US FOREST SERVICE NORTHERN RESEARCH STATION

Research *Review*

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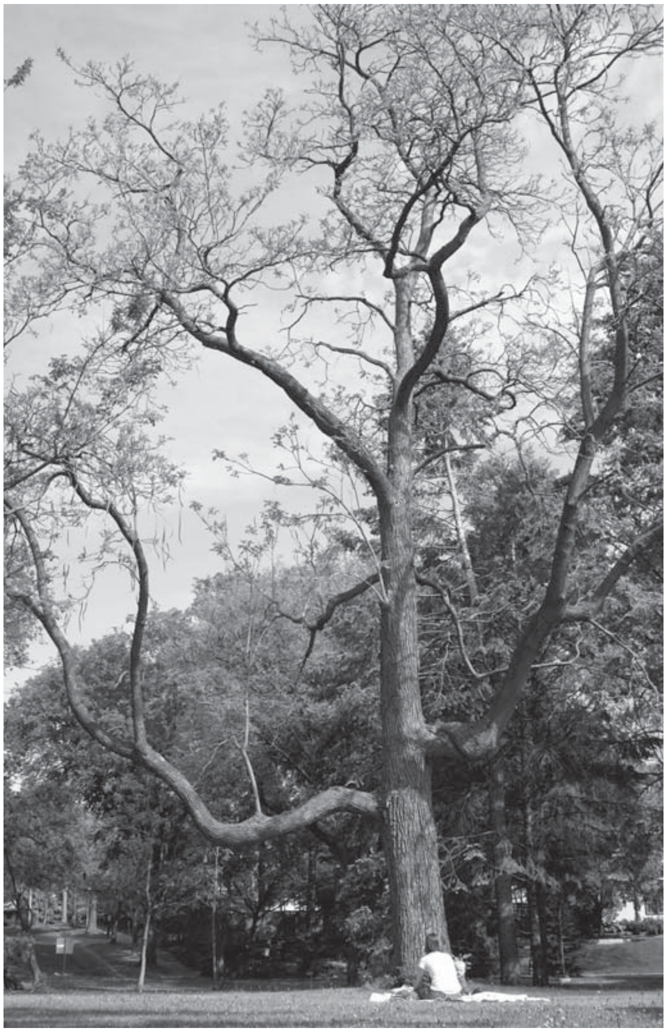
Study Suggests Tree Ranges Are Already Shifting Due to Climate Change



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Northern catalpa, a species that may thrive at higher latitudes if temperatures are warmer.

One of the big uncertainties of the global climate change phenomena is what will happen to trees. Although some predict that increased carbon dioxide levels could increase growth, what really concerns scientists and forest managers are the effects that changes in mean annual temperatures and precipitation patterns will have, not just on individual trees, but on forests and plant species distributions. The uncertainty raises many questions: What will happen to specific tree species as temperatures increase and a species' optimum temperature range moves northward? Will most spruce and firs, which thrive in the colder environments of mountain heights and higher latitudes, disappear from the central Appalachian Mountains? What about the spruce bogs in northern New England and Minnesota? Will iconic, economically important trees such as sugar maples "move" to Canada? Many trees are already under various stresses from invasive pests and diseases, and additional stresses could create major additional problems for individual trees and greatly change our forests. How will our trees and forests cope? There is concern that some tree species might disappear from parts or even all of their ranges if climate changes are severe.

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TIME IS OF THE ESSENCE

Trees cope with stress in the only way they can—mature trees will start producing more seeds. Those seeds will travel, as they usually do: some will simply roll downhill, others will be carried by wind or water, others by bird or squirrel power. Those that arrive in suitable places may sprout and grow. But with warming temperatures, places to the north that previously were unsuitable for a particular species may become suitable, and thus that species' range will have "moved," with more seedlings growing and thriving further to the north than before.

