A CENTURY OF RESEARCH IN NATURAL RESOURCES

UNIVERSITY OF MINNESOTA
There are no “U of M” logos on our forests, national parks, boulevards or homes that credit a panorama, eagle nest, or ski trail to “university research.” Yet the impact of our scientific endeavor on natural resources is significant. This publication celebrates and documents a century of contributions by researchers within the University of Minnesota College of Natural Resources.

The College’s programs began in 1903, a time when citizens were concerned about fire prevention and reforestation of the vast pine forests of northern Minnesota. Our wildlife and fish resources were threatened by over-harvest and habitat loss from a growing human population. It was an uncertain time, but visionary leaders turned concern into hopeful concepts: bag limits for hunting and fishing, land set-asides for conservation, replanting and repopulating nature, establishment of parks.

Our scientific pursuit to understand complex human-nature interactions has yielded many positive outcomes:
- U of M wildlife investigations helped restore bald eagle populations
- Forest ecology studies led to restoration of pre-European pine stands
- We grow twice as much timber as we harvest
- Lands converted to agricultural production are being returned to forests
- Lakes and rivers are healthier than a generation ago
- New tax policies were developed to help sustain family forest lands
- After decades of study we know the key factors that control ruffed grouse survival and abundance

Yet, there is so much we do not understand. U of M researchers are investigating the effects of trace amounts of human estrogen on fish. We struggle with policy decisions related to wildlife habitat loss from an ever-expanding human population. We’re learning more about the effects of global warming on forest biodiversity. And, U of M natural resource scientists are informed leaders in the movement to better understand the risks of introducing genetically modified organisms.

Minnesota is a unique place to study these environmental issues, situated at the confluence of three great ecological biomes: western prairies, northern boreal forests, and southern hardwood forests and oak savanna. Water flows from three major watersheds: the Mississippi River, the Great Lakes, and the Red-Rainy Rivers flowing north to Hudson Bay. So, what we learn here on this varied landscape is beneficial to a wide swath of North America and beyond.

The future of natural world discovery faces another challenge: public funding for this research is on the wane. Unlike the fields of medicine, technology, or agriculture, there is no private sector tradition of funding research to improve wildlife, water, forests, fisheries, or recreation. Add to this the longevity of trees and wildlife, plus gradual environmental changes, and it is obvious that progress in natural resources can take decades or even generations to realize. Stable, long-term funding is essential.
The vast majority of the discoveries in this publication were funded with tax dollars through the University of Minnesota's Agricultural Experiment Station. For a century U of M College of Natural Resources students have worked side-by-side with teachers on research projects such as those highlighted on the following pages. Their acquired knowledge and familiarity with research techniques will help future generations deal with local, national, and global resource issues.

A 1928 proposal from pre-eminent naturalist Aldo Leopold launched game management research at the University, but not without caution on the part of University president Coffman. The proposal suggested the University undertake a demonstration of natural quail farming, and accept a fellowship and research support from the Sporting Arms and Ammunition Manufacturer's Institute.

Coffman was skeptical: "They want more quail so that more arms and ammunition can be sold. The University has no interest in the project for that purpose."

Leopold convinced Coffman that the University would not be dealing directly with a "commercial concern" because the U.S. Bureau of Biological Survey would select the research fellow and administer the funds. Then Leopold suggested pheasants or ruffed grouse would be more appropriate subjects for a Minnesota study, and Coffman agreed. And so June 1, 1929, marked the start of what is recognized internationally as an outstanding upland game investigation, with ruffed grouse research at the Cloquet Forestry Center continuing to this day.

Researchers set out to determine the factors responsible for fluctuations in abundance of the birds. In the 1930s, the first grouse researcher, Ralph King, developed a technique still commonly referred to as the "King Census Method." In the '60s and '70s, forest management for grouse changed based on Gordon Gullion's determinations that quaking aspen is the most critical species for the bird and that a mix of aspen sizes within a relatively small area constitutes optimum habitat. Gullion showed that crowded younger trees provide protection for the birds whereas the flower buds of mature male aspen are the primary winter food source.

Along with habitat understanding came prescriptions for the commercial harvest and successful regeneration of aspen—not a valuable timber resource at first, but today the one of the most widely harvested species in Minnesota. The hunt for grouse knowledge became more complex near the end of the last century, and serves as an example of how natural resource issues are interrelated, and that research-based knowledge is essential to make good decisions.

With the link established between ruffed grouse and aspen, questions of forest management became more important to wildlife managers. University expertise in forest ecology, modeling forest growth, remote sensing of woodlands, logging methods that minimize wetland disturbance, weighing competing social demands, and developing public policy all contributed to the 1990s discussion of Minnesota's future forests.

Research on the ruffed grouse continues, in the context of those issues and of increasing societal expectations of having more information and more say in how natural resources are managed. That is the role of the University of Minnesota, to provide the means to generate knowledge and make informed decisions on whatever natural resource challenges come to the front.
ENVIRONMENT

FROM REFORESTATION OF TIMBERLAND TO RESTORING THREATENED SPECIES

Long before there was an "environmental movement," University of Minnesota scientists were examining and promoting ways to conserve and protect natural resources. The forestry program was founded at the turn of the century in the shadow of widespread logging and influenced by a regional drive to convert cut-over lands to agriculture. The University responded by initiating research in reforestation and today develops and promotes practices for sustainable forest and wildlife habitat management in vulnerable areas here and throughout the world.

Our researchers lead projects in many countries promoting conservation and sustainable use of renewable natural resources. Application of our research in low-impact practices helps developing countries harvest their valuable forests in ways that will sustain their growth for generations. These innovative plans are typically two-fold: to design and apply management practices on the ground, and coordinate at landscape and regional levels. In doing so, support from research and education is essential.

From setting some initial standards for the federal Clean Water Act to writing Minnesota’s voluntary timber harvesting guidelines, University of Minnesota scientists have helped government agencies, legislators, and interest groups see both costs and benefits of management decisions. The University is acknowledged as a center of excellence for discovering how natural ecosystems and humans can coexist in a human-dominated landscape, and for designing policy and management approaches that reflect our values. Minnesota Agricultural Experiment Station research has shown there are many ways to create change: broad-based education, tax incentives, and one-on-one technical assistance are effective alternatives.

