MINNESOTA FOREST RESOURCES PARTNERSHIP

Forest Health and Productivity Task Group White Paper

Recommendations for Improving Productivity in Minnesota

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Executive Summary

Productivity, as discussed in this paper is defined as improving the quantity and quality of Minnesota's forest resources and the effectiveness of their use. More vigorously growing forests broaden the range of management options on individual ownerships and increases the supply and quality of timber from a forestland acre. Increased productivity also improves forest health by making forests more resilient to insect and disease outbreaks.

Reasonable raw material supply costs are an important factor in maintaining the profitability of forest products industries. The wood using industry is critical to the vitality of Minnesota's economic health and social well being. Most of the wood used in these mills is produced and harvested in Minnesota. Having productive forests in Minnesota is critical in order to continue to meet demands of this vital industry. Higher quantities of fiber can come about through increasing the amount of fiber grown and increasing capture of that fiber through higher utilization rates.

Improving forest productivity provides benefits beyond improved timber supply. Improved growth and reduced mortality can reduce fire danger, advance forest stands so they mimic characteristics of older serial stages sooner, broaden opportunities to change forest structure, make forests more resistant to disease and insect outbreaks and expand opportunities to manage for a wide range of land management objectives. Improved productivity can also occur by cutting mature and over-mature stands and converting them to younger more vigorously growing stands.

The issue of forest productivity has arisen on a number of occasions throughout Minnesota forest policy activities. The most recent efforts include recommendations contained in the Governor's Task Force on the Competitiveness of Minnesota's Primary Forest Products Industry and formation of a working group on forest productivity as part of the Blandin Foundations Vital Forests/Vital Communities initiative.

One of the findings from these efforts is that Minnesota is operating far below its potential in both the quantity and quality of its forest resources. Current productivity of available forestland in Minnesota is .32 cords/acre/year which represents only 30 percent of the potential. Adopting an investment orientation towards Minnesota's forest resources can yield dividends resulting from reduced mortality, increased growth, and improved forest quality.

Fundamental to improving Minnesota's forest productivity is ability to measure progress toward that goal. Metrics can be described as simply monitoring the condition of Minnesota's forests through some form of forest inventory. A forest inventory is a description of a forest using attribute data such as stand cover type, size, and age class. Large forestland management organizations use some form of an on-going forest inventory program to monitor forest conditions and growth on their holdings over time. The USDA Forest Service's Forest Inventory and Analysis program is relied upon to provide monitoring data across ownerships, including non-industrial private ownerships.

While there are a number of ways to assess increases in productivity, such as greater utilization of current harvests or decreases in losses to insects and disease, one of the more comprehensive estimates is average net annual growth of growing stock. Net annual growth of growing stock is change in volume of sound wood in live trees greater than five inches in diameter plus the volume from trees entering that size class minus the volume lost due to mortality.

Numerous policies impact the management of natural resources and efforts to improve productivity. Fiscal policy can have a powerful influence on forest land holdings and forest management activities that can be used to increase productivity. Tax incentives, bonding, and dedicated accounts for forest management are all examples of fiscal policies that can impact activities which can increase productivity. Operational policies guide management activities on the ground and are perhaps the second most powerful tool available in the policy arena to enhance forest land productivity. Education/outreach policies can also impact productivity if designed for that purpose as can general legislative policies concerning transportation or the environment.

Planning determines organizational or individual objectives and how to achieve them within the boundaries established by the policy environment. Planning most often is operational in focus concerned with specific budgets, outputs, and decision frameworks over specific periods of time. Strategic planning outlines central organizational focus and direction while tactical planning determines what steps are necessary to achieve the goals contained within the strategic plan.

Information systems useful in addressing productivity enhancement include forest inventory, geographic information systems, and forest modeling. Data and analysis from these systems serve as an input to planning and illustrate where geographically and temporally investments in productivity will yield the best results.

The timely application of proven and new silvicultural techniques, matching appropriate species to appropriate sites, and prompt attention to regeneration and tending can improve the quantity and quality of forest resources by increasing growth and reducing mortality. Site selection is an important first step in improving productivity. Proper site selection will maximize site/species relationships and identify appropriate sites for intensive management regimes. Timely stand establishment following harvest is one of the key factors in maintaining and improving timber productivity. Delays in regeneration, inadequate competition control and the inability to achieve optimum initial spacing can take sites out of production or lead to higher investments in silvicultural treatments in order to boost the productivity of the resulting stands.

Once initial investment have been made to regenerate a stand, the stand should be monitored periodically and additional investments made to keep competition minimized, maintain optimum stocking to develop trees with good form and small limbs, manage insect and diseases, and capture natural mortality. Density management is accomplished through weeding and thinning of less desirable trees which are crowding and competing with the desirable crop trees.

The application of harvesting practices within the timber management cycle provides several important opportunities relative to achieving full productivity on a site. Timely management and harvest results in production of planned volumes, minimal loss of volume to mortality, and achievement of desired rotation ages. By maximizing utilization of products during harvesting, productivity of the site is most fully realized. The timing of the harvest can affect productivity of future stands. Care must be taken to design and implement projects so as to minimize effects on soils. Improper harvest design can also reduce productivity by increasing the incidence of an insect or disease pest in the regenerated stand.

Utilization is often overlooked as an important area within which to capture productivity. Growing more fiber is one issue, making the best use of quality volumes when they become available for harvest is another. By increasing growth, more fiber will be available in the future. By increasing utilization, more fiber is available now from existing harvests.

Research can also contribute to increasing productivity in Minnesota's forests. On-the-ground demonstrations and physical displays of the practices needed to improve productivity can garner public and legislative support for productivity investments. Genetic improvement research is ongoing on several fronts in Minnesota and an important contributor to productivity enhancement. Equipment advances are another important avenue to research as an avenue to increasing the efficiency of harvesting, reduce site and stand damage from harvesting and improve wood fiber utilization. Finally, there is a wide array of silvicultural practices that may work to increase productivity. Among these are planting genetically improved stock, nutrition, density management, competition control, and intermediate treatments such as thinning. Documenting that these practices really work, and that they can be applied broadly across ownerships, agencies and landscapes will help build support and secure resources needed to implement these practices.

This paper provides a wide range of suggestions for improving forest health and productivity in Minnesota that can be adopted by numerous agencies, industries, and land managers. Those deemed most critical by members of the Minnesota Forest Resources Partnership Productivity Task Group are:

- Establishment of a productivity cooperative.
- Harvest on economic rotations.
- Improve wood fiber utilization.
- Develop detailed productivity guidelines (similar to those contained in the Appendix to the report)
- Fund investments in precommercial treatments.
- Undertake additional deer control measures.

