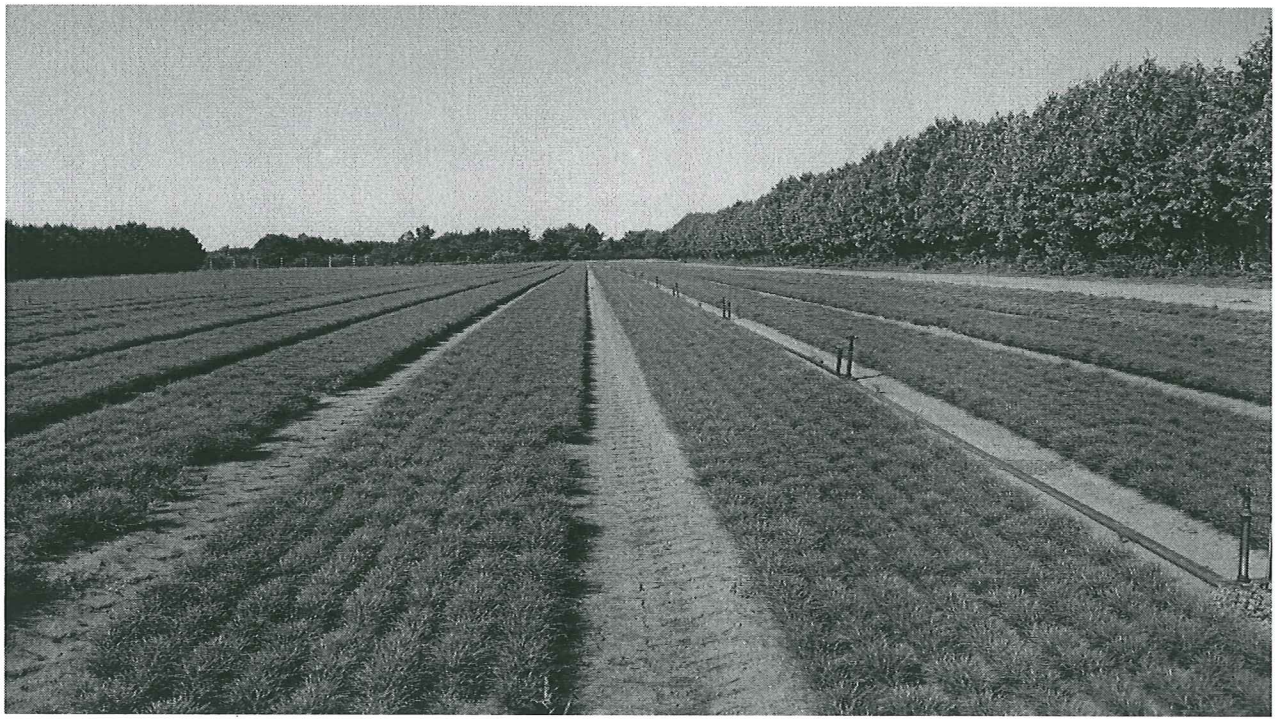
State Forest Nursery Program
Seedling Production
Seed Production
Tree Improvement Program



Challenges, Opportunities, Roles, and Recommendations to Improve Minnesota's Future Forests

Winter 2014

Minnesota
DEPARTMENT OF NATURAL RESOURCES

Executive Summary

This report was produced to meet the requirements of Laws 2013, chapter 114, article 3, section 4, subdivision 4, which directed the commissioner of Natural Resources to develop a plan and recommendations on utilizing the state forest nurseries to 1) ensure the long-term availability of ecologically appropriate and genetically diverse native forest seed and seedlings to support state conservation projects and initiatives, 2) protect the genetic fitness and resilience of native forest ecosystems, and 3) support tree improvement research to address evolving pressures such as invasive species and climate change. It also addresses funding to improve state forest nursery and tree improvement capabilities.

The report presents an overview of the current and future challenges to the sustainability and health of Minnesota's forests from invasive species, climate change, and a declining forest land base. It describes the roles that seed, seedling, and tree improvement programs can play in responding to these challenges. It identifies both needs and opportunities for public and private forest nurseries and the Minnesota Tree Improvement Cooperative to work together to address these issues. It also identifies potential roles the State Forest Nursery Program (SFNP) and Tree Improvement Program (TIP) can play in responding to these issues.

The current operation levels within the SFNP and TIP have a stable funding source through forest tree seedling sales. As directed by the legislation, this report provides funding options to improve the infrastructure of the state forest nurseries and support the report's recommended goals. This includes identifying $3.95 million for facility needs and one-time equipment and supply costs. Annual operational program and research costs of $450,000 are also identified to support expanded cooperative efforts in tree improvement research and native forest seed production. These are listed as specific funding options the state's legislature and administration can consider to address the issues that are the basis of this report.

No major recommendations are made within the report to revise the statutory purpose and structure of the SFNP. The report, however, clarifies that the requirements for self-sufficiency within nursery operations are specific to seedling production. It identifies the critical roles and long-term investments that need to be addressed to enhance the department's seed production and tree improvement efforts.

The 2013 session laws also directed the commissioner to update the SFNP business plan submitted to the legislature on January 15, 2012. This update was produced by the Management Analysis Division of the Minnesota Management and Budget Department. It addresses the ability of the SFNP to maintain self-sufficiency during the 2015-2016 biennium and beyond. The business plan updates the financial impacts of revised market projections but does not include analysis of the proposed changes within this report.

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This document and additional information about the Minnesota State Forest Nursery Program can be found on the Internet at www.mndnr.gov/forestry/nursery.

This information is available in an alternative format upon request.

I. Introduction

The Minnesota Department of Natural Resources (MNDNR) has broad statutory authority and responsibility to support statewide conservation initiatives and reforestation efforts (see Appendix B, page 24). This report, developed in response to a legislative directive by an interdisciplinary team representing broad conservation interests (see Appendix C, page 26), presents broad recommendations and specific options for improving the State Forest Nursery Program and Tree Improvement Program.

In 2013 the MNDNR was directed to develop recommendations on utilizing the State Forest Nursery Program (SFNP) and Tree Improvement Program (TIP) to 1) ensure the long-term availability of ecologically appropriate and genetically diverse native forest seed and seedlings to support state conservation projects and initiatives, 2) protect the genetic fitness and resilience of native forest ecosystems, and 3) address evolving pressures such as invasive species and climate change. Solutions to these challenges cannot be achieved by the MNDNR SFNP working independently. It will require working partnerships with private forest nurseries, the University of Minnesota, and public, industrial, tribal, and private forest landowners.

