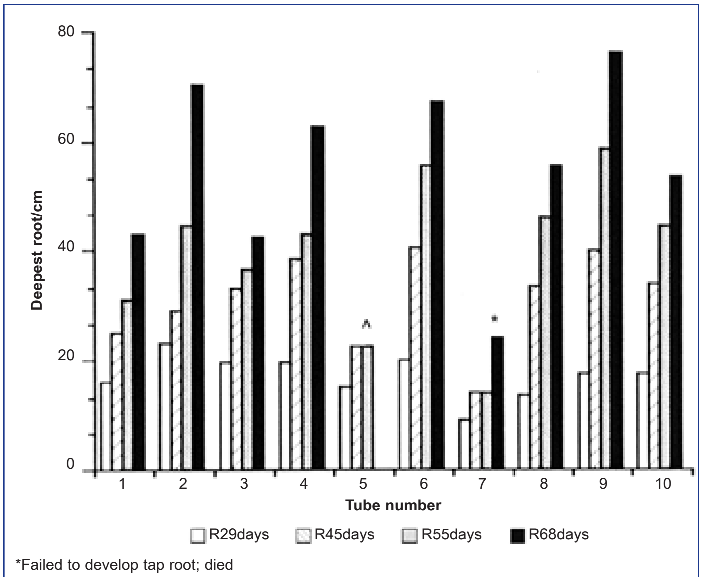

Figure 1. Root growth in the desert plant *Parkinsonia floridum*. (Data source: Unpublished experiment by David Bainbridge).

1988, Bainbridge 2007). Taller containers are more expensive both to grow in the nursery and to plant in the field, but they can improve survival significantly and should constitute at least part or most of the stock used in outplanting efforts on harsh, dry sites.

Plants are typically started in flats or smaller containers and are then transplanted into tall containers. Root growth can be very rapid for many desert species, and roots typically reach the bottom of the container within a few months, even if the seedling is only 8 in (20 cm) tall or less. Tall containers do not take up as much space for plant production as wider, shorter containers with similar volume. Tall containers benefit from racks or holders at the nursery and during transportation to the field. The staff at Joshua Tree National Monument (JTNM) discovered the value of racks after the 1992 Landers earthquake toppled their tall pots (but did little damage to the plants). The large soil volume protects the roots during transport and planting and sets the stage for rapid growth of the undamaged roots in the field.

Figure 2. Tall pots, Joshua Tree National Monument. (Photo by David Bainbridge, 1990).

Success with Deep Containers

I first tried the deep containers made with 10 cm (4 in) layflat plastic tubing in 1987, but found that they were too pliant and hard to handle. Around the same time, Bob Moon and his staff at JTNM (now Park, located in the Mojave Desert of southern California) had also discovered the value of tall containers in their effort to meet a visual restoration goal of only 7 years. They developed and refined a robust tall pot container made with 32 in tall (81.3 cm), 6 in diameter (15.2 cm) (AR = 0.18) smooth wall PVC pipe (Apache 2729) with a wire mesh base held in place by crossed wires (figure 2) (Holden 1992). With smooth-walled PVC, the plant can simply be eased out of the container into the planting hole with minimal disruption to the roots.

In one of JTNM's largest revegetation projects, with more than 1,500 plants, survival was 77 percent after 3 years (Holden and Miller 1995). A large percentage of plants produced flowers and fruit within the first year in the field. Palo verde (*Parkinsonia florida* [Benth. ex A. Gray] S. Watson) has even established at JTNM without supplemental irrigation (Connor and others 2008). Survival and growth of many species is impressive, reaching 3 ft (1 m) within 2 or 3 years after planting.

After visiting the JTNM nursery, I switched to the tall pot system and found it worked well for the desert restoration work I was doing for the California Department of Transportation; California State Parks; U.S. Department of the Interior, Bureau of Land Management; and the U.S. Department of Defense in the Sonoran and Mojave Deserts.

Other deep container solutions have also been developed. In Australia, split pipe tied together has been used as a deep container for planting on unconsolidated sands after mining (Newman and others 1990); and, the Las Lunas Plant Material Center (LLPMC) in New Mexico modified the tall pot design to a split pipe, 30 in tall (76.2 cm), 4 in diameter (10.2 cm) (AR = 13), held together with filament tape (LLPMC undated). Commercial tree pots that are quite deep have also been developed, for example the tapered TP430 Long Pot (Stuewe and Sons 2012).

Planting Deep-Rooted Seedlings

The planting process for plants produced in tall pots is simple. A hole is made with a 6 in (15 cm) auger or post-hole digger and moistened with at least 1.6 gal (10 l) of water. The screen at the bottom of the tall pot is removed, and the walls of the pipe are rapped with a hammer to loosen the mix. The container is then gently placed in the hole, partially back-filled, then the container is eased out of the planting hole as as backfilling continues using a stick to ensure that air pockets are filled. The plant is then watered again and a tree shelter is installed around the shoot. An experienced planting crew of 5 people can plant 50 plants per day under average conditions.

The cost per plant is high, but survival is generally excellent and rapid growth is common. Creosote bush (*Larrea tridentata* [DC.] Coville) or mesquite (*Prosopis glandulosa* Torr.), for example, may be 3 ft tall (0.9 m) 1 year after outplanting from an initial size of 6 to 12 in (15 to 30 cm). Tall pots are highly recommended for achieving a high percentage of larger living plants on harsh sites. Tall pots also provide excellent protection from bureaucratic delays (which can lead to plants outgrowing container size) and biological uncertainty (lack of rainfall). To minimize costs, however, nursery staff must collect the tall pots and return them to the nursery, where they clean them and use them again and again.

Wick Irrigation for Deep Containers

Delivering water deep into the soil can be done with deep pipes (Bainbridge 2006a, Bainbridge 2006b, Dreesen and Fenchel 2010) or with wicks. I first read a paper from India where wicks were used in conjunction with buried clay pot irrigation (Mari Gowda 1974; Bainbridge 2001, 2002). As a result, I began a series of trials in 1988 with gravity wicks. Wick irrigation uses a fiber wick to transfer water by gravity, capillary flow, or pressure (figure 3). Capillary mat systems have become increasingly popular in greenhouses, container production, and interior plantscaping as a way to conserve water and minimize runoff (Neal and Henley 1992). Capillary fiber wicks have also been used to water houseplants and were recently reintroduced as a window box watering system (Editor 1955, Wickinator 2012). Capillary wicks have also been used more recently in greenhouses, with the wick fed into the plant container (Millon and others 2007). It also appears, however, that capillary or gravity wicks have excellent potential for field use in gardening, farming, agroforestry, and environmental restoration (Bainbridge 2007).

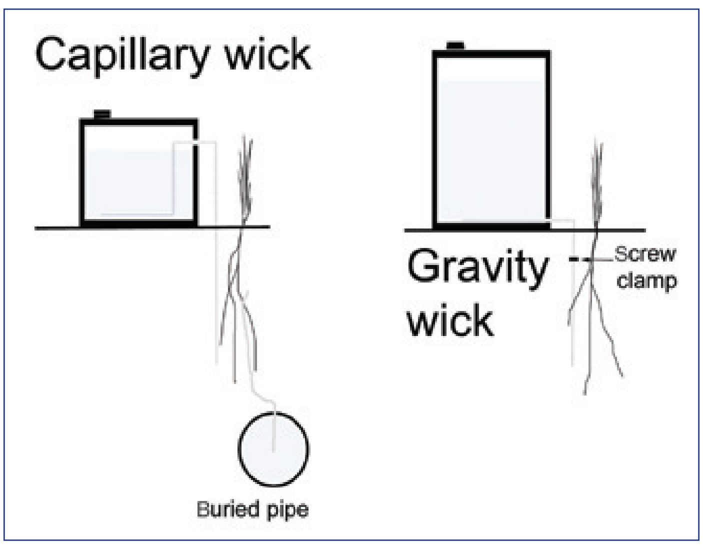

Figure 3. Wick system options: gravity and capillary flow. (Data source: unpublished by author).

Wick materials can range from solid braid nylon (very good durability and capillary rise) to polyester felt, cotton fabric, or many other fibers. My experience has led me to use a gravity nylon solid braid wick system when plant growth is desired, while capillary wicks may be used where the goal is to keep a plant alive until it finally rains. In a recent test, I found that a 7/16 in (11 mm) solid braid nylon wick wetted to 12 ft (3.6 m) within 15 min, suggesting wicks may be very useful in guiding deep roots to groundwater.

Trial to Evaluate Tree Shelters as Deep Containers Along with Wick Irrigation

Tree shelters, and particularly twin-walled tree shelters, have proved very valuable for increasing growth and survival of most outplanted desert species (Bainbridge 1994b). In 2008, I initiated an experiment to evaluate Tubex™ tree shelters (Tubex Ltd, South Wales, UK) as both deep containers and subsequent tree shelters. After planting, the tree shelter (that had been used as a deep container) was used to protect the plant; this procedure eliminated the need to return anything to the nursery.

