Minnesota's Forest Resources Research:

Assessment & Needs

Minnesota Forest Resources Council
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Executive Summary

The Minnesota Forest Resources Council (MFRC) is statutorily required to periodically conduct an assessment of forest resources research in the state of Minnesota. This includes:

- an assessment of the current status of forest resources research in Minnesota,
- an assessment of progress toward previously identified priorities and
- identification of priority research needs for the future.

The MFRC and its Research Advisory Committee (RAC) convened an advisory panel, comprised of senior researchers and administrators, to carry out the charge as stated above with the intention of creating a product that encourages and guides investments in forest resources research in the state.

These panel members and other researchers were asked to provide their expert opinions on the progress the research community has made regarding priorities developed in the late 1990s. Fifteen of the seventeen areas of research previously identified were noted to have had limited to somewhat substantial progress in addressing these priority research needs over the past dozen years. It was also noted that most of the current research involves ecological functions and integrity as well as the monitoring and modeling of forest resources.

The panel conducted a survey of 13 entities in the state that conduct research related to forest resources. This proved to be a diverse group of organizations, with $11.4 million in total annual funding (2009) for forest resources related research in the state. Most of the entities reported flat or declining funding levels for research in this area over the last three years. These organizations noted substantial existing infrastructure and human resources and indicated that the scientific community, public agencies and interest groups were the main users of the information generated through research.

The research panel, utilizing a framework illustrating the interrelationships between research topics, identified 20 general areas in need of research over the next decade. Through a prioritization process, the panel identified five priority areas of research and specific questions to further define these topics:

- Forest health threats,
- Implications and mitigation of climate change,
- Forest fragmentation, parcelization and development,
- Changes and losses in biodiversity, and
- Woody biomass harvesting and energy.

Seeking broader input, the RAC conducted two public forums. The forums confirmed the importance of the previously identified topics and, as a result of these forums, a second tier of important research topics were also identified:

- Methods of forestland management/ silviculture,
- Water quality and forests,
- Health of the forest products industry,
- Forest productivity concerns and implications, and
- Long-term ecological impacts of timber harvesting.

Through a vigorous and inclusive process, the RAC has developed two tiers of priority research topics. By widely vetting these topics, it is envisioned by the RAC that this document should be used by researchers and administrators to encourage the direction of, and investments in, priority forest resources related research in the state of Minnesota by the public, non-profit and private sectors. ■

Background

Minnesota has 16.2 million acres of forestland, covering approximately 32 percent of the state. This forestland is a mosaic of forest types and ownerships. Over half of the forestland is in three cover types: aspen (31%), northern hardwoods (12%) and black spruce (10%). Minnesota's forestland is divided fairly equally between public and private ownership. Major owners or administering bodies include family forest and tribal owners (36%), the State of Minnesota (24%), the USDA Forest Service and other federal agencies (17%), county and local governments (16%) and industry and corporate interests (8%).

These forestlands are important habitat for countless species of plants and animals; are widely used for recreational activities such as hunting and fishing, hiking, riding and camping; and support a multitude of large and small businesses, from industrial paper production to berry gathering. Including primary and secondary industries, Minnesota forestland supports more than 53,000 jobs, benefitting families and communities statewide. The forestland provides a host of other benefits including clean water, energy, carbon sequestration, and cultural and spiritual values. It is through research that we inform our ability to maintain and improve the myriad benefits provided by forest resources in our state.

Statutory charge. The Minnesota Forest Resources Council (MFRC) carries out its statutory responsibilities in supporting forest resources related research through the MFRC's Research Advisory Committee (RAC).
In accordance with state statute 89A.08, the RAC is required to:

(1) Periodically undertake an assessment of strategic direction in forest resources research based on input from administrators, researchers, practitioners, and the general public and include:
   a. an assessment of the current status of forest resources research in the state;
   b. an identification of important forest resource issues in need of research;
   c. an identification of priority forest research activities whose results will enable a better understanding of site-level and landscape-level impacts resulting from timber harvesting and forest management activities; and
   d. an assessment of the progress toward addressing the priority forest resources research needs identified.

   The forest resources research assessment must be made widely available to the research community, forest managers and users, and the public.

(2) Promote and disseminate those research needs identified above.

Past activities. This effort, as described above, was last undertaken in 1998, and culminated in a report, "Forest Resources Research in Minnesota: Meeting the needs of the next decade."[1] Citizen, resource manager and scientist input, collected during public forums, formed the foundation of the report. The 1998 research assessment included a review of the current status of forest resources related research in Minnesota, an agenda for forest resources

Members of the RAC

Allen Levine, Chair – Dean, College of Food, Agriculture, and Natural Resource Sciences, University of Minnesota

John Beebe – Senior Research Scientist, National Council for Air and Stream Improvement

Dave Epperly – Forestry Division Director, MN Department of Natural Resources

Michael Lalich – Director, Natural Resources Research Institute, University of Minnesota - Duluth

Tom Martinson – Land Commissioner, Lake County

Peter Reich – Regents Professor, University of Minnesota Department of Forest Resources

Tom Schmidt – Assistant Director, Northern Research Station, USDA Forest Service

[1] www.frc.state.mn.us/documents/council/MFRC_RAC_Forest_Research_Assessment_1998-07-01_Report.pdf

research for the next decade, and challenges to accomplishing research in the ensuing decade. Numerous forest researchers also provided insights on areas where knowledge was lacking or incomplete. Four general categories of research needs were identified:

(1) Understanding forest ecosystem function and integrity,
(2) Assessing economic and social aspects of forest resources,
(3) Developing information and technology to support sustainable forest management and planning, and
(4) Designing effective policies and programs for forest use, management, and protection.