Minnesota's forest land managers, including nonindustrial private landowners and the forest products industry, require an ample supply of native tree and shrub seedlings and seeds to reestablish forest vegetation after harvesting, wildfire, and windthrow. The SFNP was permanently established with the creation of Badoura Nursery in Akeley, Minnesota, in 1929 and the creation of General C.C. Andrews Nursery in Willow River, Minnesota, in 1939. The SFNP has actively worked with private nurseries since the 1980s to purchase and supply seeds and seedlings. The SFNP began seed-source control and seed zone establishment in 1980. In 1998, the SFNP implemented strict protocols for seed-source control, and its seed and seedling production processes and products were formally certified by the Minnesota Crop Improvement Association. These controls ensure that tree and shrub seedlings and seed produced for use in forestry and conservation initiatives are ecologically appropriate for growing conditions across the state. In addition, the MNDNR's tree improvement efforts, started in the 1950s, identify genetic variations with higher productive potential, pest resistance, and greater regeneration success than wild seed. Genetic improvement efforts are increasingly important as climate change alters precipitation and temperature regimes, which impacts species distribution and health. Shifts in climate trends have already brought about increasing threats from invasive species and native insects and diseases. This report presents options for improving the SFNP (for seedling and seed production) and improvements to the TIP that will help sustain the health of the state's forests and meet the challenges of climate change and invasive species. These three functions (seedling production, seed procurement, and tree improvement) are separate but intricately connected. Each one can be a significant contributing factor to the overall future health and productivity of Minnesota's forests.

This report offers:

- **Seedling Production**—recommendations and options to 1) continue production of native source-identified tree seedlings and shrubs for reforestation, wildlife habitat establishment, and other conservation needs and 2) upgrade production system capabilities in the state of Minnesota.

- **Seed Production**—recommendations and options to 1) expand seed production, procurement, processing, and availability of native forest species and 2) expand seed evaluation and testing capabilities for quality and diversity.

- **Tree Improvement**—recommendations to expand tree improvement research and evaluations to improve genetic diversity, quality, and fitness, including establishing new seed orchards for improved and natural populations of ecologically and commercially important tree and forest plant species.

II. Challenges Posed by Climate Change, Invasive Species, and Reforestation

Minnesota's forest managers face unprecedented challenges in their efforts to sustain the state's forests and the benefits they provide. These challenges occur in three major areas in which the SFNP and TIP play a critical role: 1) climate change and its effects on the state's forested areas, 2) response to invasive plants and pest introductions, and 3) sustaining the state's forest resources through tree planting and regeneration. The ability to expand tree planting will be needed to regain and improve the health and sustainability of Minnesota's forest ecosystems now being hindered by the impacts of invasive species and weather anomalies (drought and floods). Providing appropriate, high-quality genetic materials will be necessary to ensure that new plantings have improved abilities to withstand and survive the impacts of invasives and climate change so the state's forests can thrive in the future. As identified in the 2013 State Forest Nurseries Business Plan, the SFNP's ability to make **new** investments in seedling and seed production and expand tree improvement operations is restricted by current financial limitations. Research efforts to identify and improve the resistance, resilience, and adaptability of native forest trees and plants will play an essential role in meeting these challenges.

Climate Change

Climate change will be the most significant threat to Minnesota's forests over the next century. Changes in Minnesota's climate will directly affect forests by creating more habitat for some tree species and reducing habitat for others, and indirectly, but no less significantly, by intensifying existing threats from wildfire, pests and disease, invasive species, and extreme weather events.

Climate. Changes in Minnesota's climate are already apparent (Minnesota Department of Natural Resources, 2011). Average, minimum, and maximum temperatures in all seasons have increased over the last century, with greatest increases in winter. Precipitation, particularly in summer and fall, has increased, with more of that precipitation coming in heavy events of 3 inches or more. Snowfall in the north has decreased despite an increase in winter storms.

Greater changes are on the way. All global climate models predict that temperatures will increase with increases in atmospheric greenhouse gases. In Minnesota, average annual temperatures will increase 5-9 degrees Fahrenheit by the end of the century. Temperatures will increase more in winter than in other seasons, leading to changes in snowfall, soil frost, and other winter processes. Growing seasons will be longer, but changes in precipitation patterns could negate the potential benefits of a longer season. Average annual precipitation may increase by 6-12 percent, **but** most of that increase will come in winter and spring and soils will likely be drier later in the growing

season. In addition, droughts will extend over larger areas and be more intense and an episodic precipitation regime could mean longer dry periods between events. Extreme weather events such as intense rainstorms and high winds that blow down large areas of forest will be more frequent.

Minnesota's forests. Ecological research and forest simulation models point to several likely impacts on Minnesota's forests (Handler, Duveneck, & Iverson, 2014). There will be less suitable habitat for boreal species such as aspen, paper birch, tamarack, and black spruce (Figure A, page 7) and growth rates and competitive ability in these species will decline. Species with ranges that extend to the south, such as American basswood, black cherry, northern red oak, and eastern white pine, will have more suitable habitat (Figure B, page 8) and will be favored by higher temperatures. See Table 1 on page 9 for predicted changes in the amount of suitable habitat available for trees in Minnesota at the end of the century. As individual species respond to changing temperature and precipitation regimes, the communities they form may look little like the forest communities we recognize today.

Several factors may affect the ability of Minnesota's trees and forest ecosystems to respond successfully to changes in temperature and precipitation. In species with relatively high genetic variability, genotypes capable of flourishing under the changed temperature and precipitation regimes may persist. Species with broad ecological niches will fare better than those with narrow habitat requirements. Low diversity ecosystems are less resilient to disturbance and more vulnerable to change. Forest fragmentation creates barriers to migration for some species and these species will have less opportunity to migrate in response to climate changes. Species and communities that are now limited to particular environments because of narrow habitat requirements will have less opportunity to migrate in response to climate change.

The indirect effects of climate change on Minnesota's forests will also be significant and increase the already high rate of tree mortality in Minnesota. Trees under water or nutrient stress resulting from altered precipitation regimes and nutrient cycles are more susceptible to disease and insect damage. In addition, future winter temperatures will be less of a deterrent to the northward movement of new insect pests and diseases. More frequent disturbances such as fires, blowdowns, and ice storms will also lead to increased tree mortality. Reestablishing tree cover after harvest may also become more difficult. In many locations, deer browsing now limits the success of regeneration efforts. Deer populations likely will increase under winters with less snow cover and higher temperatures. Without adequate control of deer populations, deer browsing will hamper regeneration efforts over larger portions of the state.

Figure A: Current and predicted distributions and relative abundances of four Minnesota trees that are expected to decrease under anticipated changes in climate. Blue indicates high abundance, green moderate abundance, and yellow low abundance. Maps are based on current importance values and projected importance values under a high emission scenario in the Tree Atlas model (Prasad, Iverson, & Matthews, 2007–ongoing).