WEBLINKS
Fisheries, Wildlife and Conservation Biology
www.fw.umn.edu/Research/research.html
Social, Economic and Ecological Sustainability
www.fw.umn.edu/ssees/
Water Resources Center
http://wrc.coaes.umn.edu/research
C
The Minnesota River is one of America's 20 most endangered waterways. Most of the watershed is highly agricultural, with a significant urban influence in the lowest reaches. The University has long-term and widespread research involvement in the basin. In multiple projects, with funding from the National Science Foundation, Environmental Protection Agency, U.S. Geological Survey, and the Legislative Commission on Minnesota Resources, University scientists developed a watershed approach to study cumulative effects from the South Dakota border to the Gulf of Mexico. They analyze how the interaction of land-use, and management practices in the Minnesota River Basin will affect in-stream biological communities and export of sediments, nitrogen, and phosphorus to the Gulf.

D
One measure of lake or stream productivity is the number of fish living there and the size and health of those fish. Research in limnology—the scientific study of physical, chemical, meteorological, and biological conditions in fresh waters—began at the University in 1926 with "A Study of the Productiveness of Minnesota Lakes in Fish and Fish Food," supported in part by the Ten Thousand Lakes Association. That three-year study initiated extensive work on fish populations. Examination of the impact of Red Lake's Native American commercial fishing enterprise began in 1949 and tracked extreme population changes. Students assisting researchers learn many techniques to sample fish populations including electrofishing, trap netting, and gill netting—used later in jobs with natural resource agencies. This muskie was caught in a gill net and died; unfortunately a small percentage of fish die in the sampling process.

E
Habitat protection, the 1972 ban of DDT, and increased public awareness of the need to protect the species has helped Minnesota's breeding population of bald eagles soar from a federally threatened species to more than 700 breeding pairs.

University of Minnesota researchers were there at the beginning contributing to the discovery that eagle nests in places with little human contact yield the most young. That research led to federal guidelines to deter human interference during the nesting season. Thirty years ago, a graduate student approached this nest—likely weighing over 1,000 pounds—to check for signs of a successful hatch.

F
A unique long-term study on a stream near Afton, from 1965 to 1986, investigated the health and productivity of all levels of aquatic life. Mother Nature cooperated with a spring flood early in the study, allowing researchers to track how the fish and food populations responded to a disrupted habitat. The study's results led to increased understanding of 24-hour rhythms of the drifting aquatic insects and invertebrates, and to new methods to determine productivity in streams. Both findings are internationally recognized as groundbreaking.
Our natural resources form an interdependent web: forests need water to exist, and the quality of our streams and lakes is enhanced by forests that moderate runoff and purify water. Wildlife habitat, agriculture, and recreation rest in the balance.

It seemed simpler in 1903, when the new University forestry program emphasized reforestation and education to manage forest lands and prevent catastrophic fire. At that time, reforestation philosophy was adopted from proven methods of Northern Europe to "foster a fully stocked stand." Back then, research was focused on seeding and planting many trees per acre. Research to improve tree growth never stopped, but now foresters manage density by thinning and planting appropriately for diversity, health of the forest, other uses of the land, and ecosystem-wide concerns.

Demonstrating its stewardship heritage, Minnesota created some of the first statewide forest management plans in the mid-’70s. Today, U of M researchers provide key expertise to the team setting long-range management plans for the Chippewa and Superior National Forests in northern Minnesota as well as the teams developing water resource management plans for the St. Croix National Scenic Riverway and Voyageurs National Park.

University research that combines interrelated areas of natural resources has broadened the management vision. The interdependent web has been disrupted by exotic invaders such as Eurasian water milfoil, ruffe, zebra mussels, Dutch elm disease, purple loosestrife, and white pine blister rust.

This broader view—of forest growth and change, scenic values, recreation needs, bird and wildlife habitat, production of oxygen, and storage of carbon—is being adapted globally and embraced by the countries from which we borrowed our first ideas.
**A**

Eurasian watermilfoil is an aggressive, exotic plant that’s choking many Minnesota waters. It grows rapidly and tends to form a dense canopy on the water surface, which interferes with recreation, inhibits water flow, and impedes navigation. University of Minnesota researchers are exploring ways to control it using natural enemies rather than the expensive and intensive mechanical and chemical treatments currently in place. The native milfoil weevil, *Eubrychiopsis lecontei*, has caused milfoil decline in observations of milfoil samples in Minnesota lakes and in controlled tank studies.

**B**

U of M scientists have studied the white and red pines of Itasca State Park for almost a century. Their understanding of this well-documented forest’s ecology now helps forest managers in Minnesota and the world regenerate pine stands after logging or fire and shape vegetation mixtures to foster biodiversity.

In the early ’60s, studies at the park indicated that the picturesque pines were gradually being lost to wind, insects, disease, and overmaturity, and that root competition and shade were so intense that little natural reproduction was occurring. The University and the Minnesota Department of Natural Resources (DNR) developed management techniques to perpetuate scenic pine stands for future generations to enjoy.

University researchers also learn and share the results of an equally long, intensive study of limiting factors—soil type, moisture, nutrients, light, and competition from brush and other species at the Cloquet Forestry Center.

**C**

For more than 50 years, the Wilderness Research Center in the Boundary Waters Canoe Area Wilderness has served as the base of studies to understand the region’s ecology. By maintaining the most comprehensive biological survey reference for the area, the Center is a valuable resource for long-term studies. It documents changes such as the movement of nonnative species into the wilderness, and the impact of introduced tree diseases. Information gained applies not only to Minnesota but to similar boreal forests in Canada, Scandinavia, and northern Europe.

**D**

A decade ago Minnesota researchers led a focused effort to improve oak reproduction in the hardwood forests of southeast Minnesota. The wood of northern red oak is the most valued by the region’s furniture industry. They found that harvesting trees in the fall disturbed the soil when acorns were dropping and significantly increased the number of new seedlings; they also learned that seedlings on south-facing slopes were most successful.

Using shotguns, forest scientists also “harvested” leaves and acorns from the upper reaches of mature red oaks. Using isozyme analysis they sought to determine if pure northern red oak had hybridized with a less attractive oak species, which in some cases had occurred.