Growth in the Nursery

Mesquite seedlings were sown into Ray Leach Super Cell Cone-tainers™ (1.50 in [3.8 cm] diameter and 8.25 in [21.0 cm] depth) in July 2008 at the Alliant International University in Scripps Ranch, San Diego, CA. After seedlings reached about 4 in (10.0 cm) in height they were transplanted into either Tubex™ twin-wall, light green containers 24 in tall (61.0 cm), 6 in diameter (15.2 cm) (AR = 0.25) or white PVC pipe sections 12 in tall (30.5 cm), 4 in diameter (10.0 cm) (AR = 0.33). Shade cloth was taped to the bottom of the containers to hold in the growing medium.

After 4 months, the mean height of plants grown in the Tubex™ containers (n = 5) was 15.4 in (39 cm) compared with 5.3 in (13.5 cm) for those grown in the pipe containers (n = 17) (figure 4). One additional plant was grown in a Tubex™ container with a Tubex™ tree shelter added to protect the shoot. This resulted in even greater height, (23.2 in [59 cm]) (figure 5). All plants had roots visible at the bottom of the container after 4 months. Temperatures in the container-growing medium were not measured, but it is likely that the double wall increased the temperature in the Tubex™ containers, leading to more rapid growth. Mesquite root growth is enhanced at higher temperatures; in one study under favorable conditions, mesquite roots grew nearly 2 in (5 cm) in 12 hr at 90.5 to 93.2 °F (32.5 to 34 °C) (Cannon 1917).

Figure 4. The difference in plant growth between container types. (Photo by Laurie Lippitt, 2008).

Figure 5. The added improvement in growth from a tree shelter container and a tree shelter protecting the shoot. (Photo by David Bainbridge, 2008).

Outplanting Performance

In April 2009, the seedlings grown in Tubex™ were outplanted to a very dry site in the Colorado Desert (average annual precipitation = 3 in [76 mm]) with gravity wick irrigation systems. The trees and wicks were installed by augering a hole with an AMS, Inc., soil auger. The gravity wick system used on this project consisted of a 5 gal (18.9 l) reservoir (recycled fire foam container) with a thread to barb fitting, vinyl tube, hose clamp, and 7/16 in (11 mm) solid braid nylon wick (figure 6). The wicks, about as long as the containers were deep, were laid into the hole next to the roots. On other projects, the wicks have been driven much deeper with a steel rod. The trees released easily from the tree shelter and PVC containers by the same technique used with tall pots, although one that had been watered before planting was a bit harder to remove. After release as a container, Tubex™ was immediately reinstalled on the seedling as a shelter. Water in the reservoirs for wick irrigation lasted 2 to 3 weeks and was refilled periodically.

As of March 2012, all of the trees grown in Tubex™ containers have survived. Some species may not benefit from the increased rooting temperature and container depth, but for mesquite it was ideal. The gravity wick system provided sufficient water to support establishment in the field. Ideally wicks would be placed in a hole drilled to groundwater at 10 to 15 ft (3 to 5 m) for this site. It was useful not to have to return containers to the nursery and convenient to have the tree shelter on hand at the time of planting.

Figure 6. Transplant from Tubex™ container with gravity wick irrigation system; backfill not completed. (Photo by David Bainbridge, 2009).

Conclusion

For most projects on severe desert or seasonally arid sites, a variety of container sizes can be used to maximize survival at reasonable cost. Multiple size classes and more diverse plant architecture can be both biologically and aesthetically desirable and provide a wide range of resilience and survivability. Deep-rooted plants can be grown in tree shelters and watered after outplanting with gravity wicks for good survival on dry sites.

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Acknowledgments

The author thanks Tubex™ for supplying sample tree shelters. Melanie Howe kindly started the mesquite, John Ekhoff provided the recycled 5-gallon fire foam jugs, and the BLM allowed use of the borrow pit revegetation research site. Laurie Lippitt and Diane Haase reviewed drafts and suggested changes to improve clarity.

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Artificial Regeneration of Five-Needle Pines of Western North America: A Survey of Current Practices and Future Needs

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Abstract

After the introduction of the pathogen causing white pine blister rust, the perpetuation of five-needle white pines (5NP) in western North America is partially dependent on successful deployment of genetically resistant seed and seedlings. We surveyed managers, researchers, horticulturists, growers, and academics throughout western North America to (1) review why managers plant 5NP; (2) describe and attempt to quantify efforts to grow and plant 5NP in the West, focusing on actual deployment of seed and seedlings; (3) describe perspectives on artificial regeneration research needs; and (4) outline how managers can continue in their critical roles. We found a dedicated array of people invested in successful seed collection, disease resistance screening and deployment, orchard development, and outplanting survival.

Introduction

White pine blister rust (WPBR), caused by the fungal pathogen *Cronartium ribicola* (J.C. Fisch. ex. Rabenh), has caused widespread damage to North American five-needle white pines (5NP) since the early 1900s (Shaw and Geils 2010). In the West, WPBR spread through the range of western white pine (WWP) (*Pinus monticola* Douglas ex. D. Don) and subsequently into the range of other susceptible pine species: sugar (SP) (*P. lambertiana* Douglas), whitebark (WBP) (*P. albicaulis* Engelm), limber (LP) (*P. flexilis* E. James), southwestern white (SWWP) (*P. strobiformis* Engelm), and Rocky Mountain bristlecone (RMBP) (*P. aristata* Engelm). Foxtail pine (FP) (*P. balfouriana* Balf.) in northern California were also recently reported as infected (Kliejunas and Dunlap 2007, Maloney 2011). Great Basin bristlecone pine (GBBP) (*P. longaeva* D.K. Bailey) are susceptible but have not been discovered as field-infected to date (Sniezko and others 2011b). The decline of WWP and SP led to the establishment of tree improvement programs in the 1950s that are still active today, although WPBR intensity and mortality varies widely in both species (Bingham 1983, McDonald and others 2004, Schwandt and others 2010).

The initial WWP program began in Idaho and Montana with 400 plus tree selections (field trees exhibiting no to very few WPBR signs or symptoms) (Bingham 1983), with work in Oregon and Washington starting soon afterwards. Disease screening trials assess multiple resistance mechanisms, generally separated into partial resistance ("slow-rusting," thought to be controlled by several to many genes) and complete resistance ("immunity," controlled by a single gene) (Hoff and others 1980, Hoff 1986, Sniezko and others 2008, Sniezko and others 2011b). The gene-for-gene interaction in the 5NP/WPBR pathosystem, in which a single gene confers heritable resistance (major gene resistance [MGR]) against the pathogen has been found in SP, WWP, SWWP, and LP (Kinloch and Littlefield 1977, Kinloch and others 1999, Kinloch and Dupper 2002, Schoettle and others 2011). WWP breeding in the Inland Empire (eastern Washington, northern Idaho, and western Montana) has been characterized by three phases: Phase I (initial 400 plus tree selections), Phase II (selection of resistant progeny from 3,100 candidate WWP) (McDonald and others 2004), and Phase III (selection for resistance and gene conservation across the WWP geographic range). Phase III is just beginning, with initial screenings of phenotypic selections scheduled for 2015 (M. Rust, pers. comm. 2012). Other breeding programs have similar strategies for selection of resistance where partial resistance is more common than MGR (McDonald and others 2004). The resistance screening and breeding programs have a long, rich publication history (see Bingham 1983, Fins and others 2002, McDonald and others 2004, Sniezko and others 2008, King and others 2010, Sniezko and others 2011b for comprehensive reviews). The ecological roles, silvics, and future outlooks of many 5NP species have also been thoroughly reviewed (Arno and Hoff 1989, Kinloch and others 1996, Fins and others 2002, Schoettle 2004, Tomback and Achuff 2010, Schwandt and others 2010, Tomback and others 2011).