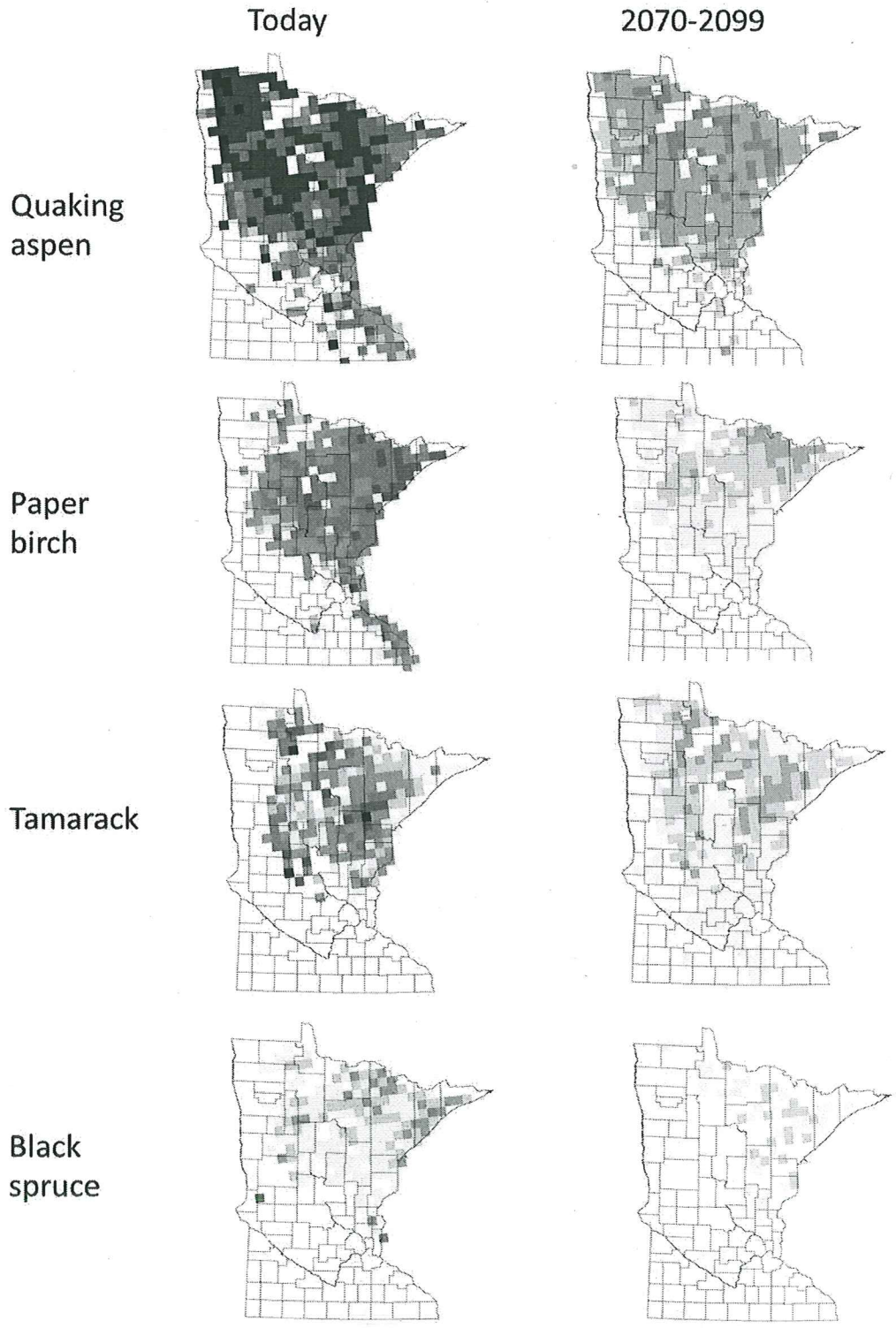

Figure B: Current and future distribution and relative abundance of three Minnesota trees that are expected to increase under anticipated changes in climate. Blue indicates high abundance, green moderate abundance, and yellow low abundance. Maps are based on current importance values and projected importance values under a high emission scenario in the Tree Atlas model (Prasad et al., 2007–ongoing).