**E**

Many early tests to determine the adaptability of tree species to Minnesota conditions were made by the University of Minnesota. Studies are ongoing at the Cloquet arboretum, planted in 1922, and in plantations established at Itasca in 1910. In the first part of the century, plantings were also monitored at the Hormel Institute at Austin and the Mayo Institute of Experimental Medicine at Rochester. A mixed conifer plantation of more than 200 acres, established by a forward-looking University forester in 1914 to protect the Lake Vadnais water reservoir of the City of St. Paul, is still available for study and recreation.
RECREATION

Concepts to manage resources for a spectrum of experiences

Following World War II, improved roads, reliable cars, and a growing economy made the great outdoors more accessible to more people. The paradox: as people surged to our forests and wildlands, these areas became less wild and the visitors’ experience changed. Researchers developed the framework that helps balance resources and facilitate recreation. The science of outdoor recreation analysis is relatively new, but can trace much of its beginnings to the University of Minnesota and the USDA Forest Service, North Central Research Station in St. Paul. The first studies—in the 1960s—were of users of the Boundary Waters Canoe Area Wilderness, Itasca State Park, the Mississippi River, and Isle Royale National Park.

Forest Service, National Park Service, Minnesota Department of Natural Resources, and university researchers work cooperatively to develop strategies to manage natural areas to sustain both the resource and the human experience. Scientists developed the concept of “social carrying capacity” to help managers think in terms of how many people a given area can handle for a specific activity before either the experience or resource is degraded.

The only remaining social sciences research program of the National Park Service is at the U of M and involves studies of the nation’s most-visited national parks, including Grand Canyon, Yosemite, and Yellowstone. And, the College of Natural Resources is host to a new collaboration to study how human actions, including recreation, affect Great Lakes area ecosystems. Researchers are also expanding their focus from public lands to include resource-based tourism and the impact of private business on the natural resources that attract visitors.

Whatever one’s passion or pastime—hunting or fishing, cross-country skiing or hiking, snowmobiling, or ATV use—it impacts soils, vegetation, wildlife, water quality, and people. The science of recreation resource management combines sociology, psychology, economics, wildlife, forestry, fisheries, conservation, and public policy. With increased demand for recreation, research helps park, land, and water managers measure needs and resources and guides them in complex decision making.

WEBLINKS
Cooperative Park Studies Program
www.cnr.umn.edu/CPSP

Great Lakes Cooperative Ecosystems Study Unit
http://www.cesu.org/CESU/currentcesu/greatlakes
A
Twenty years of river recreation studies helped shape federal and state Wild and Scenic River legislation that now guides development of public lands along the St. Croix, Kettle, and Mississippi rivers and waterways across the U.S. University researchers developed the Water Resource Management plan for the St. Croix National Scenic Riverway and lead efforts to manage multiuse trails in the Snake River watershed.

B
Access to Minnesota's northern wilderness areas, particularly in the Boundary Waters Canoe Area Wilderness and Voyageurs National Park, is a recurring debate and has generated many studies to craft balanced policies for use. The first published University studies surveyed visitors in Minnesota's "canoe country" in the late '50s and documented emerging issues: campers were looking for amenities such as more picnic tables and better toilets, while the more self-reliant canoeists basically wanted the wilderness left alone. A five-year U of M Agricultural Experiment Station study in the early years of the BWCAW found that designated campites are greatly affected by soil compaction and loss of vegetation in the first two years of use but show little degradation after, and led to the designation of fixed campites. This 1970s era campsite, with a motorboat visible and audible to the campers, is now in a canoe-only area.

C
People choose a specific setting for their recreational activities and have underlying values and expectations. For example, hiking on a rough trail in a remote setting offers some visitors a sense of solitude, challenge, and self-reliance. In contrast, a short, hard-surfaced, interpretive trail with facilities offers others more comfort, security, and social opportunities.

U.S. researchers developed a framework—classifying land use from primitive to roaded-natural to rural to urban—that helps inventory, plan, and manage recreational experiences and settings. Managers use that framework to provide a spectrum of choices for people, so the benefits they seek (from solitude to family time to making new friends) are realized.

D
The concept of riparian area development "profiles," linking biophysical and social characteristics important to shoreland development, came from a collaboration of the USDA Forest Service and U of M researchers. Profiles can be used to identify potential development hot spots so policy makers, planners, and managers can take timely steps to manage or control the impacts of development. This is an acute need as Minnesota's lake country is in demand by younger retirees with increased recreational time and more money to spend on recreational activities.

E
Park and wilderness use increased dramatically in the 1970s, and Minnesota's BWCAW became the most heavily used wilderness in the nation. It was precisely that popularity that led the USDA Forest Service to regulate use, with entry permits required since 1966, and limited access beginning in 1976.

Visitors to national parks and wilderness areas are now made aware of ways to minimize their impact; research has documented that unrestricted use can damage and even destroy the natural environment people seek.
STEWARDSHIP

SUSTAINING RESOURCES WITH MANAGEMENT AND TECHNOLOGY

Minnesota is an area of ecological transition, with quality agricultural land and remnant prairies in the south and west, majestic forests to the north, and quality hardwood forests in the southeast. Private landowners have long been concerned with effective use of their land: Could the forested property be cleared and planted to agricultural crops? Should marginal farmland be allowed to return to forest? What is an appropriate buffer between row crops and streams? What will attract deer or grouse to the property?

University of Minnesota research that benefits nonindustrial private woodland owners has evolved over the last century from helping farmers efficiently cut and properly dry their lumber and preserve their own posts, to stewardship planning, wildlife habitat management, and shoreline revegetation. With more than six million acres of “family forest land” in Minnesota, research is shared with landowners through the University of Minnesota Extension Service and outreach programs, often including the Department of Natural Resources and federal agencies.

To guide state government in assisting landowners, researchers have evaluated tax incentive programs and surveyed forest owners. In the ’70s, in the first survey of its kind, U of M researchers asked Minnesota landowners how important it was to receive cost-sharing money to plant trees. One finding: two-thirds said they probably would have planted the trees anyway. Information from these surveys directed successful changes in tax laws, management advice, and set-aside programs in states across the country.

WEBLINKS
Department of Natural Resources
www.dnr.state.mn.us
Center for Continuing Education
www.cnr.umn.edu/CCE
U of M Extension Forest Resources
www.cnr.umn.edu/FR/extension
other wildlife. Today, researchers are discovering ways that income-producing crops, such as hybrid poplars or hazelnuts, can be incorporated into farmstead shelterbelts and field windbreaks to encourage long-term stewardship.