Tree ranges in ancient times certainly shifted according to changing climates, but the changes were relatively slow. Fossil plant and pollen records show tree species' ranges shifted northward a rate of 50 km per century as temperatures rose after the retreat of the North American ice cap. Such shifts are sometimes called "tree migration," but they are really changes in a species' population density and range. The more accurate term we will use here is "tree range migration." Scientists need a faster way to determine how global climate change is affecting tree ranges so that they can start working on mitigation activities. Already, computer modeling by Northern Research Station (NRS) scientist Louis Iverson (Delaware, OH) and his colleagues has predicted possible tree range migration patterns due to several climate change scenarios (see NRS Research Review #1). Now, however, Christopher Woodall of the NRS Forest Inventory and Analysis (FIA) team (St. Paul, MN) has discovered a way to detect changes—with actual tree data—sooner than waiting for the 15 to 20 years that most trees need to mature. In recently published results, Woodall's analysis of FIA data has found that some sensitive species are already showing range shifts northward. Some other species are not so sensitive, and they have shown little change.

FOREST INVENTORY AND ANALYSIS DATA SHOW FOREST CHANGES

The Forest Service has been collecting information about trees almost since its beginnings in the early 1900s. In the recent past (1971), the Forest Service published Dr. Elbert Little's well-known tree range maps, but they aren't sufficiently detailed for comparison to our current digitized databases. For more than 75 years, the FIA program has been the national inventory of United States forest lands. Formerly, the inventory


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FIA field crew members identifying and counting seedlings.

was conducted only periodically, using sample designs and data management systems that varied by state and inventory period. These historic forest inventories (pre-1970) cannot be compared to contemporary inventories in any statistically robust manner because of the lack of digital data, inconsistent methods, and the sparse documentation. Fortunately, since 2000, FIA has performed forest inventories that are consistent and comparable across the United States. These long-term, high-quality data have proven crucial to assessing how tree species ranges are being affected by changing climate.

70 PERCENT OF TREE SPECIES ARE SHOWING TREE RANGE MIGRATION

NRS scientist Christopher Woodall analyzed already-existing data from these inventories (30 eastern states and a total of 65,953 inventory plots) to compare tree seedling densities to forest biomass (as a surrogate for the seed source), thus determining if there are changes in regeneration patterns in a particular plot and across regions. For commonly found species, he compared current geographic distributions of tree seedlings (trees with a diameter at breast height less than or equal to 1 inch) with biomass (that is, mature trees, those with a diameter at breast height greater than 1 inch). For sets of northern, southern, and general tree species in the eastern United States, he found most northern study species are exhibiting a northward migration. This "range movement" northward occurs when more seeds germinate and seedlings thrive at the northern edge or higher elevations of the species' range than at the southern edge or lower elevations. Over 70 percent of this study's northern species have mean locations of seedlings that are significantly farther north than their respective mean biomasses.

Several tree species showed negative area changes, that is the areas in which they thrived decreased. From highest amount of decrease to lowest, these species are black spruce, bigtooth aspen, quaking aspen, balsam fir, paper birch, yellow birch, northern white-cedar, striped maple, black ash, scarlet oak, eastern white pine, red pine, eastern hemlock, red spruce, sugar maple, sweet birch, American basswood, hawthorn, sourwood, and northern red oak. However, these species may thrive further north, in Canada.

Southern species demonstrated no significant shift northward despite greater regeneration success in northern latitudes and general species showed a possible expansion southward. Given current tree regeneration trends identified in this study, the process of tree migration may continue or accelerate with a rate up to 100 km per century for numerous northern tree species.

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FIA field crew member measuring the diameter at breast height of tree.