A synthesis of western 5NP artificial regeneration projects from operational and research standpoints has not been compiled to our knowledge, although some species have been synthesized separately. For example, Izlar (2007) developed a database of Intermountain West WBP planting projects from

1989 to 2005 and reported 120 WBP planting sites across several States, with very little interagency coordination of restoration efforts at the time. Compiled information of 5NP projects across the West are valuable to managers, who are relied on to incorporate research related to these species operationally. Managers benefit from knowing the details of how and where other managers are planting, what leads to success or failure, and that the efforts made across the landscape are cumulative and contributing towards widespread restoration. Since many of these projects have not been published, we conducted informal surveys of managers, researchers, seed and seedling growers/horticulturists during spring 2012 regarding planting, research, nursery and seed orchard production, and personal opinions regarding future needs and manager roles. Our specific objectives were to (1) review why managers plant 5NP, (2) describe and attempt to quantify efforts to grow and plant 5NP, (3) describe perspectives on regeneration research needs, and (4) outline the ongoing roles of managers. The full set of questions is available upon request. Survey respondents work for a wide variety of agencies (U.S. Department of Agriculture [USDA]), Forest Service; U.S. Department of the Interior, Bureau of Land Management (BLM) and National Park Service (NPS); U.S. Department of Defense; state and tribal governments; and Canadian provincial governments), universities, private companies, and nonprofit organizations. Our survey findings should be viewed as a subsample of 5NP management and research in the West because we were not able to survey every group involved in 5NP artificial regeneration efforts, nor do we include all relevant literature. Our intentions were to focus primarily on responses of those surveyed and supplement literature where appropriate.

Seed Collection, Resistance Screening, and Seed Orchards

Across the spectrum of managers surveyed, all have invested to some degree in cone (seed) collections, screening families (seedlings from the same parent tree) for resistance, and planting seedlings primarily from those resistant families; this practice was particularly prevalent for SP and WWP. Three major blister rust disease screening facilities are in the West—all are administered by the USDA Forest Service: Dorena Genetic Resource Center, OR (DGRC), Placerville Nursery, CA, with additional research screening conducted at the nearby Institute for Forest Genetics (IFG), and Coeur d'Alene Nursery, ID (CDA) (Sniezko and others 2011b). Screening is conducted for both partial resistance and MGR (figure 1). Some managers use only seed from their land base while others also use seed collected from other areas within the same seed zone; enhancing genetic diversity was cited as the primary reason

Figure 1. Resistance-screening trial for whitebark pine at Dorena Genetic Resource Center (DGRC) in Oregon. Each row represents one family. (Photo by Richard Sniezko, DGRC 2006).

for using seed from other source areas. Although seed collections are preferably from trees with known resistance (MGR and/or partial resistance), collections from plus trees in areas with high levels of WPBR infection are used where resistance screening is not yet complete.

Sugar Pine

In California, many land managers work in close collaboration with the USDA Forest Service Regional Genetic Resources Program to collect seed, screen families, and share the resulting seed from identified resistant trees; most of these efforts have focused on SP (table 1). California landowners also share the resistant genetic material for orchard establishment; this cooperative effort creates a buffer against loss of any single orchard (McDonald and others 2004). For example, the USDA Forest Service has established three clonal SP seed orchards that include both MGR and partial resistance and represent three breeding zones targeted to supply seed to the western Sierra Nevada range (table 1) (USDA 2012; B. Boom, J. Dunlap, pers. comm. 2012); 500 resistant clones are duplicated in the Sierra Pacific Industries orchards (table 2, G. Lunak, pers. comm. 2012). The BLM has a long history with SP seed orchard development in western Oregon, with first-generation resistant orchards developed in the 1970s and 1980s. They have recently installed a 1.5-generation orchard with space to include second-generation material in the near future. The BLM works cooperatively with USDA Forest Service (including resistance screening at DGRC) and private industry to disseminate seed from their orchards. Internal BLM demand for seed in southwestern Oregon is 121 lb (55 kg) annually, with industry demands of an additional 24 lb (11 kg) (M. Henneman, pers. comm. 2012).

Western White Pine

Only portions of the WWP range (Oregon and Washington) contain MGR, and then only in low levels (Kinloch and others 1999, McDonald and others 2004), thus the selection and breeding programs for WWP often focus on partial resistance (King and Hunt 2004, King and others 2010, Mahalovich 2010). In the Inland Empire, the Phase I early selection and seed collections included 400 trees, while Phase II screening trials included many more (table 1) (Bingham 1983, Mahalovich 2010). Seed orchard establishment is more advanced for WWP than SP (table 2). In the Inland Empire, the USDA Forest Service established eight orchards and one 19-acre

Table 1. Survey responses related to seed collection efforts for sugar pine (SP), western white pine (WWP), and whitebark pine (WBP) for different resistance types (single gene [MGR] or partial) across land ownerships and locations.

5NP species	Number of families MGR	Number of families MGR and/or partial resistance (screened or in screening)	Estimate of annual seed production or total inventory	Location/land ownership	Personal communication/ literature source
SP	1,807	909	2,007 lb (910 kg)	California—all ownerships	USDA 2012, J. Dunlap, B. Boom
	300			Sierra Pacific Industries, CA (1.7 mil acres/688,000 hectares)	G. Lunak
	41			Soper-Wheeler Co., LLC, CA (60,000 acres/24,000 hectares)	P. Violett
	64			Lake Tahoe Basin, CA and NV	M. Mircheva
	6			Blodgett Forest, University of California (4,000 acres/1,620 hectares)	K. Somers
WWP		400 (Phase I)	2,500 lb (inv)* (1,134 kg)	Inland Empire, non-Federal	M. Rust
		3,438 (Phase II)	1,372 lb (inv)** (622 kg)	Inland Empire, Federal	M. Mahalovich
WBP		823		Northern Rockies, Federal	M. Mahalovich
		380		Oregon, Washington, and British Columbia, Canada	Sniezko and others 2011
		359	275,000 seeds (inv)	Oregon and Washington	Aubry and others 2008

*17-yr supply, Phase I; **8.5-yr supply, Phase II

Table 2. Seed orchard status and production for sugar pine (SP), western white pine (WWP), and whitebark pine (WBP).

5NP species	Total size (ac/ha)	Number of orchards	Production	Number of breeding zones	Number of seed zones	Number of parents represented	Location/land ownership	Personal communication/ literature source
SP	60/24	Multiple*	NA**	NA	NA	NA	Oregon and Washington, Federal	Lipow and others 2002, A. Bower
	70/28	3	~960 cones (2009, 1 orchard)	3	10	>700	California, Federal	USDA 2012, J. Dunlap, B. Boom
	15/6	NA	In development	5	22	NA		J. Dunlap
	NA	2	In development	2	NA	500	Sierra Pacific Industries, CA	G. Lunak
WWP	90/36	Multiple	NA	NA	NA	NA	Oregon and Washington, Federal	Lipow and others 2002, A. Bower
WWP	NA	1	Expected in 3–5 yrs	NA	NA	46	Quinault Indian Reservation, WA	J. Plampin
WWP (Phase I)	42/17	4	12,360 lb (5,606 kg) (1970–2010)	NA	NA	NA	Inland Empire, Federal	Mahalovich 2010, M. Rust
WWP (Phase II)	30/12	4	NA	NA	NA	NA	Inland Empire, Federal	Mahalovich 2010
WWP	NA	2	Advanced generation orchards in development	NA	2	NA	British Columbia, Canada	N. Ukrainetz
WBP	12/5	4	In development	4	NA	NA	Northern Rockies, Federal	M.F. Mahalovich

*Exact data not provided. **NA = data were not provided by survey respondents. Only the Inland Empire WWP program includes specific phases.

(7.7-hectare) clone bank that are producing seed (table 2) (Mahalovich 2010). The R.T. Bingham Seed Orchard, part of the Phase I breeding program, began producing seed in 1970 and is now the primary seed source in the Inland Empire for non-Federal entities (table 1). The Quinault Indian Reservation (QIR), WA has also established an orchard (J. Plampin, pers. comm. 2012) which is expected to produce seed in the near future (table 2); past and current QIR plantings are from resistant seed collected from the USDA Forest Service Denny Ahl Seed Orchard in cooperation with the USDA Forest Service (J. Plampin and A. Bower, pers. comm. 2012). In British Columbia, Canada, WWP seed orchards are producing seed from screened parents and progeny; continued breeding is underway with enhanced genetic material expected from the coastal program (pollinated using MGR trees to build more durable resistance) in 2 to 5 years and from the interior program (one-half of these orchards are composed of Idaho breeding program material) in 10 to 15 years (table 2) (N. Ukrainetz, pers. comm. 2012, King and Hunt 2004, King and others 2010).

Whitebark Pine

Many regions are actively collecting WBP seed for restoration programs, WPBR screening trials, and gene conservation (Mahalovich and Dickerson 2004; Mahalovich and others 2006; Aubry and others 2008; Mahalovich 2011; Sniezko and others 2011a, 2011b; M.F. Mahalovich, pers. comm. 2012). A comprehensive restoration plan has been designed for WBP in the Pacific Northwest (table 1) (Aubry and others 2008) and more recently for the entire WBP range (Keane and others 2012). Of the six high-elevation 5NP species, WBP has the most parent trees in rust-resistance screening trials, including families from California, Oregon, Washington, the Northern Rockies (Idaho, western Montana, and Wyoming), and Canada (Sniezko and others 2011b) (table 1).