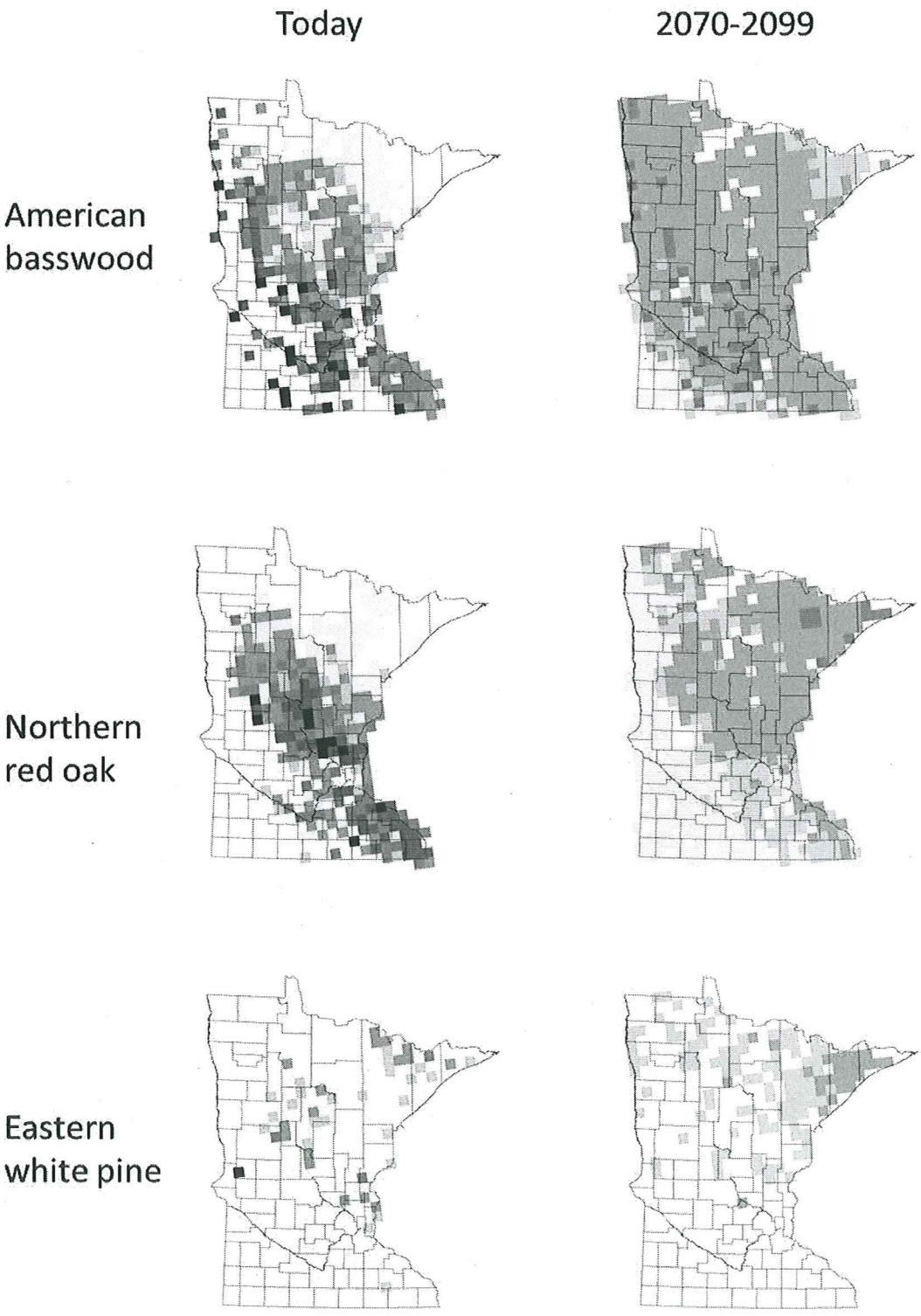

Table 1: Potential changes in suitable habitat for 74 tree species in northern Minnesota from the Tree Atlas model under a high greenhouse gas emission scenario. Change categories are based on a comparison between end of the century (2070–2099) and current values for habitat suitability based on Forest Inventory and Analysis data. A potential change of "new habitat" indicates species not currently in northern Minnesota that would find suitable habitat in the future.

Common Name	**Potential Change**
Balsam fir	Large decrease
Balsam poplar	Large decrease
Black spruce	Large decrease
Butternut	Large decrease
Mountain maple	Large decrease
Northern white cedar	Large decrease
Paper birch	Large decrease
Bigtooth aspen	Decrease
Black ash	Decrease
Jack pine	Decrease
Quaking aspen	Decrease
Tamarack	Decrease
White spruce	Decrease
Yellow birch	Decrease
Choke cherry	No change
Northern red oak	No change
Pin cherry	No change
Striped maple	No change
American basswood	Increase
Bur oak	Increase
Eastern hophornbeam	Increase
Eastern white pine	Increase
Green ash	Increase
Red maple	Increase
Red pine	Increase
River birch	Increase
Rock elm	Increase
Sugar maple	Increase
Wild plum	Increase
American elm	Large increase
American hornbeam	Large increase
Bitternut hickory	Large increase
Black cherry	Large increase
Black oak	Large increase
Black walnut	Large increase
Black willow	Large increase
Boxelder	Large increase
Eastern cottonwood	Large increase
Eastern red cedar	Large increase
Hackberry	Large increase
Northern pin oak	Large increase

Peachleaf willow	Large increase
Silver maple	Large increase
Slippery elm	Large increase
Swamp white oak	Large increase
White ash	Large increase
White oak	Large increase
American beech	New habitat
Black hickory	New habitat
Black locust	New habitat
Blackgum	New habitat
Blackjack oak	New habitat
Chestnut oak	New habitat
Chinkapin oak	New habitat
Eastern hemlock	New habitat
Eastern redbud	New habitat
Flowering dogwood	New habitat
Honeylocust	New habitat
Mockernut hickory	New habitat
Northern catalpa	New habitat
Ohio buckeye	New habitat
Osage-orange	New habitat
Pignut hickory	New habitat
Pin oak	New habitat
Post oak	New habitat
Red mulberry	New habitat
Sassafras	New habitat
Scarlet oak	New habitat
Shagbark hickory	New habitat
Shingle oak	New habitat
Sugarberry	New habitat
Sweet birch	New habitat
Sweetgum	New habitat
Yellow poplar	New habitat

The Impacts of Invasive and Adaptive Native Pests

Forest managers will need to increase tree planting efforts to compensate for mortality from a combination of plant and animal pests. Invasive insects such as emerald ash borer and gypsy moth, already established in Minnesota, will impact a wide-range of tree and plant species in forest ecosystems.

Gypsy moth populations established in Cook and Lake counties are expected to build to outbreak levels and spread south and west into high-value oak resources. Factors affecting tree mortality after gypsy moth defoliation include: 1) severity, frequency, and distribution of gypsy moth defoliation events; 2) site and stand factors such as soil type and stand composition; 3) environmental conditions such as results from drought or frost events; and 4) tree vigor and crown condition (Davidson, Gottschalk, & Johnson, 1999). As forest tent caterpillars (which prefer many of the same host species as gypsy moths) have shown, defoliation events in Minnesota can affect up to 7 million acres at a time. The 2004–2005 gypsy moth outbreak in central Pennsylvania cost the state hundreds of thousands of dollars in lost revenue on over 300,000 acres as a result of oak mortality (Eggen, 2013).

Invasive plant species such as buckthorn compete with native species and hinder the successful reestablishment of native forest vegetation. Woody invasive plants are already a serious threat to the sustainability of Minnesota's oak forests. In areas infested with buckthorn or other woody invasive species, producing adequate oak regeneration requires a multi-year treatment regime including underplanting prior to harvest. Without such measures, woody invasive species crowd out oak sprouts before they can reach maturity. As buckthorn continues to spread northward and gypsy moth populations expand from the north, oak forests across the state are at risk of serious degradation.

Modern commerce, through global air travel and shipping, has created new transport opportunities for pests that have evolved on other continents. Some examples:

Emerald ash borer. The emerald ash borer (EAB) arrived in the United States on solid wood-packing material sent from the Far East. Minnesota has nearly a billion ash trees (the largest number in the United States) susceptible to attack. In other states affected with EAB, 99 percent of all ash species have died as a result of infestation; almost all trees greater than 1 inch in diameter. As the remaining ash seedlings increase in size, they too are invaded and killed (Herms, Gandhi, & Smith, 2011). Research has started looking at the surviving 1 percent of ash trees to begin to identify potential genetic material for future ash tree improvement (Knight, Herms, & Plumb, 2013). However, that work has so far been confined to Michigan and Ohio. In Minnesota, a large proportion of the stands dominated by ash have few, if any other tree species available to help maintain a forest canopy or the stand's hydrology if the ash component is lost. Substantial work is needed to identify stands where management is possible. Considerable work is also needed to develop plant material suitable for planting under Minnesota conditions.