The Minnesota Forest Resources Partnership hopes that individual landowners will act on those suggestions they find most attractive and achievable to benefit Minnesota's forest resources.

Introduction

i. Making the Case

Why invest in increasing forest productivity in Minnesota? Because it makes good sense economically and environmentally. More vigorously growing forests broadens the range of management options on individual ownerships and increases the supply and quality of timber from a forestland acre. Increased productivity also improves forest health.

The wood using industry is critical to the vitality of Minnesota's economic health and social well being. It is the fourth largest manufacturing industry in Minnesota based on employment and generates 11 percent of the total dollar value of all manufacturing shipments. It employs in excess of 55,000 employees and accounts for $1.9 billion in wages paid. Value added worth of the wood using industry in Minnesota is $4.7 billion which is capital that stays within Minnesota.

The industry includes 5 pulp and paper mills and 1 paper mill with no pulping facility; 3 recycled pulp and paper mills; 3 hardboard and specialty mills; 6 oriented-strand/structural board mills; 500+ sawmills; and 150 associated industries. There are also over 850 secondary manufacturers.

Most of the wood used in these mills is produced and harvested in Minnesota. In 2001, 2.7 million cords of pulpwood and 288 million board feet of lumber were harvested in Minnesota. In order to continue to meet demands of this vital industry, having productive forests in Minnesota is critical. Productive forests not only can produce the necessary raw materials to keep the mills operating, but also can significantly contribute to flora and fauna biodiversity important in meeting the recreational and spiritual needs of Minnesota's citizens.

Improved productivity is key to social and economic advancement and has also been proven key to environmental protection efforts. Prosperous communities and societies can afford to spend resources on outdoor recreational pursuits, environmental amenities, and infrastructure/ programs that protect environmental quality. Improved productivity is also key to supplying societies ever increasing demand for wood products.

a. History

The issue of forest productivity has arisen on a number of occasions throughout Minnesota forest policy activities and discussions. The first serious consideration of the issue in Minnesota occurred over 30 years ago during debate concerning federal designation of the Boundary Waters Canoe Area as a wilderness area. Loss of softwood timber supply from one million acres of productive forest land by such a designation was a prominent concern to the state's forest products industries.

It was recognized that investments in establishment and tending of softwood resources outside the BWCA could address this concern if such investments improved the extent and productivity of treated sites and stands. As part of the legislation that created the BWCA, "95-495 funds" were designated by Congress and the State Legislature to undertake such investments.

Forest productivity became a prominent issue once again in the early 1990's during completion of the Generic Environmental Impact Statement on Timber Harvesting in Minnesota (GEIS). The main issue was whether increased timber harvests to meet current and projected timber demands could be achieved without negatively impacting other forest resources. The GEIS included over 20 recommended strategies to mitigate the potential impacts from the increased level of timber harvesting to ensure sustainability of all forest resources. Most of the strategies have been implemented to some degree through passage of the Sustainable Forest Resources Act (SFRA). One strategy not adequately addressed by the SFRA was improving forest productivity.

Prompted by the sale and closure of several forest products companies, Governor Pawlenty formed a Task Force on the Competitiveness of Minnesota's Primary Forest Products Industry in 2003. Ten factors were identified as sources of competitive disadvantage to primary forest products industries in Minnesota. One of those factors was forestland productivity. The study found that Minnesota was achieving only 30 percent of potential productivity compared to 50 percent in states such as Alabama, Georgia, Oregon and Washington.

As the Governor's Task Force was completing its charge, the Blandin Foundation began an initiative aimed at undertaking projects to strengthen forest products industries and the rural communities dependant on them. Forest productivity is one factor being examined under this initiative.

These efforts have often not yielded the type of advancements and investments needed to make significant progress on improved forest productivity statewide. The MFRP offers the suggestions which follow to get on with the job of truly realizing Minnesota's potential in the growth and management of the state's forest resources.

b. Current Level of Productivity

Minnesota is operating far below its potential in both the quantity and quality of its forest resources.
The report from the Governor's Task Force indicates that current productivity of available forestland in Minnesota is .32 cords/acre/year which represents only 30 percent of the potential. This was the second lowest rate of growth in the nine state and five country comparison that was made. In terms of achieving productive potential, Minnesota tied with Wisconsin and Canada in being dead last. Sweden, in contrast, with a climate similar to Minnesota's, has current productivity of .73 cords/acre/year and is achieving 70 percent of its forests productive potential.

c. Investment Orientation to Productivity Improvement

What explains the differences in these growth rates and the ability to capture a high percentage of forest growth potential? In the case of states or countries with similar climates and soils, the answer is investment and its timely application. Forests have not been viewed in the past as capital assets – that orientation has to change. Just as a garden has to be weeded and tended to produce the best quality and quantity of produce, so to does the forest.

It is widely recognized that a business invests in equipment to increase the productivity of its workforce. States invest in schools to capture the productive potential of their youth. Investments are made in sewage treatment plants to maintain the productive potential of water bodies for recreation, wildlife, and drinking water. Investing in Minnesota's forest resources can also yield dividends resulting from reduced mortality, increased growth, and improved forest quality. Such investments will provide a return directly to the investor and the state as a whole.

ii. Measuring Productivity

Fundamental to improving Minnesota's forest productivity is ability to measure progress toward that goal. Metrics can be described as simply monitoring the condition of Minnesota's forests through some form of forest inventory.

Monitoring forest conditions serves a number of useful purposes. One of the most crucial is being able to assess forest health conditions in order to develop strategies and programs to address serious losses from insects and diseases. Monitoring and assessment is also important in making investment decisions both on-the-ground and in forest products industry facilities. Forest industries, in particular, use forest inventory information as one of the key elements in making investment decisions and developing their respective wood procurement strategies.

a. Forest Inventory Systems

Large forestland management organizations use some form of an on-going forest inventory program to monitor forest conditions and growth on their holdings over time. A forest inventory is a description of a forest using attribute data such as stand cover type, size, and age class. Data is collected using some form of remote sensing (e.g. aerial photography, satellite imagery) and on-site visits. Some forest industries periodically re-measure permanent plots established on their lands in on-going continuous forest inventories that generate information on past and current growth and mortality. The Minnesota Department of Natural Resources' Division of Forestry (DOF) uses a cooperative stand assessment program that delineates and classifies every forest stand on state timberlands by forest type and stocking.

In the case of smaller ownerships, particularly Minnesota's 147,000 non-industrial private forest land owners, it is often not efficient or economically feasible to utilize similar inventory programs. Consequently, monitoring conditions on these ownerships can be challenging. One inventory program that can provide information on these private ownerships as well as other major landowner categories is the USDA Forest Service's Forest Inventory and Analysis (FIA) program. FIA collects data on permanent plots located across the state and provides statistically reliable estimates on numerous measures of forest conditions for various geographic aggregations. FIA inventory is widely recognized as the most reliable database of information across multiple ownerships.