Seed orchards are now being established for WBP, with the first scion planted in 2009 on the Lolo National Forest, MT (table 2). A breeding orchard is in development, with pollen collection beginning in 2011 (M.F. Mahalovich, pers. comm. 2012). Recent research suggests that five seed zones fully capture the genetic variation throughout the Northern Rockies (Mahalovich in press). Eight long-term performance tests are planned, with the first two installations expected in 2014 (Mahalovich 2011). It is not known yet if seed orchards are a viable option for WBP in Oregon and Washington, although pilot grafting and scion projects are underway and 15 to 30 resistant families will be planted in WBP habitat for future seed production (Aubry and others 2008).

Other 5NP Species

Seed collection and storage efforts are ongoing for LP, GBBP, RMBP, and FP for the national Genetic Conservation Program through USDA Forest Service, Forest Health Protection (Dunlap 2011; Mangold 2011; A. Schoettle, M. Mircheva, pers. comm. 2012; Schoettle and others 2011; Sniezko and others 2011b). Extensive research and, to a lesser extent, operational collections have been made across USDA Forest Service and BLM land ownership in the Inland Empire, central and southern Rocky Mountains, and some populations in the Southwest for LP, RMBP, and GBBP (A. Schoettle, pers. comm.). Pollen has also been collected from resistant LP trees in the southern Rocky Mountains (A. Schoettle, pers. comm.). Operational collections of SWWP were completed periodically since the 1980s; collections will commence for the Genetic Conservation Program in 2012 (by authors). Resistance screening (both short- and long-duration tests for an array of resistance mechanisms) for LP (Schoettle and others 2011), RMBP (Vogler and others 2006, Schoettle and others 2011), GBBP, and FP are underway at DGRC and IFG (Sniezko and others 2011b). Screening for a diverse array of resistance mechanisms in SWWP is also underway at DGRC, IFG, and CDA (Sniezko and others 2008, 2011a).

Seedling Production

From a production standpoint, most growers producing 5NP found them to be harder to propagate than other western conifers. WBP was often cited as the most difficult species to grow. Successful seed treatment and storage protocols to maximize seedling production methods for both WWP and WBP have been developed (Burr and others 2001; Bredeen and others 2007; Riley and Coumas 2007; K. Eggleston, pers. comm. 2012). A common problem with both SP and WWP seeds is *Fusarium* spp. (T. Jopson, pers. comm. 2012; James 1985; Jenkinson and McCain 1993) and is mitigated through proper nursery management and growing conditions (T. Jopson, pers. comm. 2012). Root aphids can also be a problem in WWP during the summer growing season (D. Livingston, pers. comm. 2012). Both WWP and SP are notorious for their lack of fine root development, although techniques such as q-plugs, transplanting, and improved container stock production methods have alleviated this issue somewhat (K. Wearstler, pers. comm. 2012).

Despite these challenges, many nurseries successfully propagate and produce 5NP seedlings annually (figure 2, table 3); although 5NP are often only a small percentage of overall production (T. Jopson, D. Livingston, K. Wearstler, pers.

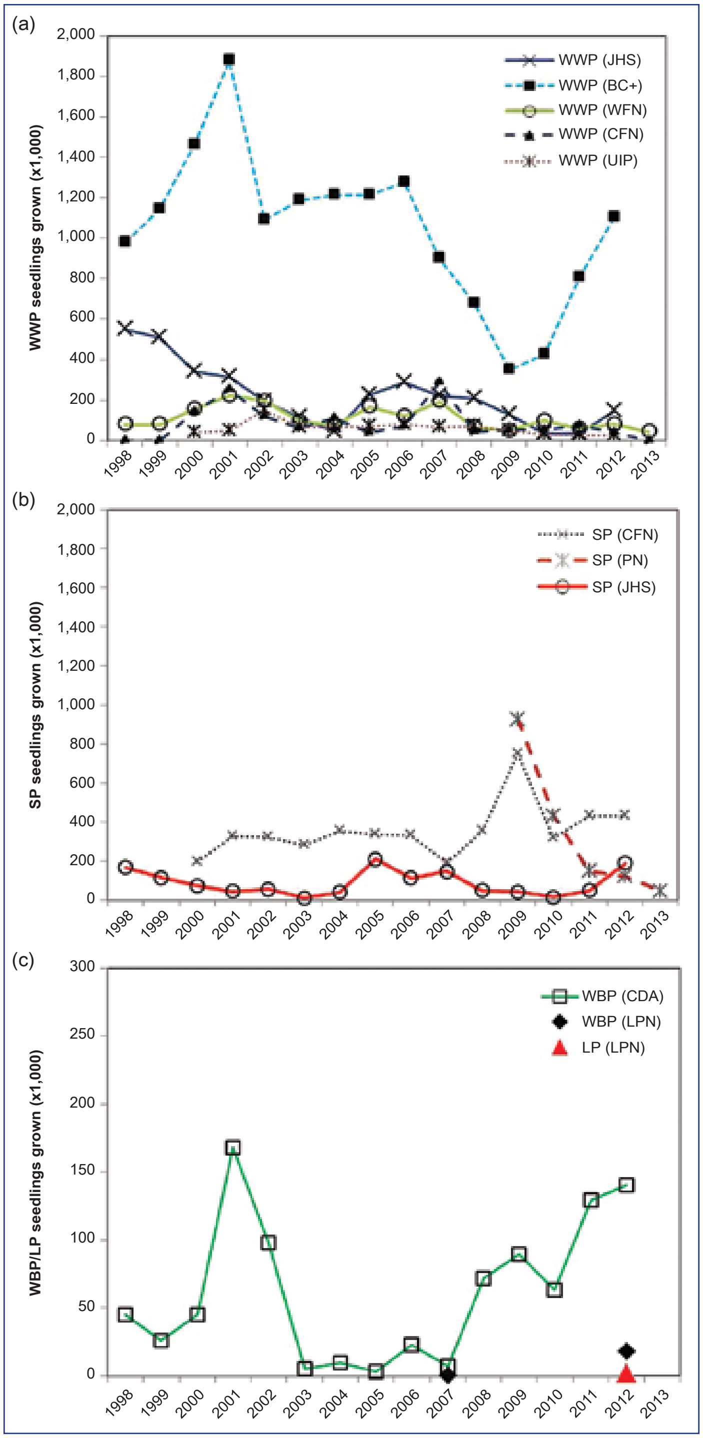

Figure 2. Annual number of (a) western white pine (WWP), (b) sugar pine (SP), (c) whitebark pine (WBP), and limber pine (LP) seedlings grown at nurseries throughout western North America.

BC+ = British Columbia, Canada nurseries, including 8 Pacific Regeneration Technologies, Inc., nurseries and 13 additional BC nurseries; CDA = Coeur d'Alene Nursery, ID. CFN = Cal-Forest Nurseries, CA. JHS = J. Herbert Stone Nursery, OR. LPN = Lucky Peak Nursery, ID. PN = Placerville Nursery, CA. UIP = University of Idaho Pitkin Nursery, ID. WFN = Webster Forest Nursery, WA. No marker indicates zero seedlings that year. Note the difference in seedling production scale of WBP (c) relative to SP (a) and WWP (b). All seedlings are container grown with the exception of bareroot seedlings produced at JHS. (Data sources: B. Boom [PN], A. Brusven [UIP], J. Dunlap [PN], K. Eggleston [CDA], T. Jopson [CFN], D. Livingston [BC+], R. Mallory [JHS], J. Sloan [LPN], and J. Trobaugh [WFN]).

comm. 2012). In addition to larger scale annual production of SP, WWP, and WBP by several nurseries (figure 2), Lucky Peak Nursery (LPN) in Idaho has historically grown WBP and LP less frequently in smaller amounts, but expects the demand to grow and has started programs to produce 2,000 LP and 18,000 WBP annually (J. Sloan, pers. comm. 2012) (figure 2). In addition, growers at Charles E. Bessey Nursery (NE) recently produced 1,000 2-0 LP seedlings for outplanting in Colorado and also sell 6,000 to 12,000 SWWP annually for windbreaks across eastern and central Nebraska (R. Gilbert, pers. comm. 2012).