Current process. In 2008, the MFRC requested that the RAC undertake an updated research assessment and prioritization of important forest resources related research needs in the state. The RAC reviewed the statutory charge and previous efforts and chose to engage a panel of forest resource scientists and administrators to create a framework for the assessment and inform the research needs prioritization process. The chair of the RAC sent invitations to 15 potential members who all agreed to serve on the panel.

The charge from the RAC to this panel was to generate a product that is of value to the broad range of stakeholders concerned with the forest resources of the state. The specific charge was to create a product or products that can:

(1) inform federal, state, local, and private decision-makers of priority research needs;
(2) encourage investment in priority forest resources research;
(3) increase efficiencies and encourage collaboration between research institutes, and
(4) assess the competitiveness of research dollars within the region relative to other sectors.

The panel was convened twice, once in 2008 and once in 2009. Additionally, the group operated extensively through e-mail and other electronic survey techniques. The panel provided extensive advice on the assessment of the current status of forest resources research in the state and the assessment of progress toward addressing previously identified needs, however, the bulk of this group's efforts were devoted to the development of current forest resources research priorities. ■

Forest Research Advisory Panel Members

John Beebe – Senior Research Scientist, National Council for Air and Stream Improvement

Bill Berguson – Program Director, Natural Resources Research Institute, University of Minnesota-Duluth

Francesca Cuthbert – Fisheries, Wildlife and Conservation Biology Department Head, University of Minnesota

Alan Ek – Forest Resources Department Head, University of Minnesota

Dave Epperly – Forestry Division Director, MN Department of Natural Resources

Steve Hirsch – Ecological and Water Resources Division Director, MN Department of Natural Resources

George Host – Senior Research Associate, Natural Resources Research Institute, University of Minnesota-Duluth

Pam Jakes - Research Forester, USDA Forest Service, Northern Research Station

Jim Marshall – Forest Resources Manager, UPM-Kymmene

Brian Palik - Team Leader/Research Ecologist, USDA Forest Service

Michael Prouty – Field Representative, Northeastern Area, State and Private Forestry, USDA Forest Service

Shri Ramaswamy – Bioproducts and Biosystems Engineering Department Head, University of Minnesota

Peter Reich – Regents Professor, Department of Forest Resources, University of Minnesota

Jim Sanders – Forest Supervisor, Superior National Forest, USDA Forest Service

Dave Schad – Fish and Wildlife Division Director, MN Department of Natural Resources

Research Assessment

Assessment of progress. Responding to the statutory mandate regarding an assessment of progress toward addressing priority forest resource research needs, the University of Minnesota – Department of Forest Resources, USDA Forest Service Northern Research Station, Natural Resources Research Institute-Center for Water and the Environment, Natural Resources Research Institute-Applied Forestry Program, MN DNR-Division of Fish and Wildlife, University of Minnesota-Department of Fish, Wildlife and Conservation Biology, The Nature Conservancy, MN DNR-Division of Ecological and Water Resources, Dovetail Partners, USDA Forest Service-Chippewa National Forest, UPM-Kymmene, USDA Forest Service-Superior National Forest, and the MN DNR-Division of Forestry were asked about progress made toward addressing the research needs identified by the MFRC in 1998. These identified research needs were meant to ensure that:

- Minnesota forests are managed with primary consideration given to long-term ecosystem, integrity and sustaining healthy economies and human communities;
- Forest resource policy and management decisions are based on credible science, community values and broad-based citizen involvement; and
- The public understands and appreciates Minnesota's forest resources and is involved in and supports decisions regarding forest resources use, management, and protection.

The degree to which these organizations felt that progress has been made in addressing previously identified research needs is listed in Table 1.

Table 1. Assessment of progress and current activity in MN

	Progress*	Current Activity**
Ecological Functions and Integrity		
Changing vegetation patterns and conditions	2.3	••••
Riparian zone integrity and function	2.3	••
Forest stand composition and quality	2.3	••••
Wildlife habitat and availability	2.1	•••
Soil productivity	2.0	•••
Economic and Social Aspects		
Fragmentation of Minnesota's forest land base	2.4	••
Timber productivity and management opportunities	2.3	•
Changes to Minnesota's forest land base	2.3	••
Local and regional economic contributions of forest resources	2.2	••
Forest products development/utilization	2.2	•
Interactions involving wood products and tourism/outdoor recreation industries	1.7	•
Information and Technology Development		
Monitoring changes in forest resource conditions	2.4	•••
Modeling forest resource conditions	2.3	•••
Enhancing access to and quality of information describing forest resources	2.1	••
Timber harvesting and forest management technology	2.1	•
Policies, Programs and Planning		
Public-land policy and program design	2.2	•
Private-land policy and program design	1.9	•

* Progress was indicated on a scale where 1=no progress, 2=limited progress, and 3= substantial progress

** Current activity as indicated by •= number of organizations currently conducting research on indicated topic

It is notable that all but two of the listed research needs identified in 1998 were indicated as having made limited to substantial progress from 1998 to 2009. Of the research priorities derived in 1998, much of the current research activity involves ecological functions and integrity, as well as the monitoring and modeling of forest resource conditions.