Asian long-horned beetle. Unlike EAB, which sticks to species of ash, the Asian long-horned beetle (ALB) can attack and successfully kill all species of maple, basswood, poplar, and willow. While ALB has not yet become established in Minnesota, it can spread via firewood and solid waste-packing material in much the same way as EAB. Considering the large infestation in Ohio, it's likely that ALB will hit Minnesota at some point in the future. The United States has not yet

experienced outbreak levels of ALB, so the full extent of the damage they can do is unknown. With the combination of gypsy moth, EAB, invasive plants, and ALB, Minnesota's northern hardwoods face a difficult future. This substantiates that developing and planting suitable tree species will be critical to future forest sustainability in the state.

Even native insects are increasingly more destructive to Minnesota forests. Some examples:

Eastern larch beetle. Tamarack has lost greater acreages in its natural range due to eastern larch beetle than any other tree in the last 200 years. Originally covering 6 million acres, tamarack occupies just over 1 million acres today (Minnesota Department of Natural Resources, 2013). Eastern larch beetle has killed approximately 18 percent of the state's mature tamarack resource over the past decade. This insect kills the trees by breeding in the water-conducting tissues, effectively girdling them. Current research in the forest insect laboratory at the University of Minnesota is beginning to reveal how a changing climate is affecting beetle reproduction. Earlier springs and warmer summers and falls have expanded the seasonal reproductive window and enhanced developmental rates for the eastern larch beetle, leading to many more insects on the landscape than in previous years.

Mountain pine beetle. Like eastern larch beetle, the mountain pine beetle kills trees by breeding in their water-conducting tissues. Native to the western United states, mountain pine beetle is typically kept in check by winter temperatures below -40 degrees Celsius (= -40 degrees Fahrenheit) that kill the larvae during the winter. In recent years, climate warming trends in the western United States have relaxed the northern boundaries of this insect (Carroll, Taylor, & Régniere, 2004). It has spread over the geographic and climate barrier of the western Rocky Mountains and is now reproducing in jack pine forests of western Canada (Safranyik, Carroll, Régniere, 2010; Cullingham, Cooke, & Dang, 2011; de la Giroday, Carroll, & Aukema, 2012). Jack pine stretches through the boreal forest of Canada to the Great Lakes region where it mingles with white, red, and Scots pines. Mountain pine beetle reproduces on almost all types of mature pines, making it a critical emerging forest health threat that endangers Minnesota's pines.

These two examples illustrate the necessity to maintain a thriving nursery program in the face of current and emerging forest insect threats. Both of these aggressive, tree-killing bark beetle species are native insects that have altered their historic behavior in response to a changing climate. Given the increasing rate of introductions of forest pests (Brockerhoff, Liebhold, & Jactel, 2006), the state needs to be prepared for mitigation strategies in the face of future introductions (e.g., Asian gypsy moth and European spruce bark beetle).

The combination of newly introduced invasive species, increasingly pernicious native pests, and a warmer climate will significantly alter forest ecosystems. A diversity of trees for forest plantings will be needed to avert wholesale losses of plant communities and species that could be threatened with extirpation. Efforts to improve the genetic variation and fitness of native tree species will also play a key role in responding to these challenges.

Reforestation
State laws require that MNDNR sustain forest resources on state-administered forest land and support sustainable forestry on all forest landownerships. In practice this means that forest cover must be reestablished on every acre of state-administered forest land that is harvested. MNDNR accomplishes this through a combination of natural regeneration via stump sprouting and seed tree retention, direct seeding, and planting seedlings. As the housing market and other sectors of the economy recover from the 2008 recession, demand for forest resources and harvest levels will return to normal. In addition, new wood fiber markets (i.e., potential expansions in the use of wood fiber for bio-energy production and bio-chemical industries) will increase the volume of timber harvested and the number of species harvested. Regenerating harvested sites will continue to be the primary use of seed and seedlings on public and private lands.

Significant additional demand for seed and seedlings, however, will be associated with climate change. Responding to climate change-driven increases in the frequency and intensity of wildfires and blowdowns will require seed and seedlings. Replacing species that are subject to climate change-driven increased mortality from water or nutrient stress, pests, and diseases with species or varieties better suited to new growing conditions will require additional seed and seedlings.

Acting on Minnesota Climate Change Advisory Group (MCCAG) recommendations to expand ecosystem carbon sinks and reduce the state's greenhouse gas emissions could require substantially more seed and seedlings. MCCAG recommendations focused in part on establishing new forests on up to 1 million acres, ensuring that forests on public lands are fully stocked, and emphasizing carbon management using carbon-friendly management methods. An economic analysis of afforestation opportunities requested by the legislature (Turner, Becker, & Taff, 2010) found that establishing forests on 1 million acres of private lands currently in other uses would be cost prohibitive, but that about 34,000 acres could be forested if relatively small public payments are added to income to landowners from carbon markets and timber sales. Non-economic incentives for tree planting to mitigate climate change were not evaluated in the study, but could contribute significantly to an increased demand for seed and seedlings.

III. Responding to the Challenges

The challenges facing Minnesota's forest ecosystems will require cooperation between the state's public and private nurseries and significant additional efforts by the SFNP and TIP. Together they must:

- Maintain the capacity to produce a significant portion of the seeds and seedlings needed for reforestation in Minnesota.
- Assure that the seedlings and seed they make available are ecologically appropriate and genetically diverse.
- Expand the number of species offered by Minnesota nurseries to include species whose future range due to climate change is likely to include Minnesota.

Assuring the ecological appropriateness and genetic diversity of the seeds and seedlings used in Minnesota will require them to:

- Acquire seeds from outside the current seed zones and of species that have received little attention to date, including nonwoody forest plants and rare, threatened, and endangered plants.
- Maintain detailed provenance records for seeds and other regeneration stock and control the distribution of seeds and seedlings to appropriate locations.
- Evaluate the potential of seeds from new sources to perform well in Minnesota ecosystems.
- Select for genotypes and varieties that resist insects and diseases and can tolerate a wider range of soil moisture conditions.

The range of products available should enable forest managers to regenerate and restore forest vegetation efficiently and effectively. Forest managers should be able to select from:

- A variety of seedling types, including bareroot and containerized seedlings, transplant and caliper-size variations, root-pruned seedlings, and painted seedlings (seedlings actually painted to make them more visible in the ground after planting).
- Seed and seedlings treated to encourage germination and discourage deer browsing.
- Packages of trees, shrubs, and forbs assembled to be appropriate for specific locations and conditions.