Individual seedling costs varied widely, with resistant WWP and SP seedlings selling for as little as \$0.18 to \$0.28 per seedling, depending on stock type and container size (table 3). Managers working on small restoration projects reported higher costs of \$1 to \$2 per seedling. By species, screened WBP generally costs more (a result of the need for seed scarification and hand-sowing); however, the WBP seedling cost has dropped from more than \$4.00 per seedling in 1999 (K. Eggleston, pers. comm. 2012; Mahalovich 2011, table 3). WWP and SP are consistently grown and outplanted using 5, 6, 8, or 10 in^3 (82, 98, 131, or 164 cm^3), 1-year-old container stock. Most CDA Nursery customers purchase container 98 super cell, 10 in^3 (164 cm^3), 1- or 2-year-old WBP container stock (K. Eggleston, pers. comm. 2012). The Placerville Nursery reported 95 percent of its SP are sold as 1-year-old 10 in^3 container (B. Boom, pers. comm. 2012), while the University of Idaho Pitkin Nursery reported that WWP survival is greater using 2-year-old, 20 in^3 (328 cm^3) container stock, although 5.5 in^3 (90 cm^3), 1-year-old container stock is preferred for large operational plantings due to lower costs (A. Brusven, pers. comm. 2012). Several managers also reported using seedlings leftover from screening trials at DGRC at minimal costs. Several nurseries reported a decline in demand for WWP in recent years (figure 2), citing drought and a perception of low survival rates as potential causes. Demand for SP appears stable while WBP demand has been increasing (figures 2 and 3).

Operational and Research Outplanting

Outplanting Project Sizes

We found managers actively outplanting SP, WWP, and WBP (figures 3 and 4, table 4). Acreage planted operationally with 5NP is dominated by these three species and is echoed in the trend for nursery production (figure 2), but other 5NP are also used for trial and research outplanting. Outplanted WWP since 1973 and WBP since 1988 on Intermountain West

Table 3. Seedling prices reported for 5NP species by five nurseries in western North America.

Species	Nursery	Stock type	Price reported	Personal communication/ literature source
SP	USDA Forest Service, J. Herbert Stone Nursery, Central Point, OR	1-0 bareroot	$256/M*	K. Wearstler
		1-0 bareroot	$256/M	R. Mallory
		1-1 bareroot	$410/M	
		1P-1 bareroot	$163/M	
		1P-2 bareroot	$326/M	
		2-0 bareroot	$338/M	
		2-1 bareroot	$484/M	
		3-0 bareroot	$405/M	
		Q-plug-1	$312/M	
		Q-plug-1.5	$339/M	
		Q-plug-2	$383/M	
WWP	Pacific Regeneration Technologies, Inc., British Columbia, Canada	1-0 Plug Styroblock™ (4.9 in^3; 80 cm^3)	$0.25/sdlg	D. Livingston
		1-0 Plug Styroblock™ (5.8 in^3; 95 cm^3)	$0.25/sdlg	
		1-0 Plug Styroblock™ (7.6 in^3; 126 cm^3)	$0.30/sdlg	
	USDA Forest Service, Coeur d’Alene Nursery, Coeur d’Alene, ID	2-0 container	$0.34/sdlg	K. Eggleston, M.F. Mahalovich, 2011
WBP	USDA Forest Service, Coeur d’Alene Nursery, Coeur d’Alene, ID	2-0, 98 supercell container (10 in^3; 164 cm^3)	$1.70-2.06/sdlg	
WBP and LP	USDA Forest Service, Lucky Peak Nursery, Boise, ID	1-0 bareroot	$420/M	J. Sloan
		2-0 bareroot	$448/M	
		Styroblock™ 112/105 (6.5 in^3; 107 cm^3)	$575/M	
		Styroblock™ 160/90 (5.5 in^3; 90 cm^3)	$490/M	
		Styroblock™ 45/340 (20 in^3; 328 cm^3)	$817/M	
		Styroblock™ 91/130 (8.0 in^3; 131 cm^3)	$707/M	
		Styroblock™ 77/172 (10 in^3; 164 cm^3)	$653/M	
		1 gal pot	$7/sdlg	
LP	USDA Forest Service, Charles E. Bessey Nursery, Halsey, NE	1-0 container (6.5 in^3; 107 cm^3)	$0.62/sdlg	R. Gilbert
		2-0 container (40 in^3; 656 cm^3)	$5.00/sdlg	
SWWP	USDA Forest Service, Charles E. Bessey Nursery, Halsey, NE	2-0 bareroot stock	$0.59/sdlg	

*M = 1,000 seedlings.

Federal land were reported as totaling 175,818 and 3,004 acres (71,181 and 1,216 hectares), respectively (figure 4); 16,617 acres (6,728 hectares) of SP have also been planted since 1997, excluding California (M.F. Mahalovich, pers. comm. 2012, data not shown). In this survey, outplanting project sizes varied by species and project and not all plantings were summarized spatially (table 4). Approximately 2 million WWP seedlings are planted annually on Federal lands in Oregon, Washington, Idaho, and Montana (M.F. Mahalovich, pers. comm. 2012) and an additional 1 million WWP are planted annually on non-Federal lands across the Inland Empire (M. Rust, pers. comm. 2012) (table 4). Izlar (2007) reported more than 210,000 WBP seedlings were planted at 120 sites (30 to approximately 10,000 seedlings per site) from 1989 to 2005 (acreage likely included in acres reported by M.F. Maholovich, pers. comm. 2012). Sierra Pacific Industries plants 360,000 resistant SP annually in California, amounting to approximately 4,000 acres (1,619 hectares) at 15 to 25 percent of the total species composition (table 4). Several national parks including Glacier, Waterton Lakes, and Crater Lake, have planted WBP and/or LP as research or operational plantings (J. Asebrook, J. Beck, and C. Smith, pers. comm. 2012) (table 4). Six trial sites across southern Wyoming and the Colorado Front Range were planted with 2,160 LP seedlings to help develop forest-scale planting methods (Casper and others 2011) (table 4). In 2011, 1,000 WBP seedlings were outplanted on five Deschutes

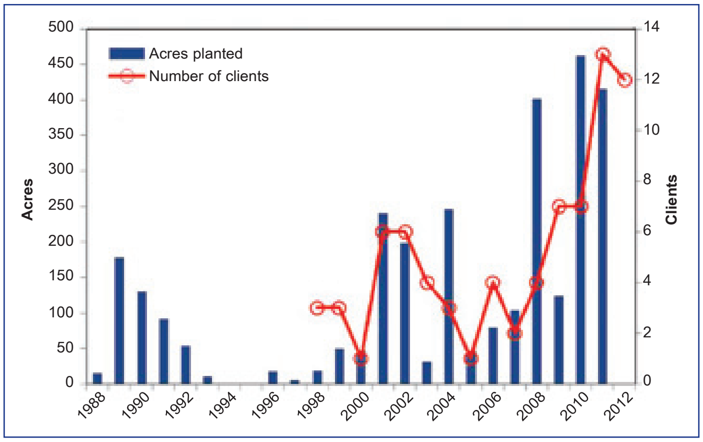

Figure 3. Annual number of Federal acres planted with whitebark pine (WBP) from 1988 to 2012 in the Northern (Region 1), Rocky Mountain (Region 2), and Intermountain (Region 4) Regions and number of clients (national forests, national parks, Bureau of Indian Affairs reservations) requesting WBP seedlings annually from Coeur d'Alene nursery, 1998 to 2012. (Data sources: M.F. Maholovich, pers. comm., 2012 and K. Eggleston, pers. comm., 2012, respectively).

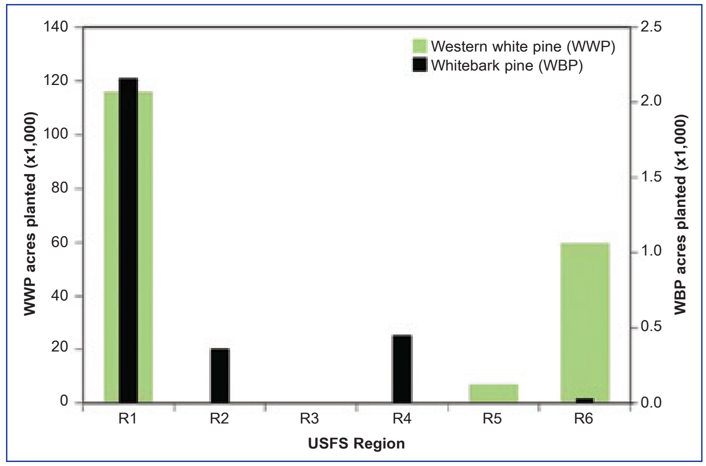

Figure 4. Federal acres planted with western white pine (WWP) and whitebark pine (WBP) by USDA Forest Service region from 1973 to 2012 (WWP) and 1988 to 2012 (WBP). R1 = Northern Region, R2 = Rocky Mountain Region, R4 = Intermountain Region, R5 = Pacific Southwest Region, R6 = Pacific Northwest Region. Note the scale difference in acres planted between WWP and WBP. (Data source: M.F. Mahalovich, pers. comm., 2012).

Table 4. Outplanting project sizes (acres or number of seedlings), operational planting densities (trees per acre), and survival rates (percent survival) reported by survey respondents.