B

No surprise that prescribed fires for forest management are controversial. Minnesota history is marked by devastating fires and loss of human lives in the towns of Hinckley, Cloquet, Moose Lake, and others. In 1905, a neighbor’s brush-clearing fire destroyed much of the University’s first experimental pine plantation at Grand Rapids. Forest management in the first part of the century was mainly to prevent fire.

At Itasca State Park, researchers documented growth of the large pine stands and the chronology of fires from the early 1600s in their quest to understand forest growth and decline in natural (unlogged) forest land. Forest fires were common in the pre-settlement era, and regenerated sizable pine stands. Established by the Minnesota Legislature in 1891, Itasca State Park was an area to be protected from the wildfires that dominated headlines of that era. By mid-century, U of M forest ecologists discovered that “protecting” the pine forest would eventually lead to its demise. Pines were being replaced by shade-tolerant species, and in 1965 researchers published a forecast of how the forest would change over the next 200 years. Nearly 40 years later, we find that model to be relatively accurate. Experiments using logging, hand clearing, herbicide treatments, prescribed burns, planting, and natural seeding led to practices that ensure Itasca State Park pine stands will continue to be enjoyed by future visitors.

C

Trees in sensitive areas near wetlands are harvested in winter to protect water resources and aquatic life downstream. Innovative, low impact stream crossing devices such as inexpensive plastic pipes laid in a stream channel and covered with planks were tested and demonstrated to industry leaders in the Great Lakes area. The water flows uninterrupted, there is no silt disturbance—even if used in the summer—and 40-ton logging trucks pass over unimpeded.

D

Assessing the health, marketability, and wildlife habitat potential of family-owned forestland based on University of Minnesota research and modeling is a key step in the development of a stewardship plan for landowners. The state and contractors provide one-on-one technical advice to owners of family forestlands. Plans may also include the landowners’ financial and aesthetic goals for the property.

E

The University and the Minnesota Department of Natural Resources cooperated in a project designed to merge satellite images with information from ground surveys and aerial photos to provide Internet access to a comprehensive, current picture of what’s on the landscape. Maps produced with MapServer software—a U of M product—provide valuable composites of data that can help landowners plan timber harvests, protect unique areas, fight fires, or find a good spot to hunt or hike.

F

Permanent plot measurements carried out at the Cloquet Forestry Center since 1910 have shown the resilience of forests, what may be expected in terms of growth and yield, and how best to manage such forest tracts—be it for wildlife habitat, timber production, or recreational use.
BEFORE WE CAN MANAGE NATURAL RESOURCES, WE NEED TO KNOW WHAT IS IN THE ENVIRONMENT AND OBSERVE HOW IT HAS CHANGED FROM PAST RECORDS. FROM GROUND OBSERVATIONS TO RADIO TELEMETRY TO AERIAL PHOTOGRAPHY TO SATELLITE IMAGERY, NATURAL RESOURCE PROFESSIONALS AND SCIENTISTS GATHER DATA AND USE STATISTICAL METHODS TO EVALUATE ITS PRECISION AND ACCURACY. THESE DATA ARE THEN USED TO DRAW OUT INFORMATION FOR APPLICATION TO THE BROADER LANDSCAPE.

But it's not enough to know what's there now—managers also need the ability to look into the future to predict how the environment is likely to change. Early University of Minnesota researchers were world leaders in forest measurements and projections. The premier, early efforts in growth modeling and yield table development by University foresters in the '20s and '30s were used as the standard for all commercial tree species in the Midwest—these "Volume Yield and Stand Tables" are still of interest today. Computers enabled foresters to make better use of forest management data, and U of M researchers developed numerous forest growth, yield, and ecosystem dynamics models. Research at the U of M pioneered the application of statistical methods for model development and testing, and the incorporation of physiological processes in models.

U of M faculty back from World War II led the use of aerial photos to make efficient estimates of forest conditions and land use. Minnesota researchers were among the first to develop aerial photo volume tables—a cheaper, easier way to measure a large area quickly. The technology evolved in the '70s to include use of satellite imagery, but aerial photos remain important for many details.

In 1988, the University received a major NASA-funded natural resource project: a half-million-dollar grant to use satellite data to inventory Minnesota forests. Later, developments under the ForNet project kept Minnesota in the technological lead, and ongoing advances in high-resolution imagery make satellite images even more useful in areas such as lake water quality assessment.

Back on the ground, University scientists lead the world in "Bio Mathematics," with large-scale measures of game theory mathematically applied to animal populations. For example, researchers at Isle Royale modeled the effect of moose on boreal forest. Broader application ecosystem modeling predicts future landscape conditions with consideration of variables such as moisture, light, and possible climate changes.
Radio tracking of birds was a University of Minnesota breakthrough. The long-term ruffed grouse research at Cloquet adopted radio telemetry in 1961, greatly enhancing the study of behavior, territoriality, and dispersal. The technology was soon applied to woodcock, bald eagles, and Canada geese, making it possible to identify and study nesting and migration habits and the establishment of territories. U of M faculty also wrote a widely circulated handbook, *Techniques in Telemetry*, and observers here were the first to use telemetry to track wolves and moose.

The first experimental forests at the Cloquet Forestry Center were planted in 1910. Wood towers were used for precise measurements of week-by-week tree growth in specific stands, taking into account soil, moisture, temperature, and species.

This half-inch otolith, a fish ear stone, is from a 22-year-old freshwater drum caught in Red Lake. University fisheries biologists developed a "temporal signature" technique to accurately date the age of fish using the microscopic rings, and then match or calibrate it to the environment and climate in which the fish lived. Otoliths are frequently found in trash near places humans lived, and can help anthropologists accurately date sites and activities. After an overall chronology is developed, instead of knowing only how old a fish was, experts can determine what year the fish was hatched and which years were more or less productive.

Following World War II, researchers adapted wartime techniques to use aerial photos to gather data over large regions, and tested specialized cameras and photo paper to improve the process. Later, U of M scientists developed techniques to use readily available 35mm cameras at low altitudes. Aerial photos can measure tree heights with stereophotographs taken from slightly different perspectives, or help identify the ages and species of trees by their heights and crown sizes.