The first FIA inventory in Minnesota was completed in 1936. Subsequent inventories were conducted every 10 to 15 years. In 1999, FIA adopted annual inventory procedures in which one-fifth of the permanent plots are measured every year. Within two years the results from the annual inventory should be available and average net annual growth of growing stock estimates should be sufficient then and in future years to assess changes in productivity on a fairly frequent basis across all ownerships.

One weakness in the FIA database is its treatment and measurement of young growth. Within the inventory, stands consisting of trees smaller than five inches in diameter (seedling and saplings) are not included in estimates of volume and growth. To address this lack of information, the Minnesota Department of Forestry has developed a procedure that could supplement FIA data using Landsat digital earth satellite imagery to provide maps of forest stands younger than 17 years of age and five acres or more in size. The northeastern third of Minnesota would be targeted for initial work under this proposal.

b. Measurement Options

While there are a number of ways to assess increases in productivity such as greater utilization of current harvests or decreases in losses to insects and disease, one of the more comprehensive estimates is average net annual growth of growing stock. Net annual growth of growing stock is change in volume of sound wood in live trees greater than 5 inches in diameter plus the volume from trees entering that size class minus the volume lost due to mortality. This statistic can serve as a key indicator for measuring change in timber productivity on NIPF lands as well as on other ownerships either at a regional or statewide scale.

While measuring timber productivity by major forestland ownership category can be addressed through FIA, measuring the effectiveness or performance of individual ownerships towards contributing to that goal remains a challenge, particularly on NIPF lands. Industrial and public forestland owners have a number of opportunities to assess their performance through internal accomplishment reporting systems.

Individual NIPF landowners can implement a number of forest management practices to improve productivity, but, assessing the degree to which NIPF landowners are implementing those practices is problematic since little data is currently collected in this area. However, a number of surveys from 1992 to 2000 conducted by the University of Minnesota's College of Natural Resources found that landowners with a written forest stewardship management plan conducted more management activities than those landowners that did not have a written management plan. The Division of Forestry maintains lists of landowners that voluntarily register their forest stewardship plans. As of 2002, there are over 10,000 landowners owning 1,000,000 acres that have received forest stewardship plans from private and public forester. Thus, the number of registered forest stewardship plans can be used as a surrogate performance measure to assess the degree to which NIPF landowners are contributing towards the goal of improving timber productivity. To encourage NIFP owners to participate in improving productivity on their lands, the first step is for them to obtain a written forest stewardship plan. In recent years, funding to assist NIPF landowners and write stewardship plan for their acreage by private and public foresters has been reduced while demand for this assistance has increased. This situation needs to be addressed if the productivity potential of NIPF ownerships is to be realized.

<u>Recommendations</u>

- Use net annual growth per acre as the basis for measuring increases in timber productivity on all ownerships.
- Fund a project to map young stands using Landsat digital earth satellite imagery to supplement FIA data that is currently weak in the measurement of young growth.
- Increase support for the forest stewardship program to assist NIPF owners in obtaining and implementing stewardship plans.

Productivity Initiatives On The Ground

I. Policy

Policy environments establish overall direction for organizations and citizens in carrying out programs and activities. Policies are generally prescriptive (defining what is and is not acceptable) and directive (defining what should be done, and often how) to encourage acceptable behavior/results and prevent unacceptable behavior/results. Consequently, policy most often creates boundaries within which specific actions and activities are established and carried out. Politicians and senior management advance and enact policy.

Numerous policies impact the management of natural resources and efforts to improve productivity. Government cost share programs can encourage certain practices on private land. Development of cooperative agreements between organizations can pool resources to pursue high priority projects related to increasing productivity. Prioritization of government land management policies and funding which favor productivity enhancing management activities can also have important effects.

A. Fiscal Policy

Fiscal policy can have a powerful influence on forest land holdings and forest management activities that can be used to increase productivity. Fiscal policy includes cost share and tax programs aimed at eliciting certain behaviors and management activities by private landowners and funding levels for public organizations and industrial landowner's management activities. The form of the funding and terms for its use are just as important as the funding level

Recommendations

- Improve tax incentives for forestland ownership and forestland investments to improve productivity.
- Seek funding for and then promote pre-commercial thinning of conifer plantations.
- Seek cost sharing for replanting of abandoned brushlands in forested areas.
- Seek funding for silviculture research.
- Seek legislation to set up a dedicated account from state timber sale receipts for reforestation on state lands.
- Seek cost sharing to offset the cost of adequate site preparation on private lands.
- Use bonding to fund pre-commercial practices that will provide the greatest productivity returns.

B. Education/Outreach Policies

Education programs have as their basis certain objectives. These objectives are defined by educational policies. Environmental groups have been particularly effective in promoting anti-productivity messages in an attempt to decrease management activities which enhance productivity. Education and outreach to counter these messages are needed to increase public support for the management needed to increase productivity.

Recommendations

- Create a technology transfer mechanism to work on:
  1) Portraying Minnesota's forests as capital assets requiring timely investment to maximize a variety of returns.
  2) Using as a central message that more productive forests allow for greater flexibility in producing needed wood fiber and other non-timber products.

C. Operational Policy

Operational policies guide management activities on the ground. Such policies are most fully developed in public agencies and industries. Operational policies are perhaps the second most powerful tool available in the policy arena to enhance forest land productivity.

Recommendations

- Develop a cooperative that is tasked with finding the most effective and beneficial avenues to improve Minnesota's forest productivity.
- Establish timber management zones dedicated to intensive management for maximum timber production.
- Increase assistance and incentives to NIPF owners.
- Convert abandoned farmlands to plantations in forested areas.

D. General Legislative Policy

General legislative policy includes such things as transportation policy which impacts the ability to transport logs during break-up, environmental policy which impacts where and how timber can be harvested, and pollution control policy which impacts costs of forestry related businesses. Such policies have an indirect impact on forestland productivity primarily by increasing costs on forest-based businesses.

Recommendations

- Seek legislation to address zoning and tax policies that encourage landowners not to subdivide and sell forestland for other land uses.
- Maintain strong markets for timber since a significant amount of forest management is accomplished through timber harvesting.
- Support the Governor's initiative on enhancing productivity.
- Explore the direct and indirect effects of various zoning policies on forest productivity and forest management activities.