Species	n*	Project size				Personal communication/literature source
SP+	3	1,000–360,000 sdlgs				D. Stubbs, G. Lunak, K. Somers
WWP+	8	7–1,200 ac (2.83 – 486 ha), 500–2 million sdlgs				A. Brusven, M.F. Mahalovich, M. Rust, N. Waldren, D. Omdal, M. Jenkins, N. Ukrainetz, C. Dowling
WBP	15	1–63 ac (0.4–26 ha), 96–5,160 sdlgs				D. Stubbs, J. Nakae, C. Smith, K. Buermeyer, R. Niman, J. Asebrook, J. Beck, V. Walker, M. Jenkins
LP	3	1–2 ac (0.4–0.8 ha), 26–1,312 sdlgs				C. Smith, W. Jacobi, J. Asebrook
Species	**n***	**Density mean TPA (TPH)****	**Density range TPA (TPH)**			**Personal communication/literature source**
SP	8	265 (678)	110–600 (282–1,536)			G. Lunak, D. Henneman, M. Crawford, M. Mircheva, K. Somers
WWP	7	362 (927)	110–600 (282–1,536)			D. Henneman, M. Crawford, C. Dowling, M. Jenkins
WBP	10	195 (500)	50–300 (128–768)			E. Jungck, D. Stubbs, J. Daily, J. Nakae, V. Walker, S. Dittman, M. Klinke, K. Buermeyer, M. Jenkins
Species	**n***	**Survival (low mean %)**	**Survival (high mean %)**	**Survival (range, %)**	**Years reported**	**Personal communication/literature source**
SP	5	72	75	10–95	1–10	G. Lunak, M. Mircheva, K. Somers, M. Crawford, D. Henneman
WWP	8	66	83	20–100	1–10	D. Stubbs, A. Brusven, B. Larkin, N. Ukrainetz, N. Waldren, V. Walker, D. Omdal
WBP	7	86	91	74–100	1–3	D. Stubbs, J. Nakae, J. Daily, R. Niman, S. Haeussler, S. Dittman, J. Beck, C. Smith, J. Asebrook
LP	4	28	57	0.5–96	1–5	W. Jacobi, C. Smith, J. Asebrook

sdlgs = seedlings. SP = sugar pine. WBP = whitebark pine. WWP = western white pine. LP = limber pine.

Notes: All species planted are included in the total; only whitebark pine is routinely planted in monoculture. Research projects often involved much higher densities and are not included here. Where a range of densities or survivals was provided, the n and mean include the high and low number from the range.

* Number of projects with specific size, densities, or survival numbers reported by survey respondents.

**TPA (TPH) = trees per acre (trees per hectare).

+ Generally not planted as monoculture so seedling numbers also provided.

National Forest (OR) sites to evaluate long-term WPBR microsite associations (C. Jensen, A. Schoettle, pers. comm. 2012). A small LP outplanting has also been planted on the Deschutes National Forest (C. Jensen, A. Schoettle, pers. comm. 2012). In Oregon and Washington, WBP plantings across nearly all conservation areas are planned as part of the Restoration Strategy (Aubry and others 2008).

Sugar and Western White Pine

The most common reasons for planting SP and WWP included maintenance of species diversity and restoring historic species mixtures on the landscape. Many managers reforest sites post-fire, with higher demand in some areas for seedlings after years with larger burned acreage (figure 2). Managers also cited maintenance of healthy populations of these species, deployment of resistant genes, and commercial value as reasons for planting these two 5NP species. In the Northwest and Inland Empire, WWP is planted on sites where root diseases (frequetly caused by *Armillaria*, *Phellinus,* and *Leptographium* species) are prevalent because WWP is less susceptible to these pathogens. We did not speak with any managers operationally planting WWP in California, because of its presence only in higher elevation forests.

Managers primarily use only resistant SP and WWP stock. Nonresistant stock (not yet screened), ideally from plus trees, is used only if screened parent trees are unavailable from a specific seed zone. In general, such trees have poor long-term survival relative to resistant stock (Bingham 1983, Kearns and others 2012). Managers relying on phenotypic resistance, however, plant these trees in areas where little-to-no WPBR mortality has occurred.

Neither SP nor WWP grows naturally in pure stands, although WWP was historically a dominant component in some areas (Fins and others 2002, Harvey and others 2008). Managers primarily plant SP in mixtures as 20 to 25 percent of the species composition and WWP in mixtures from 20 to 100 percent of the species composition. SP was most commonly planted with a mixture of ponderosa pine (*Pinus ponderosa* Lawson and C. Lawson), white fir (*Abies concolor* [Gord. and Glend.] Lindl. ex Hildebr.), incense-cedar (*Calocedrus decurrens* (Torr.) Florin), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), and Jeffrey pine (*Pinus jeffreyi* Balf.). In California, one manager frequently includes giant sequoia (*Sequoiadendron giganteum* (Lindl.) J. Buchholz) in the species mixture (K. Somers, pers. comm. 2012). No managers reported planting SP monocultures even at small scales; some cite the more virulent strain of the *C. ribicola* pathogen (vcr1) as the reason. WWP is occasionally planted as a monoculture, but more frequently in a mixture with ponderosa pine, lodgepole pine (*Pinus contorta* Douglas ex Loudon), grand fir (*Abies grandis* [Douglas ex D. Don] Lindl.), noble fir (*Abies procera* Rehder), Pacific silver fir (*Abies amabilis* [Douglas ex Loudon] Douglas ex Forbes), western larch (*Larix occidentalis* Nutt.), western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), western redcedar, (*Thuja plicata* Donn ex D. Don), and Douglas-fir. Planting densities ranged widely (table 4), with most plantings done at regular spacing with allowance for deviations related to microsite variation.

Whitebark Pine

Planting of WBP has increased in recent years, partially because of publicity of the species becoming a candidate for listing under the Endangered Species Act in 2011 and the Whitebark Pine Restoration Program initiated by USDA Forest Service, Forest Health Protection (figure 5) (Schwandt and others 2010, Schwandt 2011, Tomback and others 2011, USFWS 2011). Restoration guidelines for WBP that include steps from seed collection to outplanting and monitoring seedlings have been developed (Aubrey and others 2008, McCaughey and

Figure 5. Planted pair of whitebark pine seedlings, Shoshone National Forest. (Photo source: Betsy Goodrich, Northern Arizona University, 2008).

others 2009, Keane and others 2012). According to survey respondents, the dominant reasons for planting WBP include postfire regeneration, overstory mortality related to WPBR and bark beetles, and the need to ensure future cone crops. Additional reasons included postdisturbance plantings, species maintenance and diversity, wildlife habitat improvement, and future plans to increase national park visitor awareness of the species (J. Beck, pers. comm. 2012, Hudson and Thomas 2010). Stock that has not been screened for resistance to WPBR may be planted on sites with immediate regeneration needs (for example, postfire needs) because screening is a multiyear process. In parts of the United States and Canada, where screening programs are less developed, seedlings are planted using plus tree seed collections.

Whitebark pine is generally planted as a single species but other species may be retained or seed naturally onto the site including lodgepole pine, subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.), and Engelmann spruce (*Picea engelmannii* Parry ex Engelm.). Competing vegetation is often removed after planting to give WBP a competitive advantage. Planting densities of WBP ranged by project (table 4) with spacing of operational plantings ranging from 6 to 15 ft (1.8 to 4.6 m), with deviation of 3 to 20 ft (0.9 to 6.1 m) allowed for microsite selection. Planting WBP costs approximately $95 to $150 per acre ($38 to $61 per hectare) using contractors in the more rugged and high elevation terrain where WBP is often found (V. Walker, M. Jenkins, pers. comm. 2012).

5NP Seedling Survival

Survival of outplanted 5NP seedlings varies but, in general, has increased in the past few decades with increasing experience in both nursery production and planting (table 4). All researchers and managers emphasized the importance of careful selection of overall site and microsite planting conditions for success, a point that is also documented in the literature (Izlar 2007, McCaughey and others 2009). Survival rates range from 90 percent or more in the first year after planting to around 70 percent in the third year (table 4). Early, high mortality rates in SP and WWP were reported occasionally, with mortality related to non-WPBR agents. For example, in western Montana, heavy browse damage reduces survival. Browse preference is for resistant, planted seedlings with higher nitrogen content than wild seedlings; the higher nitrogen is likely a result of nursery practices or site-specific management (B. Larkin, pers. comm. 2012; Larkin and others 2012). Use of volunteers and choice of sites appeared to affect early survival rates of SP in the Lake Tahoe Basin (M. Mircheva, pers. comm. 2012). Long-term survival rates of WWP tend to follow expectations that resistant stock will perform better than unimproved stock, but rates of infection and mortality may still be high (Fins and others 2002, Bishaw and others 2003, Kearns and others 2012). Ultimately, field infection and survival show strong correlations with abiotic site factors (such as temperature, humidity, and presence and density of the alternate host, *Ribes* spp.), with trees growing on more susceptible sites exhibiting higher levels of infection and mortality (Bishaw and others 2003, Kearns and others 2012).