Current status of forest resources research in Minnesota.

As noted in the 1998 research assessment, there are a number of organizations in Minnesota that conduct research related to forest resources in the state. These organizations include academic institutions, federal and state agencies, non-profits, and the forest products industry. Thirteen of these prominent research organizations were surveyed; respondents are identified in the previous assessment section. For each, the organizational charter, mission, and vision; structure and nature of research units; progress on previously identified research priorities; amount and nature of funding and staffing; existing research infrastructure; and the nature and audience of research products was reviewed. Minnesota also benefits tremendously from research conducted in other states or even other countries. For instance, much of the forest resources related research conducted by the USDA Forest Service in other Great Lakes states is directly applicable to Minnesota. It is also important to note that research conducted in Minnesota is exported to other states and countries.

In reviewing the structure and vision of these various organizations, it is notable that this is a group of diverse organizations and interests. Some are public, quasi-public, and private, including both for- and non-profit organizations. Some organizations are specifically focused on forest resources, while others are more tangentially related, such as the fish and wildlife organizations. Some have a primary mission to conduct and disseminate information, while for others research is not a primary component of their mission.

The diverse group of organizations has a wide range of annual research funding levels, from almost nothing to over $5.5 million. The average research funding for these organizations is almost $900,000, although this can be misleading due to the large range of funding. Total annual funding, which varies from year to year, for forest resource related research within these organizations was over $11 million dollars in 2009. The sources of these funds are listed in Table 2.

Table 2. Forest Resources Research Sources of Funding in Minnesota, 2009.

Public	**$10,636,785**
Federal	$7,133,268
State	$3,229,352
Local	$274,165
Private	**$546,170**
Foundations	$107,420
Private Industry	$412,750
Non-profits	$26,000
Other	**$237,165**
Total	**$11,420,120**

Of the surveyed organizations that conduct research, 45 percent indicated that research funding has been declining over the past 10 years, 45 percent indicated flat funding over the past ten years, and ten percent indicate an increasing trend in funding of forest resource related research in Minnesota. Organizations indicating an increase in funding for forest resource related research accounted for only 2.9 percent of total forest resource research funding. Respondents indicated nearly 43 full-time equivalent positions in Minnesota are focused on forest resources research, with the majority of organizations noting staffing levels as flat over the last ten years. Some organizations indicated significant research infrastructure such as laboratories, greenhouses, computing and geospatial analysis facilities, and long-term research sites and permanent plot networks. It was noted, however, that skilled professionals to staff and update these facilities are increasingly difficult to find.

Research products are varied and include: reports, articles, web-based products and other publications; public forums, meetings, field tours and workshops; and training sessions. The primary audience and users of the research are quite diverse. Respondents noted that they produce reports and other research products targeted at the scientific community (77%), public agencies (77%), interest groups (62%), decision-makers (62%), the general public (46%), and businesses (38%). ■

Identification of Research Priorities

Minnesota has a rich tradition in the utilization and appreciation of its vast forest resource and all of the benefits it provides. In order to continue to enjoy the benefits Minnesotans receive from forestland in the state, it is necessary to understand the condition of its forestland resources and the changing environment in which we live. We need to understand the agents of change and the effects that those may have on our forest resources, as well as our abilities to manipulate the resource conditions and/or agents of change. We need to understand these conditions, uncertainties and tools utilizing ecological, economic and social lenses. Building on these ideas, the panel constructed a framework demonstrating the types of, and relationships among, issues to best interpret and prioritize research needs.

Forest resource conditions, agents of change, and manipulative tools. Key to charting a course for the future of Minnesota's forest resources is the basic need to understand the condition of the various resources. These conditions are ecological, economic and social in nature, and are tightly interrelated. Examples of these conditions are outlined in the *Forest Resource Conditions* diagram (Figure 1).

Figure 1.

Forest Resource Conditions

Ecological

- Biodiversity/Habitat
- Water Quality
- Soils
- Productivity/Growth

Economic

- Jobs/Wages
- Health of the Forest Products Industry
- Energy Generation

Social

- Recreation
- Demographics/Ownership
- Policy Framework
- Land Use
- Cultural/Spiritual Values

Conditions are not static and are constantly changing in response to interactions among various conditions, as well as through external forces and human manipulations. Just as the basic conditions fall into the three broad categories listed above, agents of change can be classified in the same manner, with all affecting forest resource conditions. Examples of these agents are outlined in the *Agents of Change* diagram (Figure 2).

Conditions and agents of change are also impacted by a number of manipulative tools in the broadest sense. These tools include:

- Policy,
- Forest management activities,
- Planning and assessment exercises,
- Education and technology (development, use and transfer), and
- Research activities.

These conditions, agents of change and manipulative tools are all influenced by geographies and ownership regimes and patterns including public, private, urban and other forests (Figure 3).