II. Planning

Planning determines organizational or individual objectives and how to achieve them within the boundaries established by the policy environment. Planning most often is operational in focus concerned with specific budgets, outputs, and decision frameworks over specific periods of time. Middle management and individuals conduct planning which is intended to provide direction to individuals in specific work projects/activities to achieve plan objectives and outputs.

A. Strategic

Given the fact that improvement in productivity on Minnesota's forestlands involves long-term investments, strategic planning, which includes consideration of productivity improvement, is crucial.

Strategic planning takes place at the highest levels of organizational structures. Strategic planning outlines central organization focus and direction. Within private companies, strategic planning involves determining which market segments to compete within, organizational structure, analysis of competitors, procurement strategies, etc. Within public natural resource agencies, strategic planning outlines budget and program priorities, land allocation for various uses, etc. For individuals, strategic planning related to natural resources involves such things as which species to plant for maximizing growth and long-term financial return, assessing the long-term costs and benefits of enrollment in various managed forest tax programs, etc.

B. Tactical

Once central direction and focus is set by strategic plans, tactical planning determines what steps are necessary to achieve the goals contained within the strategic plan. For example, if a strategic plan objective is to increase the growth rate and productivity of northern hardwood stands by 20 percent over five years, a tactical plan would identify how that might be done such as by accelerated thinning, fertilization, conversion, etc. Tactical plans are the operational guidelines used to implement practices to achieve strategic plan goals.

Recommendations

- Plant mixed conifer stands or interspersed blocks of pure conifer species to minimize insect losses.
- Increase harvest of the "backlog" stands. If backlog is due to low volume and value, subsidize harvest costs.
- Encourage a variety in harvest block sizes to mimic natural disturbances and create less edge.
- Plan more intensive cultural practices on the most productive acres.
- Each agency should develop long term plans and tactical plans related to forest productivity
- Conduct landscape planning/collaboration as it pertains to pest management and fire.
- Adjacent NIPF landowners should collaborate in offering stumpage and carrying out other forest management activities on their respective lands to make them economically feasible.

III. Information Systems

Forest Information Systems provide a basis for evaluation of the forest's present condition as well as an opportunity for resource planning (forest modeling). Most importantly, a good forest information system allows for checking stand performance with expectations when implementing productivity treatments. Good forest information systems consist of a forest inventory, a Geographic Information System, and forest modeling tools.

A. Forest Inventory

As stated earlier, a forest inventory is a description of a forest using attribute data such as stand cover type, size, and age class. Data is collected using some form of remote sensing (e.g. aerial photographs or satellite imagery) and on-site visits. To be useful for complex forest modeling and provide answers to numerous questions on forest conditions that bear on productivity, a good inventory system should provide information that is current and easy to update. It should provide information that can be used with a degree of accuracy appropriate to the scale of detail necessary to answer queries of its database.

B. Geographic Information Systems

Geographic Information Systems (GIS) add powerful spatial and analytic components to forest inventory data. GIS software solutions provide foresters and natural resource managers with powerful tools for better analysis and decision making. GIS provides the resource manager with the "big picture" about the forest resource they are managing.

Recommendations

- Maintain a GIS for forests being managed using good ground control points.
- Keep spatial information up-to-date.

C. Forest Modeling

Forest modeling is a way to predict the effects of silvicultural treatments over long periods of time. It is also a means to calculate sustainable harvest levels and optimize desired outcomes from management prescriptions. The ability to model the forest is very important when testing various silvicultural treatments aimed at increasing productivity. Modeling is used as a guide to what is theoretically possible and to establish parameters within which to make operational decisions. It is only as good as the assumptions and input data used. A major benefit of forest modeling is that it provides the opportunity to explain forest productivity investments to decision-makers - moving from the realm of anecdotal testimonials to analytical, tangible facts that will allow for confident investments.

Recommendations

- Use inventory data, GIS data and yield curves as input into the modeling system.
- Know the desired silvicultural treatments.
- Define constraints and desired outcomes.

IV. Silviculture

A silvicultural system is a planned series of treatments for harvesting, regenerating, and tending a forest stand. A silvicultural system is made up of silvicultural prescriptions which are treatments designed to regenerate the current stand composition and structure or change stand composition or structure to meet management goals in light of ecological, economic and societal constraints. Timely application of various prescriptions can greatly enhance productivity by maximizing site/species relationships, improving growth on the best trees, reducing the impact of insects and diseases, and capturing mortality.

Silviculture activities which can affect productivity are organized by the topics: A. Site Selection, B. Stand Establishment, and C. Stand Maintenance. Discussions describing each of these activities follow. With each discussion is a summary of action items that can affect productivity. The appendix contains more specific productivity suggestions organized by covertypes.

A. Site Selection

Site selection is an important element to improving forest productivity. There are two components of site selection that are important to improving forest productivity: (1) maximizing site/species relationships and (2) selecting appropriate sites for intensive management regimes. The forests of Minnesota are diverse in their productive capability. Soil structure, nutrient capacities, moisture regimes, climate, and topography affect productivity. Using ecological classification tools that factor in site capabilities are critical at both the landscape and site levels when making silvicultural decisions in site-species relationships and in selecting areas for intensive management regimes. Regardless of whether or not areas designated for intensive management can be developed, matching tree species to suitable sites provides the best possible opportunities for productivity gains and can reduce monetary investments required for critical stand treatments to meet management objectives.

Recommendations

- Identify acres for intensive management.
- Identify sites for conversion which will improve site/species relationships and contribute to desired future conditions.
- Improve site/species relationships on private lands by working with the Minnesota Forestry Association to identify landowners willing to intensify management on their lands.
- Use site classification systems to identify the best site/species relationships.

B. Stand Establishment

Stand establishment or regeneration is the reestablishment of harvested timber stands either to preexisting species competition or to a different species composition to meet management objectives. Regenerating a harvested stand in a timely manner is one of the key factors in maintaining and improving timber productivity. Delays in regeneration can take sites out of production or lead to higher investments in silvicultural treatments in order to regenerate the stands to meet management objectives. Adequate regeneration of the desired species will help in the sustainability of the forest type.

Regeneration of a stand can be accomplished through natural or artificial means. Relying on natural regeneration will reduce the investments made early in the life of a stand which can lead to a greater profit when products are harvested from the stand. However, natural regeneration may not always be the best choice for increasing productivity because relying on natural regeneration (1) can lengthen the time to fully regenerate the stand; (2) not reflect optimal species/site relationship and (3) the resultant species composition may not meet management objectives at both site and landscape levels.

Natural regeneration can also lead to lower productivity by regenerating trees genetically predisposed to disease organisms. The incidence and severity of Hypoxylon canker and white trunk rot can be increased by regenerating genetically susceptible clones to these diseases.