A synthesis of WBP seedling survival 3 to 15 years postplanting on 36 sites averaged 38 percent (range 19 to 78 percent), while first year survival at more recently planted sites was much higher at 74 percent (range 56 to 95 percent) (Izlar 2007). In WBP seedlings planted in four different physiographic conditions on the Gallatin National Forest (MT), 10-year survival rates ranged from 2 to 47 percent when 2-year survival was originally 58 to 100 percent (McCaughey and others 2009). This was echoed in our survey respondents where early WBP survival rates, in general, were high (table 4). Herbivory by pocket gophers was consistently noted as a cause of mortality, as was competition with other tree species and vegetation, including beargrass (*Xerophyllum tenax* [Pursh] Nutt.). These observations are also recorded in published literature (Izlar 2007, McCaughey and others 2009). Research indicates that ectomycorrhizal fungi may also influence seedling survival (Mohatt and others 2008, Cripps and Grimme 2011). Limber pine seedling survival was reported as low in some areas where postplanting summers were hot and dry; however, survival seems to be improving with increasing planting experience (Asebrook and others 2011, Smith and others 2011, Casper and others 2011) (table 4). Plastic netting was used to protect outplanted seedlings in Waterton National Park; those with netting were taller than those not protected, but the netting did not increase survival (Smith and others 2011). Survival was highest in areas planted with LP under denser overstory canopy cover; microsite planting appeared to improve health and survival where implemented (Casper and others 2011). An experimental planting of GBBP in California demonstrated the important effects of microsite on survival with 3-percent survival in open conditions, 10-percent survival under sagebrush cover, and 28-percent survival under wood pieces (C. Maher, pers. comm. 2012). Herbivory from small mammals was a major cause of mortality in forested areas but not outside the forest (C. Maher, pers. comm. 2012). Southwestern white pine seedlings will be operationally planted as a minor component (10 percent) in burned areas of northern Arizona in 2012 and 2013 with ponderosa pine, Douglas-fir, and white fir (A. Stevenson, pers. comm. 2012).

Direct Seeding Trials

Managers and researchers have limited success when direct seeding WBP and LP by caching clusters of seeds underground (Tomback and others 2005, Smith and others 2011, Schwandt and others 2011, McLane and Aitken 2012). Steel wire mesh "hardware cloth" can be used for seed protection, although predation may still occur (Tomback and others 2005, Schwandt and others 2011, Smith and others 2011). Where seeds are buried (plant litter versus soil) also affects germination (Tomback and others 2005). Whitebark pine direct seeding efforts in Glacier National Park had only 3 of 723 seeds germinate (Asebrook and others 2011). In Waterton Lakes National Park, 144 out of 338 cached LP seeds germinated by year 2, but 72 percent of the 133 monitored seedlings died by year 2 (Smith and others 2011). Schwandt and others (2011) conducted direct seeding trials of WBP in Oregon, Montana, and the Idaho/Montana border and found that survival was greatest in caged seeds. These and other WBP seed trials are continuing and being monitored for survival (C. Jensen, pers. comm. 2012). Assisted migration trials of WBP using direct seeding practices (two-seed caches) have found that seeds germinated across all planting areas, even outside the current WBP distribution (McLane and Aitken 2012). Seed sorting (by x-ray) and treatments (stratification and nicking seed coats) affected germination, while seed mass, temperature, and snowpack variables influenced survival and growth (McLane and Aitken 2012).

Regeneration Research Needs, Current Projects, and Management Perspectives

Some survey respondents felt that artificial regeneration of 5NPs, particularly SP and WWP, was fairly well understood, with few research needs. Other managers had specific species questions that could be answered by those with more experience or by existing research (table 5). We strongly recommend managers and researchers communicate frequently to share information and answer questions posed by those with less experience. Themes across species included a strong need for continuation of the resistance and breeding work, including seed collections, screening, and resistance durability (table 5).

A number of ongoing research projects were consistently highlighted as important by survey respondents, including ongoing disease screening trials and research to test the resistance durability under virulent strains of WPBR (A. Schoettle, pers. comm. 2012, Sniezko and others 2011b). In addition, field trials are underway in Oregon and Washington to validate resistance results from artificial inoculation trials and to follow resistance durability of WWP, SP, and WBP (R. Sniezko, pers. comm. 2012). Development of effective WPBR site hazard rating systems was noted as extremely important in durability testing and choosing where to plant. Ongoing research related to seedling physiology and seed germination may facilitate applications to long-term survival as well (C. Harrington, pers. comm. 2012). In western Montana, field trials comparing cold hardiness and success of stock produced from seed orchard seed with natural reproduction are planned on the eastern edge of the WWP range (B. Larkin, pers. comm. 2012), and other studies on adaptive traits are ongoing for several 5NP species (table 5). Current research in WBP and WWP incorporating ectomycorrhizal associations with seedling survival and the role of endophytes in resistance and survival were listed as promising and necessary (Cripps and Grimme 2011, Larkin and others 2012). Direct seeding, including the development of seed protection and treatment protocols, was stressed as a knowledge gap for WBP and LP and could lead to larger operational plantings. Managers appear confident in the WBP restoration programs across the regions (Mahalovich and Dickerson 2004, Aubry and others 2008, Mahalovich 2011) but listed needs to improve seedling quality and reduce costs. There appears to be a need in the northern range of WBP to determine whether methods developed elsewhere are sufficient farther north. For RMBP, GBBP, SWWP, and FP, very little regeneration and outplanting information exists, which increases the need to quantify and define nearly everything associated with successful restoration of these species (figure 6, table 5).

The virulent strains of the WPBR pathogen affecting WWP and SP have left some managers feeling vulnerable to high loss and advocating for research into clonal propagation of seedlings with durable resistance (table 5). In addition, we found regional differences in attitudes about 5NP, in particular for WWP. We routinely heard that managers are not achieving the success rates they expected from resistant stock, which can lead to reluctance in investing limited resources into a species with high mortality rates. Collaborations in place may need to emphasize realistic expectations of gain and mortality, in addition to the general importance of these species in the landscape. The current 60- to 70-percent survival rate of WWP on low to moderate hazard sites is encouraging from a genetics perspective but is often considered too low and too costly by managers.

Table 5. Research and monitoring needs identified by survey respondents for seven five-needle pine species: SP = sugar pine, WWP = western white pine, WBP = whitebark pine, LP = limber pine, RMBC = Rocky Mountain bristlecone pine, GBBC = Great Basin bristlecone pine, and SWWP = southwestern white pine.

Research and monitoring needs listed by survey respondents	Species						
	SP	WWP	WBP	LP	RMBC	GBBC	SWWP
Continuation of the breeding program to maintain durable resistance	X	X	X				
Continued screening for resistance	X	X	X	X	X	X	X
Histology of white pine blister rust (WPBR): mechanisms of infection, resistance and tolerance, and interactions between the host and pathogen		X	X	X	X		X
Continued research on inheritance of WPBR resistance mechanisms	X	X	X	X	X		X
Species genomics to speed the screening process using genetic markers	X	X	X	X	X		X
Continued work on operational (pathological) pruning	X	X		X	X		
Development of effective site hazard rating systems	X	X	X	X	X	X	X
Species adjacency and growth response	X	X					
Long-term plantation and operational planting success (>20 yrs old), including resistant vs. nonresistant survival rates	X	X					
Other pathogen ecology and damage	X			X	X	X	X
Why regeneration is less after clearcut harvesting	X						
Where should planting occur to maximize genetic mixing (near healthy/declining populations? In areas where species used to exist?)	X			X			
Rangewide understanding of population structure (including hybrid zone) and gene flow			X	X			X
Management options for introducing resistant trees in late successional reserves under the new Northwest Forest Plan		X					
Can seedling production be altered to lower susceptibility to ungulate browse?		X					
Ribes ecology and distribution maps		X					
Continued work on mycorrhizal relationships/seedling survival			X	X			
Climate change effects on species and ecosystem interactions, assisted migration, seed transfer guideline adjustments			X	X	X	X	X
Adaptive traits and resistance relationships			X	X	X	X	X
What is the best site prep to support high survival of planted seedlings? In areas where you cannot Rx burn?			X	X			X
When is the optimal time in the invasion process to plant resistant stock or stimulate natural regeneration in populations with resistance? Under what conditions?				X	X	X	X
Outplanting survival (< 20 yrs) (seasonality, microsites, locations)			X	X	X	X	X
What is the potential for understory release for different species?			X	X			
Seed storage, germination knowledge, effective planting strategies					X	X	X
Determine best season to plant				X	X	X	X
Reduce seedling costs			X				
Operational direct seeding			X	X			

Roles of Managers in 5NP Management

Survey responses regarding what the role of managers should be in 5NP research and management fell into three major categories: collaboration, management strategies, and policy/funding. Continued collaboration across regions and institutions was deemed important for all 5NP species. Working collaborations already exist for WWP and SP in Oregon and Washington, SP in California, WWP in the Inland Northwest, WBP in Oregon, Washington and the Interior West, and LP in the southern Rocky Mountains. Every 5NP species needs (and seems to have) a group of committed managers, researchers, and academics for species persistence in our current and future landscapes.