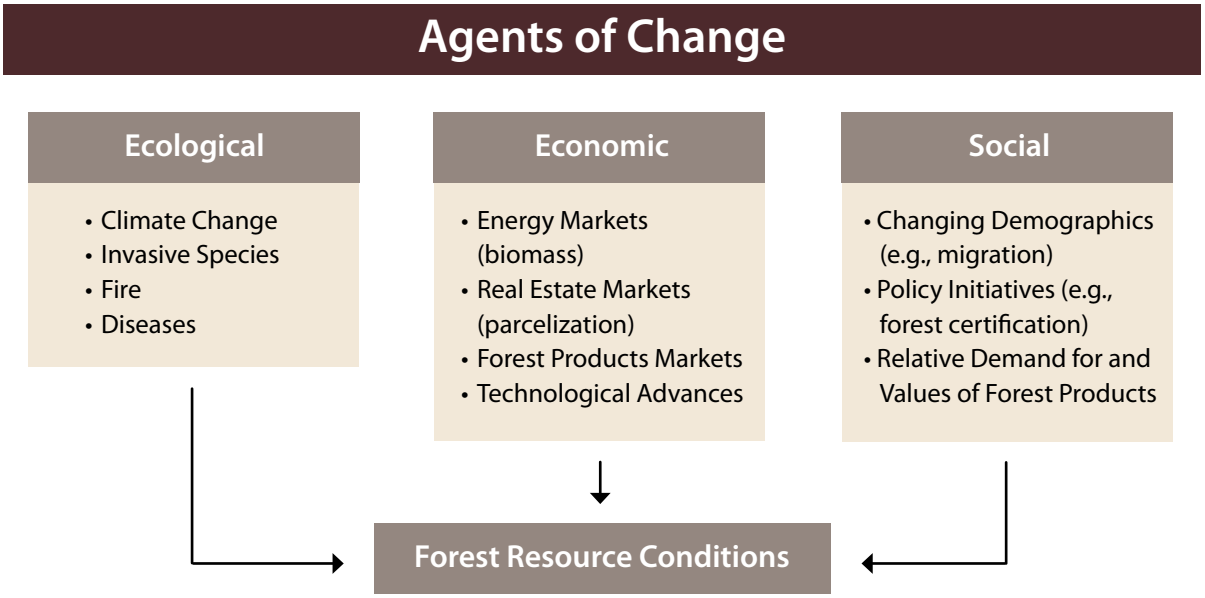
Keeping this framework in mind and appreciating the complex interrelationships within, the panel identified research questions that are related to these conditions, agents of change and manipulative tools.

Within this framework, a host of important research needs and policy issues have recently been identified by this panel, as well as by the Minnesota Forest Resources Council, the Minnesota Forest Resources Partnership, the Governor's Task Force on the Competitiveness of the Primary Forest Products Industry, the Blandin Foundation's Vital Forests/Vital Communities Initiative, the USDA-Forest Service, as well as a host of other public and private groups and agencies. Significant and timely issues are organized below into the generic framework:

Forest Resource Conditions

- Changes/losses in biodiversity
- Changes/losses in fish and wildlife habitat
- Forest productivity concerns and implications
- Forest recreation (adequacy of funding and capacity, conflicts)
- Health of the forest products industry
- Water quality and forests

Figure 2.



Agents of Change

- Fire considerations (suppression, fuel loads)
- Forest health threats (invasive insects, diseases, and plants)
- Forestland parcelization, fragmentation and development
- Implications/mitigations of climate change
- Need for certification
- Woody biomass harvesting/energy

Manipulative Tools

- Adequacy of forest information/inventory
- Methods of forestland management/ silviculture (harvesting levels, riparian management, regeneration, deer browse)
- Need for increased integration in forest planning
- Private sector natural resources professional capacity
- Public understanding/education

Geography and Ownership

- Adequacy of public land management (funding, professional capacity)
- Private forest management (stewardship plans, incentives, taxes)
- Urban and community forests

Prioritization of research needs. After compiling numerous areas of priority research and fitting those ideas into an organizing framework, members of the panel were asked to indicate what they felt were priority forest resources research needs. With various backgrounds and expertise around the table, it was felt that the group would come up with a very robust set of priorities. Each member was asked to indicate the need for research regarding the subject areas identified earlier by the panel on a scale of 1-4, where 1 = low priority and 4 = high priority. In turn each member was asked to rank their top five priority research needs. Through this survey, topic areas most in need for research were determined to be those programs that were rated above 3 for need, ranked in the top 5 by at least a third of the group and equaled or exceeded 10 when adding up the values of the top five ranking. The top five are highlighted in Table 3; the next six were either identified as a second tier of priority research needs or were folded into existing priorities. The bottom nine were not identified as priority research needs. ■

Figure 3.