Artificial regeneration, i.e. planting or seeding, may require significant investments which are carried over the length of the rotation and negatively affects profitability at the time of harvest. However, the initial costs can be off set by the sites regenerating more quickly than relying on natural regeneration. Also, early investments will often pay dividends in the future by producing harvestable crops of trees which maximize fiber production.

Artificial regeneration has the advantage of being able to control planting stock quality. Planting stock from known genetic parent material and stock of sufficient root collar caliper to better insure initial survival can increase productivity and decrease investments. Artificial regeneration can also take advantage of site characteristics and capabilities so regeneration costs are reduced and better quality products can be produced at an earlier age.

Artificial regeneration can create conditions that increase the potential for damage and mortality from insect and disease organisms if managers lack the training to recognize and avoid certain practices in specific situations. An example is regenerating red pine under an overstory of red pine. Disease such as shoot blights can buildup on the older overstory trees and infect the understory trees causing significant mortality.

Optimal spacing of regenerating stands is a critical factor in increasing productivity and reducing additional management investments that can affect the quality and form of developing trees. Optimum spacing will give trees room to grow, allow trees to grow faster so that crop trees more quickly occupy the site shading out competing vegetation, and reduce the need for intermediate stand treatments later on. (Note: attempts to ensure optimal initial spacing through planting have often met with failure due to wildlife depredation and competition. As an example from the past, planting oak at the recommended spacing often resulted in poor survival of the trees and poorly formed trees that often needed corrective pruning. Direct seeding of desirable hardwoods has shown to be very effective by establishing dense stands of the trees that eliminate the need to control competition of the annual weeds, minimize deer depredation through the sheer numbers of regenerating trees, and result in trees of good form that have trained by competing with each other. Once tree height above deer browsing has been achieved (usually in three years), the stand can be pre-commercially thinned to achieve optimum spacing without the need to do any corrective pruning of large limbs. The point is that there are other options to achieve optimum spacing then just depending on spacing at spacing densities at initial planting.)

Newly regenerated stands, less than ten years of age, are vulnerable to catastrophic losses from animal damage, insects and diseases, and weather. Timely monitoring can help reduce these losses. If mortality occurs, it is nearly impossible to maintain a productive stand without investing in more artificial regeneration.

Recommendations

- Regenerate harvested stands as quickly as possible after the harvest is completed.
- Use initial spacing to minimize the need for precommercial stand treatments.
- Use planting stock produced from seed collected locally or from trees that exhibit the qualities sought after, i.e. straightness, fast growth, less limbs, disease resistance, etc.
- Establish seed orchards with known genetically suitable parent lines.
- Select harvesting practices to support regeneration methods prescribed for the site.
- Conduct periodic site inspections to ensure adequate levels of regeneration and address mortality issues.
- Regenerate sites to a fully stocked condition.
- Schedule harvesting, where desirable, to accommodate good seed years.
- Avoid planting red pine under an existing overstory of red pine.
- Convert aspen stands with a 25% or greater incidence of Hypoxylon canker.
- Work with deer hunting interests to reduce deer herd numbers below at least 15 per square mile.

C. Competition Control

Competition control may be necessary both before the site is regenerated (site prep) and after regeneration when trees are becoming established (release). Woody, herbaceous, and grass competition with planted or seeded crop trees can reduce growth rate, affect tree form and quality, create conditions for disease build up by increasing the moisture around the crop trees, and kill the crop trees by over growth reducing the available sunlight and moisture in the soil. Site preparation practices reduce both the above ground and below ground vegetation competition and provide a better chance of tree survival. Release reduces both woody and herbaceous vegetation that is overtopping the planted or seeded trees or competing for moisture with the young trees.

Both site prep and release increase survival chances and allow the tees to attain a "free-to-grow" condition at an earlier age. In some situations, both site prep and release will be required to ensure regeneration survival. Often, however, adequate site prep can reduce the need for release. There are more options with site prep techniques since site prep occurs before planting or seeding. Both site prep and release can be accomplished by mechanical or chemical means or a combination of the two.

Recommendations

- Use site preparation techniques which will help reduce establishment time.
- Control both woody and herbaceous competition in newly planted/seeded areas.

D. Fertilization

Fertilization or appropriate soil amendments may produce better growth rates of merchantable products in less time or produce more volume during the normal rotation for the particular species. However, any potential gains need to be balanced against any possible side effects such as altered stem properties and increase insect and disease occurrence.

Recommendations

- Consider fertilization or appropriate soil amendments on those soil types or land forms where soil limitations have been identified.

E. Density Management

Once initial investments are made in the stand during regeneration, the stand should be monitored periodically and additional investments made to keep competition minimized, maintain optimum stocking to develop trees with good form and small limbs, manage insect and diseases, and capture natural mortality. Density management is accomplished through weeding and thinning. Weeding is removing undesirable tree species which are crowding and competing with the desirable crop trees or are providing food and habitat niches for insect and disease organisms that can cause damage to crop trees. Gypsy moth is an example of an insect where damage is often associated to the species mix of the stand.

Thinning reduces un-desirable species or trees so that the stand does not stagnate and optimum growth can be maintained. Crowded stands create stress on all the trees increasing their vulnerability to insects and diseases such as bark beetles and root rot fungi. Removal of poorly formed trees and trees with conks and cankers can also occur during thinning. Thinning can maintain optimum spacing so trees develop better form and fewer limbs.

There is a risk when carrying out thinning and weeding activities. Repeated entry into stands increases the opportunities to compact the soil and wound residual crop trees. Compaction reduces productivity by slowing down growth and, in the worst case, causing tree mortality. Wounding, both on the bole and to the root system, causes entry points for decay organisms and leads to stain which can reduce the quality and value of the final product.

Weeding and thinning enhance productivity by maintaining optimal growth, reducing conditions that favor insect and disease pests, promoting better quality trees, and capturing mortality that would occur from natural thinning. If weeding and thinning can be carried out when merchantable products can be produced from the stand, then costs associated with these intermediate practices can be off set.

Recommendations

- Plan on periodic thinnings and weedings to maintain optimum density.
- Thin aspen to capture mortality.

- Invest in precommercial thinning to prevent stand stagnation.
- Avoid soil compaction by using light-on-the-land logging equipment or confining operations when soil conditions are not conducive to compaction.
- Thin pine stands when the risk of bark beetle infestations is low.
- Thin oak stands to help them better withstand gypsy moth infestations.
- Confine wounding to <5% of the residual trees by choosing logging equipment that has been designed to operate with residuals, avoiding times of the year such as spring when bark is vulnerable to damage, and developing incentives so that the operator is rewarded for not wounding trees.
- Remove trees with conks and cankers when thinning hardwood stands.
- Thin oak stump sprouts at an early age to promote larger crowns and more vigorous trees.