The University is a world leader in making information available and usable for agencies and the public, from developing the pioneering timber stand tables in the '20s to the MapServer software widely used today. Developed by College of Natural Resources researchers at the advent of the Internet, MapServer merges information from satellite images and existing ground sources into a data-rich picture of an area. It helps agencies and individuals quickly and accurately assess terrain characteristics for many uses, from predicting fire danger to planning forest regeneration. Enhancements to the software have extended its application to agriculture, environmental assessment, and urban development. Recently it was used to display where residue from a damaged oil tanker would flow in ocean waters.

Conventional measurements of timber stands such as this plot of red pine at the North Central Research and Outreach Center, Grand Rapids, help scientists calibrate and evaluate computer models of forest growth.

Throughout its history, the college has led the world in developing new techniques to assess our natural resources. The University's Remote Sensing Lab accesses satellite data, which researchers make user-friendly through innovations in computer software.
Can we have our natural resources cake and eat it too? Not until we begin making better choices. University of Minnesota researchers have investigated questions of life cycle analysis of products, helped industry produce more with less environmental risk, helped consumers make better decisions, and discovered new products and processes that lengthen the life of products made from wood. U of M researchers are also helping resource managers and land-use planners make better decisions by understanding the myriad social, ecological, and economic aspects of environmental issues.

Pioneering research by University faculty advanced the wood preservation industry in the United States and helped Minnesotans find commercial uses for their timber. By 1929, Minneapolis-St. Paul was described as the largest utility pole distribution and treating center in the United States. Studies in wood preservation continue to improve the service-ability of wood, saving trees, and saving budgets.

University research in moisture properties of wood is world-renowned. Basic research on the movement of liquids through wood provided the basis for closely related studies of the effects of chemicals and high drying temperatures on the strength of wood.

Researchers demonstrated in the 1970s that it was possible to make wood-like panels from such raw materials as cornstalks, wheat straw, and sunflower hulls. Processes that incorporate wheat straw into structural and nonstructural panels have recently begun to be commercialized in the Upper Midwest; perhaps marking the beginning of a major new industry based on agricultural residues. More recent research in the College of Natural Resources has examined the potential for using some of these agricultural by-products to supplement the use of wood fiber in paper production.

U of M scientists also shaped wood science and technology education through the publication of the world’s leading textbook in the field, *Forest Products and Wood Sciences*, now in its 4th edition.

**WEBLINKS**

Wood and Paper Science
http://www.cnr.umn.edu/WPS

Consortium for Research on Renewable Industrial Materials
www.CORRIM.org
fleets of planes similar to his giant wood airplane known as the "Spruce Goose." However, plans were scrapped when a cost-benefit analysis concluded it wasn't practical.

B

Birch and aspen occupy about one-third of Minnesota's forest land. With a shortage of harvest-sized aspen over the next several decades, Minnesota scientists in the 1980s developed processes to incorporate birch into panel construction. Wood from aspen and birch has very different properties, but U of M research overcame those differences, showing how birch could be used to supplement aspen in oriented strandboard production. Today, that research is being used to fill some of the gap in the aspen supply.

C

University of Minnesota scientists in aquatic toxicology worked closely with the Environmental Protection Agency to examine the effects of various pollutants on fish and invertebrates. Through research in fish growth and reproduction, they helped shape the initial federal Clean Water Act regulation of hydrogen sulfide and cyanide. Today, researchers investigate more subtle effects of endocrine disrupting compounds on fish reproduction.

D

Researchers continue to investigate ways to use wood residue for products, yielding profits while reducing the amount heading to landfills. Wood waste can be shredded and used for animal bedding, composted to improve soil, chipped for mulch, or burned as fuel. But University wood product researchers have explored other uses of by-products since the beginnings of the paper industry in Minnesota.

Early studies of the chemistry of cellulose and lignin (a by-product of paper manufacturing) were made in the 1930s. It appeared impossible to make a functional plastic containing more than 25 to 40 percent lignin until 1998 when a U of M wood chemist created a material composed of 100% alkylated kraft lignin that is similar to polystyrene in tensile strength. Methods were devised to injection-mold the material into tough pieces. Creating plastic from lignin provides a profitable use for surplus kraft lignin that cannot be used in pulp mills. And properly formulated, lignin-based plastics are easily biodegraded by common fungi. Finally, wood is renewable, while petro-chemical plastics are not.

More recently, techniques developed by U of M scientists use waste wood, kraft lignins, and waste plastics to create a durable product that can be extruded for windows, doors, siding, and building materials for decks.

University marketing researchers worked with the world's largest window maker in the world, located in Minnesota, to track prospective customer contacts and develop a highly successful "Prospect Management Plan" for windows manufactured with the extrusion technology.

E

In 1904, University researchers started testing the durability of treated and untreated fence posts—testing continued for more than 30 years. From a 1908-09 report: "About three thousand fence posts composed of basswood, cottonwood, willow, birch, hard maple, red oak, and ash have been treated with preservatives....The possibilities in the way of using our cheap woods ... with preservatives will last as long or longer than our best cedar posts. If the farmers of our prairies can be shown how to treat these ... it is an important matter." The findings found wide application throughout the wood products industry.
ALTERNATIVES

PROVIDING RESOURCE OPTIONS TO CITIZENS AND LEADERS

For every natural resource issue, there is often a multitude of approaches. Scientists synthesize the various alternatives, seek new options, and identify the value in each to help managers, administrators, and legislators make difficult choices about our lands and waters and the plant and animal life they support.

University of Minnesota researchers have assembled a wealth of data to analyze the costs and benefits of environmental practices, and have emerged as recognized leaders in shaping policy and legislation from local to international levels. The work is often multidisciplinary: U of M economists and silviculturists devised strategies to evaluate the benefits of county ownership of tax-forfeited lands, and analyzed whether tax incentives influence environmental practices used on family owned forests. And, researchers define optimal harvest rates for timber in Minnesota’s national forests using computer models developed here.

Research can take years, and sometimes results may not be visible for a generation or more. New approaches to natural resources are tested by researchers in other parts of the world, and by public agencies or commercial interests. Finally, public opinion must decide if the new idea sinks or swims. In the above examples, Minnesota’s forest tax incentive program and logging best-management practices have been very successful; both are now national models.