IV. Improvements Needed to Meet Minnesota's Challenges

The challenges facing Minnesota's forest ecosystems can be met only if improvements to the state's existing seedling production, seed production, and tree improvement facilities are made and efforts to improve the genetic fitness and resiliency of seed and seedlings are expanded. The following improvements will only be met through the efforts of both public and private nurseries:

Improve Seedling Production, Diversity, Capacity, and Distribution

- Increase production of diverse seed sources and the variety of tree and forest plant species offered. Examples include:
  a) Diversity of stock (bareroot seedlings, containerized seedlings, and transplants and caliper-size variations).
  b) Specialty products (e.g., mixed seedling species packaged for ecologically diverse plantings, treated species to respond to deer depredation, and root-pruned and painted seedlings).
  c) Diversity of seed sources (native, source-identified tree seed and seedlings available from collections throughout Minnesota).
  d) Genetically improved seed and seedlings.
  e) Diversity of species (conifers, hardwoods, shrubs, herbs, and forbs).

- Expand the development and production of improved seedlings.

Increase Genetic Fitness and Resiliency

The sustainability of Minnesota's future forests will hinge on the genetic resilience of forested ecosystems. The genetic quality of the tree seedlings that are planted can improve or detract from ecosystem fitness. Local seed sources that possess sufficient genetic diversity are considered the

lower risk option for planting projects, but appropriate locality may need to be redefined in light of climate change. To achieve genetic fitness and resiliency for the state's future forests, the following tree improvement functions must be implemented:

- **Evaluation and testing**
  a) Improve genetic evaluation and material testing in Minnesota to determine and propagate the most desirable species that best respond to climate changes. To achieve this, Minnesota needs to accelerate efforts to collect or acquire improved seed. Minnesota also needs to evaluate the potential for novel genotypes or species to grow and thrive in forests affected by invasive pests and climate change.
  b) Expand seed procurement beyond historical seed collection zones to increase capacity to evaluate and utilize the most adaptable seed available and identify suitable locations of wild seed.
  c) Identify and expand native wild seed collection areas throughout Minnesota; explore expanding seed procurement of nonwoody forest plants to establish foundation stock for seed production and expand availability of regeneration materials for sustaining diverse forest plant communities.
  d) Investigate seed collection and propagation of rare, threatened, or reduced-range species of forest trees, shrubs, and plants to support natural migration and breeding populations in the wild.
  e) Investigate alternative methods and processes to improve the genetic diversity of seed available.

- **Research**
  a) Improve techniques to propagate trees through grafting and/or cuttings to facilitate efforts to conserve unique or valuable genotypes.
  b) Investigate the stability of seed-transfer distances within Minnesota and adjacent states to develop rigorous standards to guide movement of forest seed.
  c) Identify replacement genotypes and species to plant in forests threatened by invasive species and climate change.
  d) Explore the influence of the environment on gene translation (which affects gene expression) through studies of adaptation via epigenetic mechanisms (i.e., heritable changes in gene expression due to nongenetic factors).

- **Material breeding improvements**
  Public (e.g., MNDNR, University of Minnesota) and private sectors (e.g., forest industry, commercial nurseries, Minnesota Nursery and Landscape Association) must collaborate with the Minnesota Tree Improvement Cooperative to:
  a) Breed trees with improved resistance to pests (both insects and diseases) and improved tolerance to a future with a warmer and likely drier climate.
  b) Develop seed orchards that provide a stable source of seed with quantifiable improvements in resiliency to grow and thrive in future conditions.
  c) Develop seed collection areas that can serve as off-site conservation areas and a seed source for reforestation in targeted areas.

V. Roles of the State Forest Nursery and Tree Improvement Programs

The MNDNR has the statutory charge and authority to lead the effort of addressing the challenges facing Minnesota's forest ecosystems. The state over the SFNP's 85-year history has established broad experience and significant facilities associated with seed collection, seedling propagation and growth, materials distribution, and tree improvement operations. These investments include two major public land bases developed for these efforts. This section outlines how these facilities could contribute to meeting the challenges facing Minnesota's future forests.

Options for the Badoura State Forest Nursery Facility

- **Seedlings**
  a) Continue to produce 6 million seedlings of the total statewide annual demand (currently this is approximately 15 million) for bareroot seedlings.
  b) Serve as a broker of seedlings produced by private nurseries. Badoura Nursery currently brokers seedlings from private nurseries to meet the needs of its customers. Developing closer ties to private nurseries would be mutually beneficial and facilitate conservation efforts.
  c) Increase the number of forest species for which seedlings are produced, focusing on additional native tree, nontree woody, and herbaceous species; additional nontimber species; and additional tree species whose future range due to climate change is likely to include Minnesota.

- **Seeds**
  a) Increase the volume of seeds procured each year and increase seed handling and storage capabilities accordingly.
  b) Increase the number of species for which seed is collected from the wild, including species that are rare, threatened, or endangered.
  c) Establish orchards of naturally diverse native and non-native forest species expressly for producing seeds on state forest lands in several climatic regions of the state.
  d) Expand current wild seed collection zones to include more climatic variation including areas outside of the state.
  e) Develop a means of evaluating the performance of seeds and the seedlings they produce based on the location and climatic conditions from which they were collected and their resistance to pests and diseases.

Conversion of the General Andrews Nursery to a Tree Improvement Facility

General Andrews Nursery (GAN) has been the center of operations for the MNDNR's TIP since the program's inception in the 1950s. Historically, improved seed orchards were established in dispersed locations across the state. Since seedling production operations have been consolidated into the Badoura Nursery long-term, refocusing the use of the GAN facility as a site for future orchards was initiated in 2012 under existing limited funding. Consolidating new orchard investments at GAN will reduce costs and improve management efficiency. It is proposed that any future expansions in tree improvement research and orchard development take advantage of GAN for cost efficiency.

VI. Facility, Program, and Funding Options

The SFNP as detailed in the 2013 State Nurseries Business Plan has the ability to maintain its current seed, seedling, and tree improvement operations without new funding. This includes the ability to annually produce and distribute bareroot seedlings, collect and process native seed to meet nursery and state forest seeding needs, and maintain limited cooperative tree improvement activities. The long-term consolidation of seedling and seed production at Badoura Nursery will require facility investments and equipment upgrades to maintain a viable infrastructure over the next 20 years. These investments are both identified below and in the 2013 State Nurseries Business Plan. If necessary, these investments will be funded over time by increasing seedling prices.

Diversifying the species or intraspecies genetics available with SFNP products will require expanded tree improvement research and studies, as well as expanded facility capabilities to support these operations. They will be long-term investments to meet the challenges facing Minnesota's future forests with limited financial returns. Expanded operations would require the investments identified below in greenhouse, laboratory, and seed processing capabilities. As directed by the 2013 legislative charge, funding options to improve state forest nursery and tree improvement capabilities are identified. (See Appendix A on page 23 for a summary table of all funding options.)