Managers are critical to the continued maintenance and restoration of these species; as such, they need to be informed of the most up-to-date strategies and tools available for successful management. Specific tools include hazard rating and site selection, resistant stock availability, silvicultural tools, and regeneration/species ecology. Managers can then use these best management practices for each species, evaluate and support continued research, and aggressively deploy hearty,

Figure 6. Newly emerged southwestern white pine seedling being grown for research. (Photo source: Betsy Goodrich, Northern Arizona University, 2012).

resistant stock. Managers must also embrace some level of flexibility in meeting stand management goals, and implement adaptive management and continuous monitoring of plantings and natural regeneration.

Finally, managers have a role in the funding and policy aspects of 5NP management. This may include everything from securing funding for seed collections and outplanting pilot programs, securing sites for field resistance trials, continuing and/or finding more commercial applications for the nontimber species, and writing restoration plans. To be successful, managers need to be aggressive in communicating to upper level management that these species should remain present on the landscape and in facilitating grassroots organizations and volunteer opportunities to keep species visible to nonscientific communities. Managers needing to meet economic objectives may have difficulty explaining high losses from planted trees and be encouraged to plant other species instead; in such instances, having strong backing from researchers and specialists may enable continued planting even with economic loss. Some survey respondents said that industry, employers, and stakeholder groups needed to be convinced that conservation and restoration are necessary. In speaking with managers, we found this principle already deeply embedded in the management of both WWP and SP, suggesting that communication needs to occur in both directions. Perhaps the most important role is finding creative means and partnerships for securing the funding required to conserve and restore 5NP species.

Conclusions

Across the West, a dedicated and diverse array of people continues long-standing efforts to perpetuate, conserve, and restore 5NP in the landscape. Experience from SP and WWP has carried over to more recent work in WBP and other high-elevation 5NP species; continued research and management successes across all species should be shared to ensure a greater proportion of success. Regeneration of 5NP increases the diversity of western forests, and deployment of resistant genes into the landscape paves the path for future self-sustaining and genetically diverse 5NP populations. We appreciate the dedication of those involved in artificial regeneration efforts in 5NP, the enthusiasm of most people for our project, and their willingness to spend valuable time providing the information presented here (appendix A). We welcome additions to our data and would be glad to help connect managers, researchers, horticulturists, academics, volunteers, and any others interested in perpetuating 5NP in the West.

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Acknowledgments

The authors thank the many people listed in appendix A for the advice, information, and reviews they provided. In particular, Richard Sniezko and Mary Frances Mahalovich were instrumental in helping us complete this project.

Appendix A. Names and titles of survey respondents. Contact information provided with permission of respondents.

Contact		Title	Company/agency/university	E-mail
Asebrook	Jennifer	Biological Science Technician	Glacier National Park, Montana	
Beck	Jen	Botanist	Crater Lake National Park, Oregon	jen_beck@nps.gov
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Bower	Andy	Area Geneticist and Pacific Northwest Region Whitebark Pine Restoration Program Lead	Olympic National Forest, Washington	abower@fs.fed.us
Brusven	Annette	Nursery Sales and Extension Associate	University of Idaho Pitkin Forest Nursery, Idaho	
Buermeyer	Karl	North Zone Vegetation Manager	Blackrock Ranger Station, Bridger-Teton National Forest, Wyoming	
Clason	Alana	PhD Student	Bulkley Valley Research Centre, University of Northern British Columbia, Canada	
Crawford	Mike	Seed Orchard Program Manager, Tyrell Seed Orchard	Bureau of Land Management, Oregon	
Daily	John	District Silviculturist	Okanogan-Wenatchee National Forest, Washington	
Dittman	Sidnee	Forestry Technician/Culturist	Idaho Panhandle and St. Joe National Forests, Idaho	
Dowling	Chris	Supervisory Forester/Timber and Vegetation Program Manager/Forest Silviculturist	Olympic National Forest, Washington	cdowling@fs.fed.us
Dunlap	Joan	Forester/Geneticist	Pacific Southwest Region Genetics—Sugar Pine Rust Resistance Program Placerville Nursery—Eldorado National Forest, California	
Eggleston	Ken	Horticulturist/Forester	Coeur d' Alene Nursery, Idaho	
Gilbert	Richard	Nursery Manager	Charles E. Bessey Nursery, Nebraska	regilbert@fs.fed.us
Haeussler	Sybille	PhD, RPF, Research Scientist	Bulkley Valley Research Centre, University of Northern British Columbia, Canada	haeussl@unbc.ca
Harrington	Connie	Research Scientist	USDA Forest Service, Pacific Northwest Research Station, Washington	charrington@fs.fed.us
Henneman	Dave	Natural Resource Specialist	Bureau of Land Management, Oregon	
Jacobi	William	Professor, Plant Pathology	Colorado State University, Colorado	
Jebb	Tamara	Horticulturist	Bureau of Land Management, Oregon	
Jenkins	Melissa	Forest Silviculturist	Flathead National Forest, Montana	mmjenkins@fs.fed.us
Jensen	Chris	Genetics and Reforestation Forester	Bend Ft. Rock Ranger District, Deschutes National Forest, Oregon	
Jopson	Tom	Owner	Cal-Forest Nursery, California	
Jungck	Ellen	Zone TMA/Silviculturist	Shoshone National Forest, Wyoming	
Keane	Robert	Research Ecologist	Rocky Mountain Research Station Missoula Fire Sciences Laboratory, Montana	rkeane@fs.fed.us
Kearns	Holly	Plant Pathologist	USDA Forest Service, Forest Health Protection, Oregon	
Klinke	Mark	Forest Culturist	Clearwater National Forest, Idaho	
Larkin	Beau	Research Scientist and Property Manager	MPG Operations, Montana	beaularkin@mpgranch.com
Livingston	Dan		Pacific Regeneration Technologies, Inc., Canada	
Lunak	Glenn	Tree Improvement Manager	Sierra Pacific Ind., California	
Maher	Colin	PhD Student	University of Montana, Montana	

Appendix A. Names and titles of survey respondents. Contact information provided with permission of respondents. (continued)

Contact		Title	Company/agency/university	E-mail
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Moody	Randy	Ecologist	Keefer Ecological Services, Canada	
Nakae	Jon	South Zone Silviculturist	Gifford Pinchot National Forest, Washington	jnakae@fs.fed.us
Niman	Randy	Vegetation Manager	Chelan District, Okanogan-Wenatchee National Forest, Washington	
Omdal	Daniel	Forest Pathologist	Department of Natural Resources, Washington	DANIEL.OMDAL@dnr.wa.gov
Plampin	Jim	Silviculturist	Quinault Indian Reservation, Washington	JPLAMPIN@quinault.org
Rust	Marc	Director	Inland Empire Tree Improvement Cooperative, Idaho	
Sanchez-Meador	Andy	Forest Restoration Program Manager	Lincoln National Forest, New Mexico	
Schoettle	Anna	Research Ecophysiologist	Rocky Mountain Research Station, Colorado	aschoettle@fs.fed.us
Sloan	John	Assistant Nursery Manager	Lucky Peak Nursery, Idaho	
Smith	Cyndi	Conservation Biologist	Waterton Lakes National Park, Canada	Cyndi.Smith@pc.gc.ca
Sniezko	Richard	Center Geneticist	Dorena Genetic Resource Center, Oregon	
Somers	Ken	Professional Forester	Blodgett Forest, University of California—Berkley, Center for Forestry, California	
Stevenson	Andy	Silviculturist	Coconino National Forest, Arizona	
Stubbs	Donna	Assistant Forest Silviculturist (Genetics-FACTS-Silviculture)	Fremont-Winema National Forests, Oregon	
Tomback	Diana	Professor	Department of Integrative Biology, University of Colorado, Denver, Colorado	
Trobaugh	John	Program Manager	Webster Forest Nursery, Washington	
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Violett	Paul	Chief Forester	Soper-Wheeler Company, LLC, Calfornia	
Vogler	Detlev	Research Geneticist/Plant Pathologist	USDA Forest Service, Pacific Southwest Research Station, Institute of Forest Genetics, California	
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Wilcox	Craig	Forest Silviculturist	Coronado National Forest, Arizona	
Wunz	Eric	District Silviculturist	Blue Mountain Ranger District, Malheur National Forest, Oregon	

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