WEBSITES

Forest Resources research
www.cnr.umn.edu/FR/research/index.html

Minnesota Cooperative Fish and Wildlife Research Unit
www.fw.umn.edu/CO-OP/Co-op.html
While roads improve access to forests, they also change their character. Researchers found that almost eight million acres of Minnesota forests were lost from 1910 to 1990, most in the period up to 1950. Losses between 1930 and 1950 were primarily to agriculture; since then losses were due to expansion of transportation corridors and urban growth, in addition to conversion to agriculture.

University studies of fire history, forest ecology, acid rain, and water resources have helped shape USDA Forest Service regulations that strive to balance protection with accessibility in the BWCAW. Forest ecologists have documented 1,000-year-old “refuge populations” of white cedars, as shown. The trees survive fire and wind due to their location along the lakeshore and their short stature. The University has conducted ecological studies in this area since the early '50s.

University researchers investigated the effects of timber harvesting on soils and on water movement through forest soils in the '70s. In the '80s, a study evaluated the proposed harvest of 200,000 acres of peat in northern Minnesota to quantify the impact on stream and lake water quality. Based on that study, the peat harvest never happened.

After the logging boom in northern Minnesota, cut-over lands were sold for conversion to farms. But Herman H. Chapman, head of the University's Agricultural Experiment Station at Grand Rapids, saw that the soil was suited for timber, not agricultural crops, and believed land speculators were exploiting would-be settlers. He spoke out at the 1903 summer meeting of the American Forestry Association in Minneapolis, in a speech so controversial that he resigned immediately thereafter. Chapman's opinion was proven correct: much of the land's fertility was soon depleted, replanted with trees, ended up on county “tax forfeit” rolls in the '20s and '30s, and has been managed as county forests ever since, providing steady income to schools and local public services. Chapman was one of the first to recognize what many did not understand—that about 40 percent of Minnesota's land, almost 20 million acres, is much better suited to growing trees than food crops. The pine plantation he started at Grand Rapids in 1900 is a living testament to his pioneering efforts in reforestation.
College of Natural Resources researchers have played a key role in understanding and maintaining the genetic diversity of our fisheries and forest resources. The genetic modifications science is now capable of are tempered by an increasingly global debate over what scientists should do. We know we can make fish grow faster, which could help the fishing industry and hungry people in developing countries. But how would that change the world’s native fish populations? Faster growing fish may outcompete native populations for food and mating partners. If they reproduce, evolution of a species may be altered when unanticipated characteristics dominate, leading to changes in territoriality, seasonal migrations, and prey. Changes in enough individuals could alter the species’ traditional ecological niche.

University of Minnesota fisheries scientists were among the first to take a proactive approach to questions of risk, asserting that protocols for containment of altered fish, for instance, should be addressed up-front in the scientific process. This work led to development of the nation’s first set of guidelines to assess and manage environmental risks of genetically modified fish, and now plays a prominent role in creating international standards.

With tree geneticists, fast growth was the major goal through much of the last century, while recent interest lies in tree form, disease resistance, and fiber characteristics.

The longevity of trees makes for interesting science. Growth records, some now 100 years old, are fundamental to research. For example, selection of white pines resistant to blister rust disease began in the 1920s and continues today with new tools and much more rapid progress. Fundamental work is ongoing: such as, how far seeds can be moved from the climate in which they were produced and still thrive, which form and growth characteristics are the result of inheritance and which are shaped by environment, and which genes control certain plant characteristics.

**WEBLINKS**

Aquatic Genetics at U of M  
www.fw.umn.edu/AquaGen

Cloquet Forestry Center  
www.cnrf.umn.edu/cfc

North Central Research and Outreach Center  
www.ncroc.co.mn.edu
B

Pines are relatively new to Minnesota’s post-glacial landscape. White pine (cones shown) moved in from the east 2,700 years ago and were joined by red pine (seedlings shown) 1,000 years ago. In 1913, a major threat to white pine appeared: blister-rust disease. University research efforts have focused on identifying natural genetic resistance to the disease and understanding the conditions that limit its spread.

C

The Minnesota Tree Improvement Cooperative, a unique public/private collaboration of 30 members, was formed in 1981 to apply traditional genetic techniques to increase the quantity and quality of timber yields in the region by selecting and breeding trees that grow faster, have better form, and are more disease resistant. Certification ensures that the highest quality conifer seedlings are used to reforest public lands, informs private landowners of the geographic origin of seedlings they plant, and helps foresters understand the genetic consequences of their management activities. The Cooperative has bred white spruce that will grow 25 percent faster than wild trees.

D

The regional Aspen/Larch Genetics Cooperative at the University’s North Central Research and Outreach Center in Grand Rapids gives scientists the opportunity to improve hybrid, aspen, and larch seed production; and plantation establishment techniques. Long-term genetic research with aspen and aspen hybrids has shown gains of nearly 35% in height and more than 100% in volume growth. Ongoing work with larch species centers on seed selection to enhance adaptation and promote rapid growth.

E

U of M fisheries scientists developed the first microsatellite DNA markers for northern pike and walleye, enabling researchers to track single fish and families of origin by identifying the genes in a microscopic bit of skin attached to a fish scale. Researchers used the DNA analysis to compare survival of stocked walleye from two different sources. The findings will help guide state, federal, and tribal fisheries managers in their stocking programs.

F

University of Minnesota fisheries research has identified potential environmental impacts of releasing genetically engineered fish into natural waterways. Faster growing fish may outcompete native populations for food and mating partners. If they reproduce, evolution of a species may be altered when unanticipated characteristics dominate, leading to changes in territoriality, seasonal migrations, and prey. Changes in enough individuals could alter the species’ traditional ecological niche.
Everyday life of urban residents is improved by natural resources research that addresses indoor air quality, heating and cooling, building materials and techniques, landscape trees that provide energy savings and aesthetics, as well as wildlife and water quality near urban areas.

Today, U of M building researchers working with the American Lung Association’s “health house standards” have coordinated construction of 25 demonstration housing units in St. Paul to test the latest energy efficient, low off-gassing materials and techniques. Health professionals will monitor occupant health in a long-term study. In another partnership, 40 units will be constructed using unique panel construction, photo at left. The goal is to keep costs low and provide a more healthful house without sacrificing aesthetics or quality. The panels provide an interior finish, structural support, plus air and vapor barriers.