Seedling Production

- **SFNP seedling production facility consolidation**—The following seedling production facility and equipment improvements have been identified in the business plan and this report to address long-term SFNP consolidation at the Badoura Forest Nursery:
  a) Improve facility to consolidate both seed and seedling operations. Improvements include:
     i. Expanding the grading and packing building to provide adequate working space to grade and count the nearly doubled seedling packaging and distribution needs.
     ii. Constructing a steel building with a cement floor, all typical utilities, and a CoRayVac® overhead heating system for the counting and grading area.
     iii. Increasing cold storage capacity for seedlings and seed. This expanded freezer and refrigeration space is needed to facilitate expanded fall lifting and storage of seedlings for new spring seedling processing and distribution demands and to support operational efficiency and enhanced survival of regeneration materials. Recommended construction specifications include adequate height to accommodate forklifts and storage space for seedlings.

  b) Acquire state-of-the-art seeding equipment such as a Whitfield hardwood seeder and Love/Oyjord® conifer and small seed seeder. Equipment of this type is necessary to accommodate the control bed density seeding requirements for the range of materials envisioned to be grown by the nursery complex. Appropriate bed densities for hardwood and nonwoody plants will improve regeneration, seedling survival, and seedling quality.

c) Establish all-weather roads and surface transition areas among the seed and seedling processing, packing, and distribution facilities complex. Improvements would allow safe movement of forklifts and other equipment between buildings and provide an all-weather surface to support meeting shipping demands and seed processing in the fall.

d) Investigate alternative methods of co-generation and energy conservation for the nursery complex facilities to control and reduce energy demands over the long-term.

- **Funding estimates for options for Badoura Nursery seedling production improvements**
  a) $1,500,000 for Badoura facility expansion and upgrades (includes a packaging building and freezer building).

  b) One-time equipment purchases of $150,000 (includes the purchase of a Whitfield hardwood seeder and Love/Oyjord® conifer and small seed seeder).

Seed Production

The SFNP's current seed production program is sufficient to meet existing demands. Implementing program actions to diversify seed sources or expand seed availability are constrained by the commitment of the SFNP to self-sufficiency. This fiscal limitation is addressed in the 2014 business plan. Enabling the SFNP to support options for expanding seed production for broad forest ecosystem goals would require financial investments beyond those available from income associated with current or anticipated seedling sales.

Expanded seed production, evaluation, and collection (including zone identification and management), should be viewed as a long-term investment for the public good. The value of expanded seed production as well as improved seed quality will only be realized in the future quality and health of regenerated forests. To address Minnesota's reforestation challenges, both improvements to the current seed production facilities and program expansions are identified with an estimate of their costs.

- **Seed production options identified for the Badoura Seed Operations Facility**
  a) Improve and expand the capability to provide the highest quality seed for Minnesota conservation initiatives through development of a state-of-the-art Forest Seed Production Complex. Facility improvements within the complex include:
     i. Upgrading and expanding the native seed processing and cold storage capabilities at Badoura. Expanded physical facilities for seed extraction and cleaning operations include: 1) a separate expanded cold storage facility for improved shelf life of stored seed and expansions in seed volumes and diversity, 2) a kiln room designed to operate at safer extraction temperatures than the current oven, and 3) an expanded seed processing and storage space.
     ii. Adding a greenhouse facility to conduct seed performance evaluations and provide a source of foundation stock for nonwoody species.

b) Acquire specialized equipment to expand the capability to process the volume and diversity of seed needed to support future conservation needs. Equipment investments include:
   i. Westrup brush machine for cleaning deciduous and nonwoody seed
   ii. Vibratory cone shaker (extracts conifer seed)
   iii. Amalco plot thresher (harvests nonwoody seeds)
   iv. Belt thresher (harvests nonwoody seeds)
   v. Westrup indent cylinder seed cleaner
   vi. Conifer seed extraction straight wall system

- **Program improvements that would complement improved seed production efforts**
  a) Identify and establish seed collection areas and seed orchards for major forest species on public lands within seed collection zones to facilitate efficient seed collection and quality.

  b) Conduct an exploratory assessment on the availability and sources of native nonwoody seed and identify needs for currently unavailable seed sources that should be prioritized for foundation stock development.

- **Funding estimates for options to establish a Native Seed Production Facility at Badoura Nursery**
  a) $1,500,000 for the facility improvements and major equipment purchases.

  b) $200,000 annually to plan, manage, and implement an expanded seed production program after the facility is in place.

Tree Improvement Program

The purpose of applied forest tree improvement is to steadily and continuously improve the genetic quality of seeds, stem cuttings, and other regenerated stock for use in reforestation programs. The tree improvement program combines basic orchard management with other specialized skills such as grafting, progeny testing, and tree breeding. These types of analysis and research are conducted cooperatively with the University of Minnesota's Minnesota Tree Improvement Cooperative (MTIC) administered through the University's Department of Forest Resources in St. Paul. Improved seed and seedlings, when supporting commercial use of forest resources, can provide a financial return on investments. This return is generally only available after several years of development and testing. The differential value associated with improved seed or seedlings is generally of a short-term nature until expanded availability reduces the potential for income. Generally, financial returns are used to offset operating costs and support continuous improvement goals.

The General Andrews Nursery site is being converted into the base operation for current tree improvement work by the MNDNR. The centralized location and existing infrastructure make this a logical and cost-effective focus for expanded investments in tree improvement operations. Providing the capabilities to support implementation of statewide tree improvement strategies to address invasive species and climate change would require investments in a combination of retrofits to existing facilities for a laboratory and construction of a new greenhouse facility.

- **Options for expanding tree improvement operations at General Andrews Nursery**
  a) Existing nursery beds and fields:
     i. Convert to grafted orchards and seed orchards for a variety of tree species and seed zones.
     ii. Establish test sites to evaluate or improve seedling adaptability, resilience, pest resistance, fiber production, and quality.
     iii. Upgrade existing irrigation system to improve energy and water conservation.

  b) Propagation areas:
     i. Expand available greenhouse space and work area and include improved climate control capability, irrigation and misting systems, and energy efficiency.
     ii. Construct a working laboratory space for seed and pollen testing, grafting, and evaluating pest resistance within new selections.

- **Funding estimates for options for tree improvement expansions**
  a) $100,000 annually in increased base support for tree improvement research and development to the MTIC in the University of Minnesota's Department of Forest Resources.

  b) $800,000 for General Andrews Nursery to support the expansion of statewide tree improvement through facility improvements and acquisition of laboratory, field, and irrigation equipment.

  c) $150,000 annually to support the establishment and operation of grafted orchards and seed production areas. This budget includes program coordinator, seasonal research technician, and seasonal laborer positions.