V. Harvesting

The application of harvesting practices within the timber management cycle provides several important opportunities relative to achieving full productivity on a site. Timely management and harvest results in production of planned volumes, minimal loss of volume to mortality, and achievement of desired rotation ages. By maximizing utilization of products during harvesting, productivity of the site is most fully realized. Harvesting operations also provide the opportunity to facilitate timely and adequate regeneration of the following stand.

A. Rotation Length

Rotation lengths of managed timber types, and the corresponding volume yields, are known and expressed in common yield tables. Establishing rotation lengths with expected yields for each prescription undertaken will provide the basis for determining the expected volumes from the planned harvests.

Use rotation length to manage potential insect and disease problems. Decay increases with age of tree. Stands with signs of significant decay should be rotated at an earlier age. Species such as jack pine and balsam fir tend to be damaged greater from budworm when carried at a longer rotation. Consider reducing rotations in areas with historic budworm outbreaks.

Recommendations

- Optimize rotation lengths by timber type and, using these, determine the corresponding harvest levels and intermediate tending schedules.
- Use culmination of mean annual increment to set rotation ages.
- Use pathological rotations for stands that are declining.
- Use a rotation age of 35 to 40 years if more than 15% of the aspen stems have white trunk rot (*Phellinus tremulae)* conks.
- Reduce rotation to 40 to 45 years for balsam fir and jack pine in areas of historic budworm outbreaks.

B. Timing and Harvest Design

Timing of the harvest can affect productivity in future stands. Basic soil productivity can be affected by silicultural treatments. Care must be taken to design and implement projects so as to minimize effects on all sites. Soil compaction can reduce water infiltration and movement through the soil profile as well as make soil layers impenetrable to roots. These will reduce the productive capacity of the soils. Producing slash and piles of logs during the time when bark beetles are looking for brood wood can contribute to population buildups and cause mortality to residual trees.

Harvest design also can contribute to productivity losses. Harvesting activity on the site can help reduce the incidence of an insect or disease pest in the regeneration stand. Dwarf mistletoe in black spruce is an example of a disease where its impact can be reduced through sale design since the harvesting activity can reduce dwarf mistletoe inoculum.

Recommendations

- Establish landings in mistletoe black spruce pockets.
- Winter harvest aspen stands if stands have 15 – 25% incidence of Hypoxylon canker.
- Design timber sales so that boundaries include all mistletoe pockets.
- Avoid partial harvesting of red pine stands between March 1 and September 1.

C. Site Impacts

Basic soil productivity can be affected by silvicultural treatments. Care must be taken to design and implement projects so as to minimize effects on all sites. Soil compaction can reduce water infiltration and movement through the soil profile as well as make soil layers impenetrable to roots. These will reduce the productive capacity of the soils.

Recommendations

- Eliminate livestock from forest stands.
- Utilize winter harvesting where feasible to encourage maximum sprouting.
- Promote light-on-the-land harvesting techniques. Design harvests so as to maximize the efficiencies of this system.
- Avoid harvesting in wet periods to reduce compaction and rutting.
- Harvest when compaction and disturbance of soil can be kept to a minimum.

VI. Utilization

Utilization is often overlooked as an important area within which to capture productivity. Growing more fiber is one issue, making the best use of quality volumes when they become available for harvest is another. By increasing growth, more fiber will be available in the future. By increasing utilization more fiber is available now from existing harvests. The excerpts and suggestions below are primarily developed from a study conducted by Reino Pulkki, R.P.F. (Lakehead University) on the role of supply chain management in sustainable forestry. Actual ability to capture productivity in the woods by increasing utilization varies from site to site depending on species, equipment mix, harvest prescriptions, etc. Ability to capture productivity within manufacturing enterprises also varies and is dependent on equipment, product being produced, etc. The following suggestions should be used as guides to improving productivity by increasing the percentage of the standing volume of timber that is actually utilized in the manufacture of forest products.

Recommendations

In the woods, any increase in utilization lowers fixed costs per unit.

- Lower stump heights to prevent potential losses of 2.1 percent.
- Reduce the 5.2 percent of wood typically left behind in processing at the landing.
- Consider developing sanctions for producers underutilizing sold timber.
- Utilize fiber saving equipment components and operate equipment efficiently to reduce potential losses from sawhead kerf (.8%), roadside delimber slash (12.6%), slasher ends (1.5%) and slasher kerf (.4%).
- Change utilization standards – utilization of 3 inch top diameter material adds 7.5 cords per acre of recoverable fiber to a 32 year old aspen stand.
- Carefully choose wood designated as leave trees to ensure adequate but not excessive retention to meet wildlife goals.
- Segment and sort products into the highest value markets and increase all species utilization.
- Choose the right harvesting system depending on the circumstances.

In manufacturing, losses of fiber can be very costly since money has already been invested in material brought into the yard.

- Lower utilization standards – the price paid for raw material may be lower for smaller material and increased supply lowers dependence on incremental costs of replacement wood.
- Effectively handle and store roundwood to reduce typical losses of 3 percent of the original harvest volume.
- Efficiently debark and chip. These operations have very high potential for wood waste. Losses in drum debarking are typically 4 percent.
- Minimize wood residue to reduce discharge costs of fiber not able to be recovered for manufacturing.

VII. Research

A. Demonstration/documentation

To garner public and legislative support for productivity investments, it is helpful to create actual on-the-ground physical displays of the practices needed. There is nothing more convincing than seeing the real thing in the field. Foresters themselves become more enthusiastic when they can see a dramatic, successful demonstration of a forestry principle. Side-by-side comparisons of managed vs. unmanaged tracts are quite effective. Cooperation among interested parties and pooling resources are very effective in creating a few very good demonstrations. The Bear River Demonstration Forest (BRDF) and SAF driving tour concepts are two examples of field demonstration sites. Some companies have their own driving tours or sites existing or in the planning stages. Documentation of improvements through application of various silvicultural techniques is needed.

B. Genetic Improvement

Genetic improvement research is ongoing on several fronts in Minnesota. Improvement of aspen, larch, white pine, red pine, white spruce and black spruce is being done by the UM Department of Forest Resources through the Aspen/Larch Cooperative and the Minnesota Tree Improvement Cooperative. Genetic improvement of native cottonwood and hybrid poplar is being done by the UM Natural Resources Research Institute under the Minnesota Hybrid Poplar Research Cooperative program. Improvements in yield from 5 percent to 50 percent are expected through these programs depending on species and method of plant propagation (e.g. clonal versus seed). These programs are using the same general approach to tree improvement by refining the genetics of the trees species through selective breeding and verifying improvements through field studies. None of these projects are involved in gene transformation. Planting programs vary in size and intensity, but most agencies and companies do some planting. To the extent they choose to care for the plantations, the genetic gains are real and cost-effective. Compared to unimproved trees, genetically improved trees can exhibit higher growth rates and improved form, disease resistance, and in some cases, wood pulping qualities. With an estimated 15-20 million trees planted annually in Minnesota, the potential impact of gains in genetics is enormous.