Long ago the University began its work in urban natural resources: The 1898 textbook Forestry in Minnesota by Samuel Green made recommendations for street trees, including mulching. “One tree well-planted is better than a dozen poorly planted,” he wrote.

University scientists, more than anywhere else in the country, specialize in improving planting techniques and controlling tree diseases to improve the health of the urban landscape. Long-term studies of established boulevard trees now guide utility work and street repairs to reduce damage. And, new, resilient species have been tested and published in the Right Tree Handbook used by major utilities.

WEBSITE
Minneapolis Indoor Air Quality
www.dehs.umn.edu/homeiaq

Great River Greening
www.greatrivergreening.org

Cold Climate Housing Program
www.cnr.umn.edu/WPS/extn/cxchp.html
University housing researchers recently partnered with the Wilder Foundation in a project to build 40 affordable and healthful homes in St. Paul. Chipboard panels—24 feet long, 8 feet tall, and 11/2 inches thick—replace the usual studs. University researchers will monitor humidity, dust mites and mold, which aggravate respiratory problems.

Minnesota’s urban areas benefit from College of Natural Resources studies as diverse as songbird habitat, protecting trees from construction damage, outdoor recreation, watershed management, forests’ role in the carbon cycle, and control of tree diseases.

A severe storm in October 1949 prompted the first study of the effects of wind on boulevard trees, which was publicized to help municipalities select and maintain trees. Getting trees to grow in the city isn’t so easy. Not only is the soil often infertile and compacted; urban foresters must be aware of power lines, sewers, and zoning laws. U of M researchers have shown arborists across the country that correct planting depth is critical to long-term survival. Improper planting prompts stem girdling roots that leave trees susceptible to blowdowns.

In the early ’50s, forest pathologists recognized the threat of Dutch elm disease and initiated studies to curb the spread. An aggressive control program of early tree removal and elimination of insect breeding sites allowed cities to save many mature elms and make a gradual transition to a future urban forest. The research is a national model, endorsed by cities that followed it. And, the concepts apply to unknown, future outbreaks in other species.

What started as an “endangered species” program—before the term was coined—is so successful that the Canada goose is now considered by many to be a pest. In the early 1970s the population exploded to about 25,000 goose because of ideal food and few predators. University research to limit growth began in the early ’80s, without which there would be at least 10 times as many as there are today. Experiments showed that only goslings too young to fly can be successfully relocated. Canada goose on park paths, golf courses, and athletic fields can be very messy neighbors, and flocks that congregate near an airport can cause expensive or life-threatening damage. Today, Minnesota goose management programs save more than $1 million a year in aircraft repair and down time, and the likelihood of an airliner colliding with a goose has been reduced by 90%.

A cold-climate research facility at the Cloquet Forestry Center allows researchers to examine energy consumption and moisture performance of wall and roof assemblies and indoor air quality concerns. Exterior walls and ceilings can be reconfigured to evaluate different combinations of insulation and vapor barrier materials in 14 chambers. Current research uses radiotopes to quantify and track building moisture. It will help answer questions like how much is absorbed through the basement floor or foundation, given off by wood as it dries, or enters around joints. This unique research also seeks to identify moisture contributors to mold and mildew growth—the cause of many health problems—from both inside and outside the house.

Enormous ice dams on roofs were common through the 1970s and caused extensive damage. University research and extension efforts showed that attic ventilation and insulation is the secret to keeping roofs cold and preventing snow melt. Homeowner and industry acceptance of these new practices spread to other northern states.
INTERNATIONAL

GLOBAL EXCHANGE OF IDEAS PROVIDES UNIVERSAL BENEFITS

Current headlines suggesting a new “global environment” describe what scientists have known for a century—that natural resource and environmental issues are universal, and sharing ideas on a global scale makes sense.

College of Natural Resources researchers have a history of international interaction: in 1900 founder Samuel Green went to Europe to learn forestry practices and education, and one of the college’s first graduates spent much of his career in the Philippines. As early as the ’30s, students from China, India, and Bolivia contributed to research investigations as part of their U of M graduate work.

When the University of Minnesota was selected to help restore Seoul National University after the Korean War, a U of M forestry professor served as chief adviser for the project.

Our researchers are more active than ever around the globe, advancing the scientific foundations for reforestation practices, management for endangered and threatened species from the tigers of Nepal to the bears of Taiwan, use and protection of watersheds, use of natural areas for recreation, indicators of forest sustainability, cautious guidelines for genetic research of fish, forestry research protocols, and forest product consumption effects on tropical forests. University research guides the organization of public resource agencies and the design and implementation of natural resource policies and programs, including tax and fiscal incentive policies.

These far-ranging interests give the college a global impact. Four out of five faculty have international experience that gives students opportunities and encourages two-way global exchanges. Hundreds of students, faculty, and research administratoirs from around the world have visited the college and returned to their home countries with a better understanding of the scientific support necessary for wise resource use, management, and protection.

As 1937 U of M forestry graduate and Nobel Peace Prize winner Norman Borlaug points out, research and education and sharing ideas is the only way to make positive, lasting change in the world.

WEBLINKS
Tropical Forest Conservation and Development
http://forestry.lib.umn.edu/bib/trps .phtml
Successful efforts to reforest barren land and other international natural resource management projects have benefited from a 30-year “institution building” program between the University of Minnesota and Morocco. U of M faculty helped Morocco establish a university focused on agriculture and natural resources: the Institut Agronomique et Veterinaire Hassan II (IAV). Today it is a respected education and research institution of 2,500 students.

More than 130 of IAV’s faculty received their Ph.D.’s through the U of M. Over 200 students completed their master’s degrees at Minnesota and more than 100 faculty from the U.S. made multiple trips to Morocco to direct their students’ research.

Following World War II, University of Minnesota and Scandinavian foresters developed an exchange of ideas and faculty. Comparative research in programs and policy led to progressive laws and programs here in Minnesota. Americans are accustomed to setting aside lands for a single use such as wilderness or a park, but in more densely populated Europe, most forests are multipurpose. Within the city limits of Oslo, Norway, this park shows evidence of logging near ski and hiking trails and lakes. Researchers found the Scandinavian public both more knowledgeable about and accepting of forest practices because they experience them first hand.