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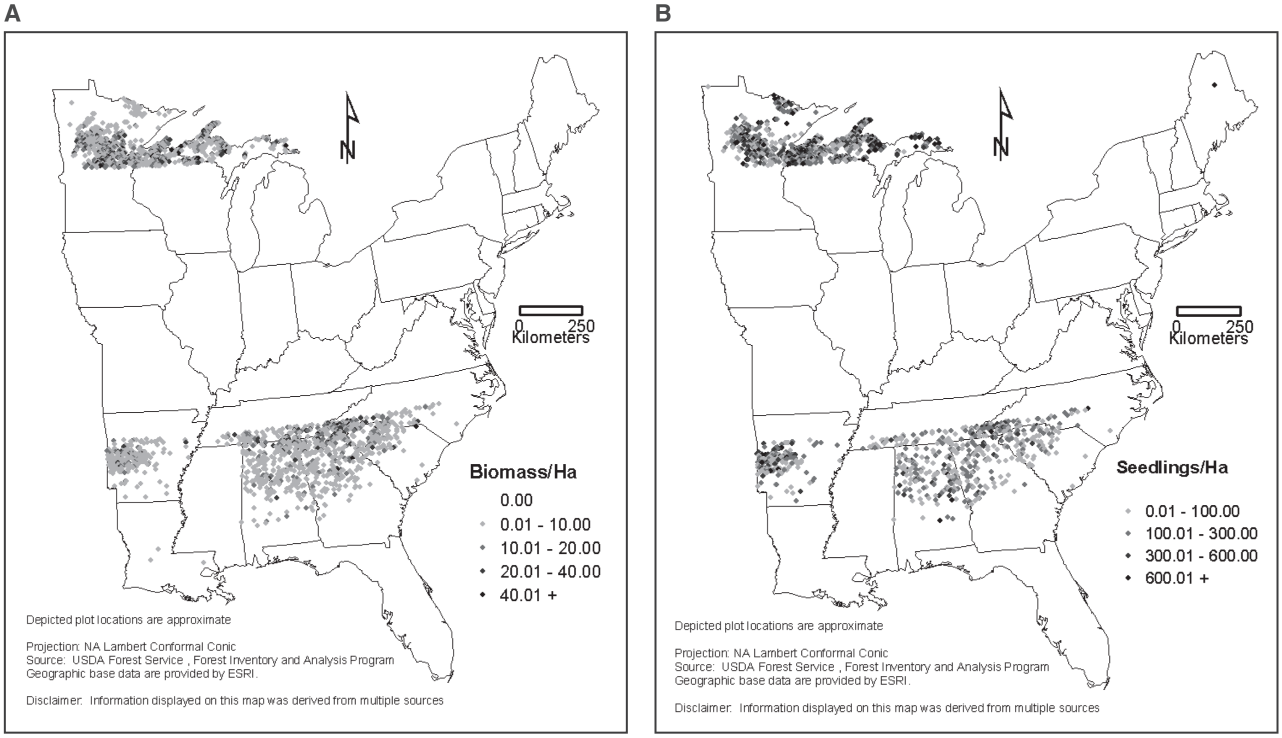
FIA field crew member locating a forest plot in the Upper Midwest.

Given these stark results and the multitude of caveats that surround this new indicator of tree species shift, future research and monitoring is highly warranted. Because forest management, both public and private, is a long-term matter, it is important that the effects of global climate change on species distribution be factored into forest planning. New species may need to be planted in woodlots and harvesting practices may benefit from alterations.

HUMANS AND URBAN FORESTS MAY PLAY A ROLE IN TREE RANGE MIGRATION

Woodall also compared tree species compositions in northern urban areas to tree compositions in forestland areas. He found that some tree species native to eastern U.S. forests of southern latitudes have been planted or are present in northern urban forests. The biomass density of urban tree species is typically less than half that of forestlands, with the majority of urban tree species found in nearby (< 100 km) forest land. Urban tree propagation is often facilitated by humans, whereas the necessary pollinators and agents of tree seed dispersal in forestlands may be lacking, regardless of climate change. These results suggest that urban areas may serve as a native tree seed source and a refuge for a limited number of forestland tree species, but also as a facilitator of nonnative tree invasion. Many scientists, foresters, and other tree professionals see that they may need to become "Johnny Oak-seed" and "Jane Maple-seed"—that is, transportation agents who move seeds and plant seedlings further north past barriers such as cities, lakes, and agricultural lands.