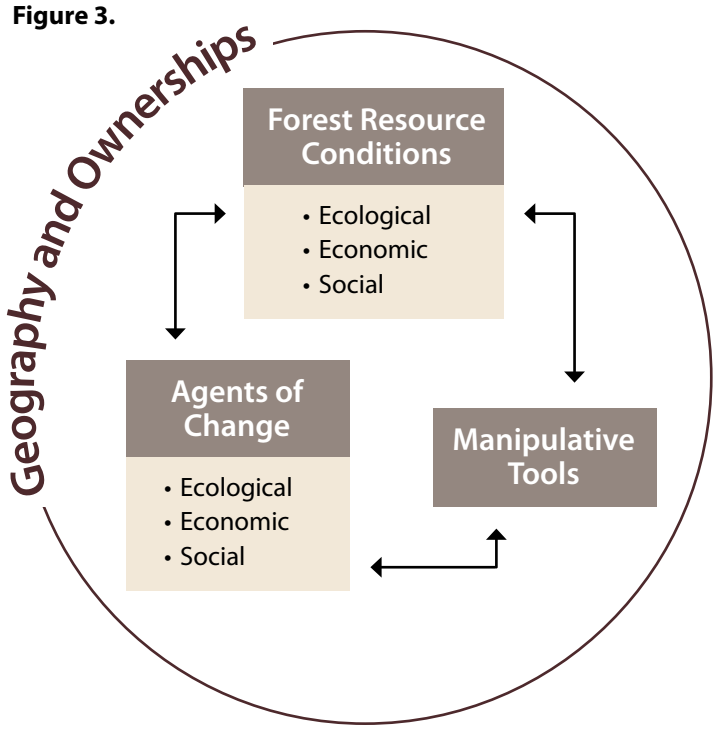


Table 3. Ranking of priority research needs in Minnesota

Topics	Average need ranking*	Top 5 Ranking**	# in top 5***
Forest health threats	3.67	37	11
Implications/mitigations of climate change	3.42	32	7
Forest parcelization, fragmentation and development	3.50	23	6
Changes/losses in biodiversity	3.33	19	6
Woody biomass harvesting/energy	3.36	10	5
Adequacy of forest information/inventory	3.00	9	4
Methods of forest land management/silviculture	3.17	8	3
Water quality and forests	3.17	7	3
Health of the forest products industry	2.83	9	3
Forest productivity concerns and implications	2.92	8	3
Changes/losses in fish and wildlife habitat	3.33	4	2
Public understanding/education	2.92	2	2
Private forest management	2.75	5	1
Adequacy of public land management	2.67	2	1
Fire considerations	2.42	2	1
Urban and community forests	2.08	1	1
Need for increased integration in forest planning	2.58	0	0
Natural resources professional capacity	2.08	0	0
Forest recreation	2.00	0	0
Need for certification	1.75	0	0

* Based on a 1-4 scale where 1 = low priority and 4 = high priority.
** Sum of rankings
*** Noted number of times issue was in the top five ranking of panel members

Priority Research Questions

Based on expertise and experience, and strategically grouped, the panel divided into five subgroups of three individuals. Each of these subgroups concentrated on one of the top five issues, as identified above: (1) forest health threats; (2) implications and mitigation of climate change; (3) forest fragmentation, parcelization and development; (4) changes and losses in biodiversity; and (5) woody biomass harvesting and energy. Each subgroup member was asked to develop and submit the top research needs or questions regarding the above listed general priorities. MFRC staff, in turn, distilled the originally submitted questions to eliminate redundancies and to keep questions and needs in comparable scope. These distilled questions were sent back to sub-group members to facilitate feedback at the next meeting of the panel. At that meeting, the subgroups worked to distill their previously generated priority research questions into approximately three top research needs as noted below. The full panel was in turn asked to comment on each of the topics.

Following this iterative process, the RAC convened two public input forums to provide feedback on the priorities established by the panel. Comments were also accepted over the course of a 60-day review period. This input was utilized to improve the report. Through this process, two tiers of priority forest resources research topics were determined. The first tier are research needs that were determined to be of the highest priority by the panel and, in turn, amended through public input. The second tier, also of priority status, were added utilizing the input from the public forums and other comments provided to the RAC.

Through the above outlined process, the following Tier I and Tier II issues were developed. Priority research questions were also developed for Tier I issues.

Tier I Issues

Priority issue: Forest health threats. The economic (e.g., timber sales and recreation), ecological (e.g., water quality and habitat) and sociological (e.g., aesthetics and cultural aspects) benefits derived from forested land are being compromised by declining forest health in Minnesota, at a seemingly quickened pace. Although precise definition of forest health is elusive or is couched in the eye of the beholder, the ability of the forest to maintain ecological functions and provide this array of goods and services can be a reasonable interpretation or measure of forest health. Development of forest health indicators would further increase our abilities to quantify forest health. Climatological changes, increasing development pressure, fragmentation of habitat and other factors will most likely exacerbate existing and new threats to forest health. For example, understanding threats from native pests, pathogens and plants (e.g., spruce budworm, oak wilt, and reed canary grass) as well as exotic and invasive pests, pathogens and plants (e.g., emerald ash borer, Dutch elm disease and garlic mustard) is vital for maintaining the benefits provided by Minnesota's forests. Better understanding of forest health threats buoys our ability to strategically address threats and aid in maintaining benefits. Information regarding early detection, identifying invasive pathways and determination of early intervention will be important considerations. Addressing the questions listed below is key to strategically addressing this issue.

1. How do we manage forests in relation to disturbances (e.g., forest insect and disease outbreaks), or lack thereof (e.g., wildfire), and what stand-level and landscape-level management prescriptions most effectively maintain or enhance forest health and which might be barriers?

2. How do we sustain native plant and animal communities and maintain ecological functions and diversity in the face of new invasives, native pests and climate change? For example:
   a. How will forests respond to EAB and the loss of ash, and
   b. How do we maintain the health of the state's aspen resource?

3. What are the people's perceptions and interpretations of "forest health"?

Priority issue: Implications and mitigation of climate change.