In developing countries, researchers examine how human domination and management has changed our understanding of diversity, fragmentation, and sustainability of forest resources. This pit saw in Rwanda is an example of indigenous knowledge and local technology that sustains the forest resource. Contrast this with a more mechanized, more economically efficient approach that causes greater environmental impact. We’re developing management approaches that balance the competing social, ecological, and economic aspects of sustainability.

Forests play an important role in the global carbon cycle. Since 1992, carbon sequestration laws permit industries in developed countries to pay land managers in undeveloped countries to protect and plant trees. University researchers evaluated new carbon mitigation projects in Chiapas, Mexico, from 1995 to 2001; goals shifted from improving the community to a sole focus on carbon sales by individual farmers. In a current study in a national park in Chiapas, graduate students are examining four-year-old plantings of native pines, comparing survival rates of trees planted by park service workers and community groups.

In developing countries of Asia, basic food production often competes with wise forest management. For example, if fuel for cooking is needed, forests are decimated and replanting stymied. University researchers work toward long-term, practical solutions to problems of deforestation, erosion, water quality, and hunger.

University of Minnesota scientists are actively investigating the many human factors that affect water quality. The research addresses aquatic ecosystems from a regional perspective, as opposed to traditional geopolitical boundaries that may ignore the interaction of water, geology, plant and animal life, soil, and other environmental realities. Some of the relationships investigated include forest harvesting, agricultural practices, urban development, climate, river basin classification, and ecological relationships between large and small rivers.

Locally, the St. Croix River process is a showpiece to the world of how to view and manage environmental issues collaboratively. Information for a Water Resources Master Plan involved many state and federal agencies. Up close, researchers investigated river sediment, snag habitat, and the invasion of exotic species. That was then expanded—using Geographic Information System technology—to a watershed view: adding housing, farmland, forests, roads, marinas, and industrial sites.

As society confronts choices about natural resources, U of M scientists provide essential information and a process for making informed decisions. The goal is to empower citizens and agencies to weigh alternatives intelligently and make defensible decisions, whether it’s the St. Croix separating Minnesota and Wisconsin, Voyagers National Park separating the U.S. and Canada, or the Nile River basin.
100 YEAR READING LIST

University of Minnesota researchers — past and present — have authored many books on natural resource topics. This partial list documents areas of expertise in the College of Natural Resources and the evolution of our depth of understanding during the last century. Also notable are the diverse audiences of Minnesota research: tourists, hunters, public land administrators, ecologists, students, international aid agencies, industrialists, children, campers, and farmers. Common to all the projects is the long-term investment that studies of the natural world require. In many of these cases that funding was provided by the Minnesota Agricultural Experiment Station. When scientists author a major publication, it is often the summary of a decade or an entire career of research. The following books are listed chronologically, by title. Many of these landmark publications are now only available through libraries. The University's Forestry Library maintains a general collection, and also provides worldwide indexes of publications in four areas: urban forestry; tropical forest conservation and development; trail planning, construction and maintenance; and social sciences in forestry; online at http://forestry.lib.umn.edu/.

- **Forestry in Minnesota**

- **Principles of American Forestry**

- **Farm Wind-breaks and Shelter-belts**

- **Scott Burton, Forester**
  Edward G. Cheyne; illustrated by Norman Rockwell.
  D. Appleton and Company, 1917. (Children's Book)

- **American Silvics and Silviculture**

- **Recreational Use of Wild Land**

- **The Farm Woodlot: A Handbook of Forestry for the Farmer and the Student in Agriculture**
  Edward G. Cheyne and J.P. Wendling.
  The Macmillan Company, 1926.

- **This Is Our Land: The Story of Conservation in the United States**
  Edward G. Cheyne.

- **Balsam Fir, Abies Balsamea**
  Egolfi V. Bakuzis and Henry L. Hansen, with contributions by F. H. Kaufer.

- **Fire and Ecosystems**
  Edited by T. T. Kozlowski and C. E. Ahlgren.

- **U.S. Investment in the Forest-based Sector in Latin America**
  Hans Gregersen and Arnoldo Contreras.

- **The Streams and Rivers of Minnesota**
  Thomas F. Waters.

- **Economic Analysis of Forestry Projects**
  Hans M. Gregersen and Arnoldo H. Contreras.

- **Forest Products and Wood Science: An Introduction**
  John G. Haygreen and Jim L. Bowyer; drawings by Karen Lilley.

- **Lob Trees in the Wilderness**
  Clifford and Elizabeth Ahlgren.

- **Managing Northern Forests for Wildlife**
  Gordon W. Gullion.

- **U.S. Wood-based Industry: Industrial Organization and Performance**
  Paul V. Ellefson and Robert N. Stone.

- **Guidelines for Economic Appraisal of Watershed Management Projects**
  Hans M. Gregersen, et al.

- **People and Trees: The Role of Social Forestry in Sustainable Development**
  Edited by Hans Gregersen, Sydney Draper, Dieter Ehl.

- **The Superior North Shore**
  Thomas F. Waters, illustrations by Carol Yonker Waters.

- **The Ruffed Grouse**
  Gordon W. Gullion; photographs by Tom Martinson.

- **Forest Resources Policy: Process, Participants, and Programs**
  Paul V. Ellefson.

- **Benefits, Environmental Risks, Social Concerns and Policy Implications of Biotechnology in Aquaculture**
  Anne R. Kapuscinski and Eric M. Hallerman.

- **Sediment in Streams: Sources, Biological Effects, and Control**
  Thomas F. Waters.

- **Water Quality: Management of a Natural Resource**
  James Perry, Elizabeth Vanderklink.

- **Hydrology and the Management of Watersheds**
  Kenneth N. Brooks, et al.

- **Lignin and Lignan Biosynthesis**
  Norman G. Lewis, editor, Simo Sarkkanen, editor.
  American Chemical Society, 1998.

- **Trends in Outdoor Recreation, Leisure and Tourism**
  Edited by William C. Gartner and David W. Lime.

- **Forest Dynamics and Disturbance Regimes: Studies from Temperate Evergreen-deciduous Forests**
  Lee E. Fredich.

- **GIS Fundamentals: A First Text on Geographic Information Systems**
  Paul Bolstad.

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