Mean tree biomass/ha (A) and seedling counts/ha (B) for northern pin oak above and below its 90th and 10th percentile latitude, respectively.

Although people's worries about global climate change most often focus on things like summer heat, drought, flooding, rising sea levels, and polar bears, there's another big worry that isn't so well publicized—the effects of all these changes on plants, particularly trees. People and animals can walk, run, swim, or fly to a more suitable habitat, but trees can't escape the heat.

Dennis May, Program Director,
Forest Inventory and Analysis, St. Paul

Christopher W. Woodall is a research forester with the Northern Research Station's FIA unit in St. Paul, MN. He received his bachelor of science in forestry (1995) from Clemson University and and his master of science (1997) and Ph.D. (2000) in forestry from the University of Montana.

His current work can be broadly summarized into various national and regional Forest Inventory and Analysis (FIA) program responsibilities involving research and coordination activities: Chair, FIA National Carbon Accounting Steering Committee; National Advisor, FIA Down Woody Materials Inventory; Supervisor, Northern FIA Carbon Accounting and Timber Products Inventory; and Lead Inventory Analyst, state of Indiana. His current research entails forest carbon inventory science, forest detritus dynamics research, refining the survey and analysis of forest products/biomass, and development of novel forest inventory analytical tools.

FOREST INVENTORY AND ANALYSIS—A VITAL FOREST SERVICE PROGRAM

For more than 75 years, the USDA Forest Service's Forest Inventory and Analysis (FIA) program has been charged by Congress to "make and keep current a comprehensive inventory and analysis of the present and prospective conditions of and requirements for the renewable resources of the forest and rangelands of the United States" (McSweeney-McNary Act of 1928).

FIA is the primary source for information about the extent, condition, status, and trends of forest resources across all ownerships in the United States. For the past 20 years, FIA has applied a nationally consistent sampling protocol using a quasi-systematic design and operates a three-phase inventory based on a carefully designed array of hexagonal sampling cells. In the north, 20 percent of the cells are sampled each year until all the cells have been sampled then the cycle begins again. Each cell contains a permanent sample location. Field crews visit sample locations with accessible forest land and collect data on more than 300 variables from fixed radius plots, including land ownership, forest type, tree species, tree size, crown health, lichens, soils, and other site attributes. (Sampling techniques are described in detail in the journal *Environmental Monitoring and Assessment,* Woodall et al. 2010.) All inventory data are managed in an FIA database (FIA-DB) that is publicly available [www.fia.fs.fed.us/tools-data/]. Annual inventories for each state in the north were initiated between 1999 and 2004, so sample intensities may vary by state. Data are analyzed for each state and published annually on the web, with more in-depth hardcopy reports published every 5 years.

Data prepared by FIA are used internally for preparing the Forest Service's Resources Planning Act Reports, Forest Health Management reports, and Forest Plans for the National Forest System. In addition, FIA data are vital sources of information for forest managers for other government agencies, tribal nations, state governments, forest industries, private landowners, academics, and forestry consultants.

Covering the country with a monitoring network that takes the pulse of forest health
—FIA motto

FIA

REFERENCES AND RESOURCES

Websites:

US Forest Service Climate Change Website Gateway: www.fs.fed.us/climatechange

USFS Northern Research Station, Forest Inventory and Analysis: www.nrs.fs.fed.us/inventory_monitoring

USFS NRS computer modeling site for tree and bird range migration: www.nrs.fs.fed.us/atlas

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Our research themes are (1) Forest Disturbance Processes, (2) Urban Natural Resources Stewardship, (3) Sustaining Forests, (4) Providing Clean Air and Water, and (5) Natural Resources Inventory and Monitoring.

There are 135 NRS scientists working at 20 field offices, 24 experimental forests, and universities located across 20 states, from Maine to Maryland, Missouri to Minnesota.