Climate is the major driver influencing the composition, structure and productivity of Minnesota's forests. Historic patterns of temperature and precipitation have defined the transition zones between boreal and broadleaf forests, and between prairie and forest. As we enter into a period of unprecedented rates of change in climate, including spatial and temporal shifts in precipitation patterns, increased frequency and intensity of storms, and changes in extreme and average temperatures, we can only expect that forests will change in response. Some of these changes, such as the gradual loss of cold-adapted boreal species under a warming climate scenario, can reasonably be predicted from current knowledge. But because of the multitude of factors that interact with climate – the spread of pests and disease, the role of trees in regulating hydrologic patterns, and even human activity – it will be difficult to fully anticipate the range of responses and the nature of our future forests. Given only the certainty of change, it will be critical to develop the knowledge base and management strategies to promote adaptation of Minnesota forests to a changing climate. Maintaining the societal valued attributes and services of Minnesota's forests: wildlife habitat, forest products, water quality and aesthetic and spiritual values, will require a concerted effort on the parts of multiple agencies and stakeholders. Strategies for this response must be multifaceted, and ranging from broad-scale cross-agency landscape planning to development of site-specific silvicultural prescriptions that promote resiliency at the stand level. Addressing the questions listed below will be key to strategically addressing this issue.

1. How will climate change, in conjunction with land use change (e.g., parcelization, development) and forest management, affect:
   a. Ecosystem structure, function and biodiversity (e.g., composition, carbon sequestration and storage)
   b. Hydrologic response and watershed management, and
   c. Forest-dependent human communities and economies?

2. What strategies and forest attributes will promote mitigation and resilience and enhanced adaptation of Minnesota's forests, dependent communities and related economies to a changing climate?

Note: Need to focus on direct and indirect consequences of climate change (temperature, moisture, means and variability, seasonality, severe disturbances) and near- and long-term effects at local to regional scales.

Priority issue: Forest fragmentation, parcelization and development.

Parcelization, the division of larger tracts of forest into smaller tracts of forest, and fragmentation resulting in changes in land use have been recognized as a top concern in sustaining the ecological, economic, and social benefits currently provided by Minnesota's forests. Nationally and in Minnesota, conversion of forestland to other uses is expected to continue over the next twenty years and beyond. Human causes of changing forest land use include increases in population and seasonal homes, a shift in ownership from industrial owners to investment companies and a high turnover in family forest landowners. Continued parcelization and fragmentation of forestland in Minnesota will have adverse effects on jobs in the forest products sector, access to outdoor recreational activities, wildlife habitat, water quality, carbon sequestration and other benefits that flow from large, contiguous blocks of forestland. To understand the impacts of drivers such as changing population and climate on forest parcelization and fragmentation, we pose a series of priority questions to be answered for Minnesota.

1. What are the impacts of parcelization and fragmentation on forests in regards to:
   a. Availability of timber and non-timber forest resources (e.g., wildlife habitat, water quantity and quality, recreational opportunities, other ecosystem services),
   b. Forest management opportunities,
   c. Forest-based industry development and expansion, and
   d. Forest disturbance (e.g., impacts on wildfire, spread and management of invasive species, efforts to mitigate global climate change)?

2. What are the efficiencies and quality of the contributions made by various owners and parcel sizes to forest ecosystem attributes and production of other forest products?

3. What are the effective policy responses to mitigate the negative impacts of parcelization and fragmentation?

Priority issue: Changes and losses in biodiversity and wildlife habitat. Forest biodiversity, broadly defined, includes the types and variety of species, genotypes, structural conditions, and ecosystem processes that characterize productive, healthy ecosystems. Sustaining native biodiversity and associated habitats in the amounts and patterns of natural ecosystems is an important consideration in the context of designing and deploying sustainable forest management systems. At the heart of the issue is a belief that natural diverse forest systems are better able to resist stress, be resilient in the face of stress, or adapt to changing conditions and thus provide greater options for the future, for both commodity and non-commodity management. Managing to sustain or restore native biodiversity is not predicated on a simple more (biodiversity) is better relationship. Rather, the premise is that managed systems that are more like their unmanaged, reference conditions in terms of species richness, genetic diversity, structural variation, and ecosystem processes are more likely to be resistant, resilient, and adaptable to stress and changing conditions. With this in mind, we have identified the following three broad priority research questions that are applicable, and in need of answering, for Minnesota's forest ecosystem.

1. To what extent are ecosystems (terrestrial, aquatic and wetland) at risk of loss of biodiversity and wildlife habitat from climate change, harvest, forest health decline and parcelization?

2. What are the stand-to-landscape management strategies that either mitigate negative changes or promote adaptation and resiliency?

3. What are the major policy needs/ impediments that arise from answers to questions 1 and 2 (e.g., state-level goals/ targets for biodiversity and the cost of sustaining versus losing biodiversity)?

Priority issue: Woody biomass harvesting and energy. The use of biomass for energy from Minnesota's forests presents opportunities to produce renewable heat, power and fuel as well as questions related to long-term sustainability and productivity of forest resources. Woody material that could potentially be used for energy includes forest residues, that portion of the tree that is considered too small to be used in the manufacture of paper and building products, as well as whole trees (small and large) that may not be in significant demand by the current industry. Along with opportunities, increased intensity of harvesting presents issues related to impacts on the future productivity of the forest. These issues include the effects of biomass removal on nutrient supply, wildlife and carbon cycles. Also, questions remain regarding the potential supply of wood for energy, the cost of the material, policy implications and potential competitive effects on the existing forest products industry, a vibrant part of Minnesota's industrial base. Due to the relatively low value of forest residues, developing new technologies to efficiently handle woody biomass is needed. At this time, significant research is also underway

in industry and university laboratories to develop conversion systems that produce a variety of products including liquid fuels and industrial chemicals. In order to guide future policy that may be implemented to encourage the development of emerging biofuels industry, research is recommended to better understand the potential conversion pathways and the suitability of these technologies to Minnesota's forest resource. The following research questions are recommended to resolve the issue of long-term sustainability, better understand the potential and limitations of the forest resource and recommend policies and technologies that maximize the benefit to Minnesota's citizens.