C. Equipment

Equipment companies around the world are continually competing for customers, and need to understand the needs of loggers and wood consuming mills. Forest engineering and equipment design research is needed to increase machine efficiency and harvesting productivity, which will in turn contribute to profitability for landowners, loggers and wood consuming mills. Harvesting equipment has the potential to influence the application of intermediate stand treatments such as thinning as well as options for final harvest.

Commercial thinning is one silvicultural tool that can help create greater diversity in the Minnesota forested landscape, while supplying a portion of the nation's wood supply. Until recently, however, most commercial forest thinning was accomplished by expensive manual methods or not at all. The advent of boom-mounted cutting heads capable of reaching into forest stands and extracting cut trees without damage to residual timber has created a new interest in performing appropriate thinning on many forest types. It is important that the best possible equipment be used for economic reasons, as well as to maintain forest and tree health after the harvest thinning.

In addition to thinning, options to efficiently harvest smaller-diameter stands or increase recovery of usable fiber on the site are directly affected by harvest equipment. There is a need to work with equipment manufacturers to test available equipment and in some case, prototype equipment, to evaluate the practical and economic feasibility of these options. Demonstrations of thinning and harvesting equipment should be done in a variety of stand types and ages. These demonstrations should be done in conjunction with research groups to ensure that time-studies and before-and-after stand data are adequately collected. This will ensure that results can be transferred to all potential users and application of equipment to a range of stand conditions can be evaluated.

D. Silvicultural Practices

There is a wide array of practices that may work to increase productivity. Among these are planting genetically improved stock, nutrition, density management, competition control and intermediate treatments such as thinning. Documenting that these practices ***really work,*** and that they can be applied broadly across ownerships, agencies, and landscapes will help build support and secure resources needed to implement these practices. Moreover, the economic efficiency must be demonstrable. Responsible business managers will want to know the estimated rate of return on invested dollars. Easily accessible tools for evaluating forest investments are available from various sources, but often not used by forest managers or field staff to justify expenditures.

In addition to genetic improvement research mentioned above, there are several public agencies and companies engaged in productivity-oriented silviculture research ranging from studies of intensive management of red pine and hybrid poplar plantations to practices such as commercial thinning of aspen. In addition, there is research underway that is targeted towards silviculture that affects other aspects of the forest such as biological diversity and species mix. A review of management tools is needed with the intent of identifying those programs that are geared towards techniques that will result in additional growth and economic returns to land management agencies and individual landowners. This review should be done with regard to the current primary industrial wood-users in the state and the needs of this industry in the future. For example, understanding the expected impact of the aspen age-class imbalance to the aspen-using mills should be better understood. Also, opportunities and incentives to manage plantations for both pulp and sawtimber products should be identified and encouraged.

A forum to enhance the exchange of results of research already completed or currently underway should be encouraged. Foresters trained in the 1970s and 80s are most familiar with hard-copy guides such as the USFS silvicultural booklets based on 1940-1970 era research. Human nature tends to gravitate toward what is easy and what is organized and practitioners will welcome a concise aggregation of information put into a useable format. Cooperative efforts are needed to develop new silviculture guides. Web-based computer technology should be employed to create user-friendly and accessible information at several interest levels—the "drill down" model. Key players may include US Forest Service Research Work Units—see website at (http://www.ncrs.fs.fed.us/4101/), University silviculture instructors and researchers, Extension Specialists, State and County Natural Resources practitioners interested in education efforts, corporate sponsorship and participants, MN Forest Resources Council Research Advisory Committee, MN Forest Resources Partnership Productivity task group. Presuming field foresters are the primary target audience, a combination of desk-top computer, hand-held computer, and pocket guides should be developed and kept current with periodic updating. Leadership is required for this to happen. Government funding is scarce, but may be the most likely avenue toward meeting this target.

Also tools to evaluate economic returns of forestry investments are needed. The Michigan Forest Development Fund technical document methodology, or Texas Timberland Decision Support System (http://tfsfrd.tamu.edu/tdss/default.htm) are useful examples. Tools such as these should be promoted and used within forestry organizations to determine financial returns before committing to large forestry investments.

Recommendations

- Establish pilot or demonstration sites for undertaking and evaluating productivity investments.
- Document productivity enhancements from the use of various silvicultural practices.
- Maintain a strong genetic improvement program through selective breeding and seed nurseries.
- Maintain involvement in the Minnesota Tree Improvement Cooperative to support tree improvement efforts and the development of seed orchards, seed collections, and the sharing of seed resources.

- Work with equipment manufacturers and research organizations to identify equipment that is most efficient for a variety of possible applications.
- Use economic analysis tools such as the Michigan Forest Development Fund technical document methodology to develop rates of return of various practices for Minnesota.
- Consolidate existing information on I&D, growth modeling, and silvics into comprehensive guides to enhance productivity.

Appendix

Information Systems

An example of powerful GIS software is ArcGIS by ESRI http://www.esri.com

An example of robust and flexible forest modeling software is Woodstock by Remsoft http://www.remsoft.com/forest/woodstock/

Productivity Suggestions by Covertypes

Aspen

Recommendations

- Harvest aspen stands in winter to maximize sprouting potential if stands have 15-25% incidence of Hypoxylon canker.
- Convert to other species if stand has >25% Hypoxylon incident.
- Establish rotation age at 35 to 40 years in stands that have more than 15% of the aspen stems with white trunk rot (*Phellinus tremulae)* conks.

Rationale
Hypoxylon cankers are often associated with Saperda insect oviposition sites. Since these insects tend to prefer more open grown, limby trees to deposit their eggs, open grown stands often have a higher incidence of Saperda oviposition. Harvesting in the winter will help promote a denser stand of suckers thereby reducing the amount of limbs and the attractiveness to Saperda. If there are fewer wounds to serve as infection sites for Hypoxylon canker, disease incidence should be less even in more susceptible clones.

Aspen clones vary in their susceptibility to Hypoxylon canker and white trunk rot. Incident rates of 15 to 25% of the basal area infected with Hypoxylon canker indicate a high level of susceptibility of a particular clone to this disease organism.