VII. References

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VIII. Appendix

A. Summary of Funding Needed to Implement Identified Options

One-time Facility and Equipment

$1,500,000	Badoura Nursery—expansion and upgrades of current facility for improving seedling production
$1,500,000	Badoura Nursery—establishment of **new** Native Seed Production Facility
$ 150,000	Badoura Nursery—one-time equipment purchases for current seedling facility
$ 800,000	General Andrews Nursery—Facility improvements and laboratory, field, and irrigation equipment to support tree improvement
$3,950,000	**Total**

Annual Funding

$200,000	For planning, managing and implementing an expanded seed production program when the Native Seed Production Facility is in place
$150,000	For establishing and operating grafted orchards and seed production areas
$100,000	For the Minnesota Tree Improvement Cooperative to do more research
$450,000	**Total**

B. Legislative Direction

***Minnesota Statutes,* section 89.01, subdivision 1. Best methods.** The commissioner shall ascertain and observe the best methods of reforesting cutover and denuded lands, foresting waste lands, minimizing loss or damage of forest resources by fire, forest pests, or shade tree pests, administering forests on forestry principles, encouraging private owners to preserve and grow trees or timber for commercial or other purposes, and conserving the forests around the headwaters of streams and on the watersheds of the state;

***Minnesota Statutes,* section 89.002, subdivision 1. Forest resource management policy.** The commissioner shall manage the forest resources of state forest lands under the authority of the commissioner according to the principles of multiple use and sustained yield. The forest resource management policy shall not supersede any existing duty or authority of the commissioner in managing forest lands, but the duties and authorities, as far as practicable, shall be exercised consistently with this policy. The forest resource management policy is not intended to exclude extractive uses of forest lands under the authority of the commissioner pursuant to state law.

Subdivision 2. Reforestation policy. (a) The commissioner shall maintain all forest lands under authority of the commissioner in appropriate forest cover with species of trees, degree of stocking, rate of growth and stand conditions designed to secure optimum public benefits according to multiple use, sustained yield principles and consistent with applicable forest management plans.

(b) Each year the commissioner shall strive to assure that (1) reforestation occurs annually on an acreage at least equal to the acreage harvested that year on all forest lands under the authority of the commissioner; (2) additional reforestation is accomplished on areas previously harvested but not adequately reforested so that the backlog of reforestation work can be eliminated; and (3) poorly stocked forest land, or forest land damaged by natural causes, shall be returned to a state of productivity.

***Minnesota Statutes,* section 89.35, subdivision 1. Definitions.** The definitions in this subdivision apply to sections 89.35 to 89.39.

(a) "Tree" means any species of tree, woody perennial, shrub, or vine approved by the commissioner for the purposes authorized in sections 89.35 to 89.39, except cultivated varieties that are capable of producing fruit for human consumption.

(b) "Planting stock" or "tree planting stock" means trees native to this state and includes native tree hybrids that have been improved for conservation purposes.

Subdivision 2. Purpose of planting. The purposes for which trees may be produced, procured, distributed, and planted under sections 89.35 to 89.39 shall include auxiliary forests, woodlots, windbreaks, shelterbelts, erosion control, soil conservation, water conservation, provision of permanent food and cover for wild life, environmental education, and afforestation and reforestation on public or private lands of any kind, but shall not include the raising of fruit for human consumption or planting for purely ornamental purposes. It is hereby declared that all such authorized purposes are in furtherance of the public health, safety, and welfare.

***Minnesota Statutes,* section 216H.02, subdivision 1. Greenhouse gas emissions-reduction goal.** It is the goal of the state to reduce statewide greenhouse gas emissions across all sectors producing those emissions to a level at least 15 percent below 2005 levels by 2015,

to a level at least 30 percent below 2005 levels by 2025, and to a level at least 80 percent below 2005 levels by 2050 ...

***Minnesota Statutes,* section 84.0895, subdivision 5. Management.** (a) Notwithstanding any other law, the commissioner may undertake management programs, issue orders, and adopt rules necessary to bring a resident species of wild animal or plant that has been designated as threatened or endangered to a point at which it is no longer threatened or endangered.

(b) Subject to the provisions of subdivision 6, management programs for endangered or threatened species include research, census, law enforcement, habitat acquisition, habitat maintenance, propagation, live trapping, transplantation, and regulated taking.

Recent Legislative Direction

This report provides recommendations on implementing the current legislative direction while also considering all past legislative authorities:

Laws 2013, chapter 114, article 3, section 4, subdivision 4. Forest Management. $50,000 the first year is for development of a plan and recommendations, in consultation with the University of Minnesota, Department of Forest Resources, on utilizing the state forest nurseries to: ensure the long-term availability of ecologically appropriate and genetically diverse native forest seed and seedlings to support state conservation projects and initiatives; protect the genetic fitness and resilience of native forest ecosystems; and support tree improvement research to address evolving pressures such as invasive species and climate change. By December 31, 2013, the commissioner shall submit a report with the plan and recommendations to the chairs and ranking minority members of the senate and house of representatives committees and divisions with jurisdiction over natural resources. The report shall address funding to improve state forest nursery and tree improvement capabilities. The report shall also provide updated recommendations from those contained in the budget and financial plan required under Laws 2011, First Special Session chapter 2, article 4, section 30.

C. Project Team Members

Olin Phillips	Project Manager, Forest Protection and Health Section Manager
Rick E. Klevorn	Silviculture Program Coordinator
Bryan Lueth	Forest Wildlife Habitat Team Supervisor
Michele Martin	Region Ecological Classification System Specialist
Carrie Pike	Minnesota Tree Improvement Cooperative Coordinator
Deb Pitt	Roads and Tree Improvement Programs Coordinator
Robert Pulford	Project Facilitator
Clarence Turner	Forest Planner
Craig VanSickle	Badoura Nursery Supervisor

DATE: February 6, 2014

LEGISLATIVE REPORT – Cost of Preparation

NAME OF LEGISLATIVE REPORT – _Minnesota Department of Natural Resources, Division of Forestry—State Forest Nursery & Tree Improvement Program: 2014 Legislative Report

Based on: _Legislatively Mandated Report

Minnesota Statute Reference: Minnesota Session Laws of 2013, Regular Session; chapter 114 Environment, Natural Resources, and Agriculture Finance and Policy Bill, section 4, subdivision 4. "Forest Management."

Prepared by: _S. Olin Phillips, Division of Forestry, Department of Natural Resources

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Description of Cost	Further explanation if necessary	Amount
Staff Time	660 hours @ $50.00/hr	$33,000
Travel Expenses	Meals and Mileage	$4, 480
Duplication Cost (includes paper)	2500 copies @ $0.05	$125
	TOTAL TO PREPARE REPORT (*Note: Right click on amount cell and choose update to complete*)	$37,605