1. What are the short- and long-term environmental impacts of woody biomass harvesting?

Note: This will require a synthesis of existing information and targeted large-scale, long-term study.

2. What is the physical, economic, technical and ecological supply of biomass?
   a. What management techniques and policy (e.g., state environmental review and federal incentive programs) will increase the utilization/supply of woody biomass, and what are potential cross-sector impacts?
   b. What are the issues with respect to scale, economics, community role and sustainability?

3. What developments will facilitate the use of woody biomass for energy and other products in Minnesota, including:
   a. What technologies/equipment/logistics should be developed for woody biomass harvesting in Minnesota (e.g., handling of bundles or chips); and
   b. Which conversion technologies and transportation technologies are appropriate, and what are the issues of scale, economics, location, community role and sustainability with respect to these technologies?

Tier II Issues

Issue: Methods of forest land management/silviculture. The methods employed in timber harvesting and forest management activities have a great influence on future forest conditions. These also can be used to mitigate the negative effects of a number of above-mentioned topics including climate change and invasive species. Questions around intermediate treatments, regeneration techniques and planting success rates among a host of other considerations lend themselves to important and timely research inquiries.

Issue: Water quality and forests. Many have explored the relationship between forest cover in a watershed and the quality of water flowing from that watershed. Certain forest practices and changes in land use have been shown to adversely affect water quality. States and others have used Best Management Practices (BMPs) and other mitigative strategies to minimize forest management activities on water quality. There are still many important questions to be answered regarding forest management actions as well as changes in land use.

Issue: Health of the forest products industry. The forest products industry in Minnesota produces over $10 billion worth of products and employs over 53,000 people. This is a very important industry to the state of Minnesota, especially in many rural areas that are limited in other types of employment. Due to the globalization of markets as well as other national, regional, and local market issues, there have been many changes in the landscape of the forest products industry in the state. Research to maintain this important economic engine, as well as the interconnectedness with forest health, climate change and other issues, is very important to the state of Minnesota.

Issue: Forest productivity concerns and implications. Related to concerns regarding the forest products industry in Minnesota, maintaining and increasing the productivity of forestland is key to the survival of forest products businesses as

well to other aspects of forest resources. With population increasing in the state and more development occurring in the forest, the need to satisfy our demand for forest products in more concentrated areas or by utilizing more advanced techniques will grow. Forest productivity also impacts wildlife habitat as well as other topics identified in this assessment.

Issue: Long-term ecological impacts of timber harvesting. The Generic Environmental Impact Statement[2] on timber harvesting and forest management in Minnesota identified a host of research needs regarding the long-term ecological impacts of timber harvesting. A number of these research questions have been explored in relation to these needs identified in the early 1990s, yet some have gone unanswered. In addition, conditions (both economic and ecological) are changing. The impacts of woody biomass harvesting, a Tier I issue, can be considered a subset of this larger topic. Further research on this topic is key to maintaining our ability to sustainably manage the state's forest resources.

Additional considerations

In addition to the determination of a second tier of issues brought forth during the input forums and comment period, a number of other items were discussed and need to be addressed. The adequacy and need for information, in particular forest inventory data, was noted as very important by a number of comments and participants. While the concern regarding inadequate data does not constitute a research need per se, inventory is a crucial tool necessary to conduct much of the research related to the more issue-based research needs. Additional tools and increased use/ development of technology to support priority research are needed. For example, enhanced database development would be very valuable, but is not an issue-based research priority.

Through this identification of priority research needs, there were suggestions to include an "Emerging Issues" category. This report would be remiss in not acknowledging that priorities will shift in importance and change over time. We would like to see the current priority research topics identified by the panel pursued with as much vigor as possible, but recognize that the topics and their relative priority will change over time. We also recognize that even the periodic revision of this assessment may not capture quickly changing issues and circumstances which should be considered in devoting resources to research activities, but does provide a strategic focus and should be amended as is warranted.

As noted above, this was an issue-based process that identified the priority issues in need of research. It is extremely important to keep in mind that these issues are highly interconnected and research regarding one topic is dependent on existing information and research being conducted in regards to other identified topics. For instance, research regarding forest health threats, needs to take into account the impacts of a changing climate and changing land use patterns, among other factors.

It is notable that the entire Tier I and most of the Tier II issues are aligned with the priority issues identified by the Minnesota Department of Natural Resources in their recently published forest resource assessment and strategies document[3]. The Minnesota Forest Resources Council's (MRFC) four priority policy issues are also entirely encompassed by the Tier I issues. ■

[2]Jaakko Poyry Consulting Inc. 1994. Final Generic Impact Statement Study on Timber Harvesting and Forest Management in Minnesota.

[3]Minnesota Department of Natural Resources. 2010. Minnesota Forest Resources: assessments and strategies.

Conclusion

Minnesota's forest resources are extremely valuable from an ecological, economic and social viewpoint. These resources provide Minnesotans with a tremendous amount of goods and services, both market and non-market. Ecological values including the maintenance of water and air quality, biodiversity and wildlife habitat, and carbon sequestration among others are vital to the state and our quality of life. The forest products industry alone supports more than 53,000 jobs and contributes over $10 billion dollars to the state's economy. Our forest resources also provide other economic benefits, including the support of a robust resort and tourism industry.