Likewise, white trunk rot. Conks indicate the presence of advance decay. Decay severity is often related to tree age. The older the tree, the more likely there will be decay present. Aspen clones with advance decay at an early age may indicate the inability to wall off and confine the decay. Also, since it takes 6 or more years for conks to be produced, the presence of conks serves only as a conservative estimate of decay.

Productivity Implications
Hypoxylon canker causes mortality of 1 to 2% of the aspen in the Lake States each year and white trunk rot is responsible for significant useable volume loss. Hypoxylon canker is the most serious mortality causing disease of aspen. It often kills young trees helping to thin the stands, but trees of all ages can become infected and die from this disease. White trunk rot becomes more significant as stands age. Reduction in both Hypoxylon and white trunk rot incidences should increase the available volume both during intermediate thinnings and during the final harvest.

Red Pine

Recommendations

- Do not regenerate red pine under an existing overstory of red pine.
- Avoid partial harvesting (thinning) of red pine stands between March 1 and September 1.

Rationale
Shoot diseases caused by fungi in the genera, *Sphaeropsis* and *Sirococcus*, can be devastating to young red pines. Both fungi can infect overstory red pines and serve as sinks and sources for the fungi to spread to understory trees. Overstory infections either do not adversely affect the overstory trees because the infections are dispersed

throughout the crowns or in the case of *Sphaeropsis*, infections often occur on second year cones. When overstory trees are infected, spores will literally rain down on understory trees. Since it is more humid closer to the ground, conditions for infection and disease development often are ideal. *Sirococcus* causes death of only current year shoots, but infections year after year will result in tree death. *Sphaeropsis* infections are not limited to current year shoots; the fungus can grow into older wood and the fungus can colonize wounds such as those made from hail.

Red pine is particularly vulnerable to bark beetles, particular of the genus *Ips. Ips* spp. have 2 or 3 generations each year in MN. The first generation emerges from overwintering in the duff on the forest floor and attacks down, green wood and standing green, live trees severely stressed. The next generation of bark beetles that are present by mid-June attack standing live trees, and can overwhelmed the natural defenses of the trees by mass attacks. Bark beetle attacks usually result in tree mortality. Since stress events cannot be controlled, brood material control should be the objective in managing bark beetles. The downed or severely stressed standing trees serve as the brood wood to build up large successive bark beetle populations. Thinning red pine during the time that bark beetles are active may increase both stress to the residual trees but more definitely provide brood material for populations to build up. Slash over 3 inches in diameter and wood stacked in landings provide ideal bark beetle habitat. Material cut before March 1 often dries out and becomes unsuitable for bark beetles or can be removed before the active bark beetle period begins. Material cut after September 1, although bark beetles may still be active until frost, becomes unsuitable for brood wood by the following spring when bark beetles become active once again.

Productivity Implications

Seedlings and saplings will be killed or stunted or deformed increasing the cost of regeneration or resulting in regeneration failure. Bark beetles can attack red pine of all sizes over 3 inches in diameter but significant damage often occurs in plantations being thinned before the age of 50. Bark beetle attacks will kill trees in pockets reducing yields from the plantations and disrupting thinning regimes.

Black Spruce

Recommendations

- Establish landings in mistletoe pockets
- Establish non-regenerating black spruce buffers between harvest areas and non-merchantable mistletoe-infected black spruce
- Design timber sales so that the boundaries include all mistletoe pockets and a 2-chain buffer of non-infected black spruce
- Cut or kill all live black spruce stems when harvesting and regenerating black spruce

Rationale

Live black spruce infected with dwarf mistletoe, regardless of height or age, when left in the stand will reinfect the new stand after harvesting. Infections often occur in discernable pockets or along a somewhat continuous front where mistletoe infections are common in non-merchantable areas of black spruce. In mistletoe infected pockets multiage black spruce stands develop when they are opened up by the death of the overstory black spruce. The mistletoe pockets commonly have black spruce that is not merchantable and some or many of these black spruce stems may be infected with dwarf mistletoe. To reduce the amount of mistletoe available to infect the regenerating stands, try to cut or kill all live black spruce trees since mistletoe infections are not always readily available. Establish landings in mistletoe pockets since activity on the landing will help to kill infected mistletoe trees that are too small to be harvested. Design the sale so that infected pockets on the edges of sale are include within the sale area so that the harvest activity can help kill infected black spruce. Establish buffers between the harvested areas and infected non-merchantable areas. This will prevent or retard the movement of dwarf mistletoe into the regenerating stand. Though tamarack can become infected with mistletoe, it is not as susceptible and can serve as a barrier.

Productivity Implications

Dwarf mistletoe is the most destructive disease of black spruce. Dwarf mistletoe is an obligate parasite seed plant which will cause black spruce mortality but often takes many years to do so. However, given the slow growth of black spruce and the long rotations, dwarf mistletoe active in the stand can lead to the loss of that stand over the length of the rotation. It has the capacity to prevent a stand from becoming merchantable in the next rotation. Trying to reduce the amount of infected black spruce seedlings and saplings at the time of stand regeneration will help insure that a merchantable black spruce stand will be present at the next rotation.

Oaks

Recommendations

- Reduce the component of gypsy moth preferred hosts
- Remove damaged and suppressed trees
- Improve tree and stand vigor
- Thin oak stump sprouts at an early age to promote larger crowns and more vigorous trees.
- Do not prune, wound, or disturb oak stands between April and July.

Rationale
Gypsy moth is an introduced defoliating insect which is not established in MN at present. It is, however, established in Wisconsin and is predicted to become established in MN within 10 years. Experience gained from gypsy moth infestations in northeastern US shows that initial infestations cause mortality in hardwood stands, and mortality cannot be avoided. However, mortality can be reduced. Mortality often is greatest in stands dominated by gypsy moth preferred food species including the oaks and in stands with lower vigor. Vigorous, healthy oaks although defoliated repeatedly often do not die due to gypsy moth feeding. Low vigor, small crown, suppressed trees will be killed.

To prepare for gypsy moth, hardwood stands can be thinned to give more room to the residual trees to build larger crowns and thereby increasing their vigor. Thinning should also reduce the amount of preferred gypsy moth species and reduce the low vigor and suppressed trees. These trees will be killed and will help sustain a gypsy moth population.

Oak wilt is the most serious disease of oaks. It will kill red oaks within the same growing season of infections. White oaks can also become infected but will take longer to die. Sap feeding beetles are prime vectors of the oak wilt fungus. Beetles contaminated with disease causing fungal spores will inoculate healthy trees when the beetles are attracted to fresh wounds between April and July.

Productivity Implications
Both gypsy moth and oak wilt have the potential to kill significant numbers of oaks. If gypsy moth is ignored, stand composition may shift away from oak to more merchantably-undesirable species.