In order to maintain, and in some cases enhance, the current quantity and quality of the benefits we derive from forests we need to understand: the current forest conditions; the agents of change which are currently or will soon be affecting Minnesota's forest resources; the tools we have at our disposal to influence the current conditions as well as the agents of change; and the geographies and ownership regimes within which these resources exist.

The Minnesota Forest Resources Council, through a deliberate and inclusive process, has developed a compilation of priority research needs regarding the forest resources of Minnesota. It is the desire of the MFRC that others use these priorities for securing research funding on these topics. The topics were developed in two tiers, with the first tier indicating top priority and the second tier being other topics of great importance. In review:

Tier 1

- Forest health threats
- Implications and mitigation of climate change
- Forest fragmentation, parcelization and development
- Changes and losses in biodiversity and wildlife habitat
- Woody biomass harvesting and energy

Tier 2

- Methods of forestland management/ silviculture
- Water quality and forests
- Health of the forest products industry
- Forest productivity concerns and implications
- Long-term ecological impacts of timber harvesting

Forest resources research on these topics is key to maintaining the many benefits we get from forest land. It is imperative that we address forest resource related research in a strategic manner and coordinate activities across disciplines and organizations to make the greatest impact on maintaining and enhancing the benefits from Minnesota's forest land. ■

Appendix – Priority Forest Resources Research Needs

The Minnesota Forest Resources Council (MFRC) is statutorily required to conduct an assessment of forest resources research in Minnesota. Through a vigorous and inclusive process, the MFRC and its Research Advisory Committee have developed two tiers of priority research topics and priority research questions.

By widely vetting these topics, it is envisioned that this document should be used to encourage the direction of, and investments in, priority forest resources related research in Minnesota.

Tier One: Priority Research Issues

Priority issue: Forest health threats.

1. How do we manage forests in relation to disturbances (e.g., forest insect and disease outbreaks), or lack thereof (e.g., wildfire), and what stand-level and landscape-level management prescriptions most effectively maintain or enhance forest health and which might be barriers?

2. How do we sustain native plant and animal communities and maintain ecological functions and diversity in the face of new invasives, native pests and climate change? For example:
   - How will forests respond to EAB and the loss of ash, and
   - How do we maintain the health of the state's aspen resource?

3. What are the people's perceptions and interpretations of "forest health"?

Priority issue: Implications and mitigation of climate change.

1. How will climate change, in conjunction with land use change (e.g., parcelization, development) and forest management, affect:
   - Ecosystem structure, function and biodiversity (e.g., composition, carbon sequestration and storage)
   - Hydrologic response and watershed management, and
   - Forest-dependent human communities and economies?

2. What strategies and forest attributes will promote mitigation and resilience and enhanced adaptation of Minnesota's forests, dependent communities and related economies to a changing climate?

   Note: Need to focus on direct and indirect consequences of climate change (e.g., temperature, moisture, means and variability, seasonality, severe disturbances) and near- and long-term effects at local to regional scales.

Priority issue: Forest fragmentation, parcelization and development.

1. What are the impacts of parcelization and fragmentation on forests in regards to:
   - Availability of timber and non-timber forest resources (e.g., wildlife habitat, water quantity and quality, recreational opportunities, other ecosystem services),
   - Forest management opportunities,
   - Forest-based industry development and expansion, and
   - Forest disturbance (e.g., impacts on wildfire, spread and management of invasive species, efforts to mitigate global climate change)?

2. What are the efficiencies and quality of the contributions made by various owners and parcel sizes to forest ecosystem attributes and production of other forest products?

3. What are the effective policy responses to mitigate the negative impacts of parcelization and fragmentation?

Priority issue: Changes and losses in biodiversity and wildlife habitat.

1. To what extent are ecosystems (terrestrial, aquatic and wetland) at risk of loss of biodiversity and wildlife habitat from climate change, harvest, forest health decline and parcelization?

2. What are the stand-to-landscape management strategies that either mitigate negative changes or promote adaptation and resiliency?

3. What are the major policy needs/impediments that arise from answers to questions 1 and 2 (e.g., state-level goals/targets for biodiversity and the cost of sustaining versus losing biodiversity)?

Priority issue: Woody biomass harvesting and energy.

1. What are the short- and long-term environmental impacts of woody biomass harvesting?

Note: This will require a synthesis of existing information and targeted large-scale, long-term study.

2. What is the physical, economic, technical and ecological supply of biomass?
   - What management techniques and policy (e.g., state environmental review and federal incentive programs) will increase the utilization/supply of woody biomass, and what are potential cross-sector impacts?
   - What are the issues with respect to scale, economics, community role and sustainability?

3. What developments will facilitate the use of woody biomass for energy and other products in Minnesota, including:
   - What technologies/equipment/logistics should be developed for woody biomass harvesting in Minnesota (e.g., handling of bundles or chips), and
   - Which conversion technologies and transportation technologies are appropriate, and what are the issues of scale, economics, location, community role and sustainability with respect to these technologies?

Tier Two: Priority Research Issues

These second tier research priorities are significant as identified by the Research Advisory Committee and were elevated as top priorities as a result of public forum comments.

Methods of forestland management/silviculture

Water quality and forests

Health of the forest products industry

Forest productivity concerns and implications

Long-term ecological impacts of timber harvesting