Joint Fire Science Program
Fire Science Brief
RESEARCH SUPPORTING SOUND DECISIONS

Field trip to the Menominee Indian Tribe. Credit: Dave Cleland.

The Great Lakes Landscape: Understanding Historic and Modern Fire

Summary

The Great Lakes region is characterized by diverse ecosystems born of significant glacial activity, a substantial and growing population density characteristic of the east, and until recently, some confusion about how historic and modern fire regimes of the area fit together. Dave Cleland and colleagues used extensive data sources including General Land Office (GLO) Survey data and modern literature to create models and maps that explain how the fire regimes associated with landscape ecosystems have changed from a pre-European era to modern times.

They found that historic rotations of forest fires ranged from only a few decades to more than a millennium, while modern day fire rotations are an order of magnitude longer for each landscape type. Interestingly, landscapes that were once the most fire resistant remain so, while those that were once more fire prone are still most vulnerable to fire even though the rotation intervals are far longer. Human activity explains the great change in fire rotation length, and has important implications for managers and planners. Maps showing historical fire regimes in the 60-million acre area offer information on fire risk, as well as vegetation, habitat, soils, and more. Cleland says that because the research relied on the detailed historic GLO data, it turned out to be the “best data set” he had ever worked with.

Key Findings

- Historic fire regimes of the Great Lakes region were characterized using ecosystem maps and reconstructed fire boundaries, which were based on GLO Survey and spatial statistics.
- Historic rotations of catastrophic forest fires ranged from periods of only a few decades within the most fire-prone ecosystems to more than a millennium within fire-resistant ecosystems.
- Modern forest fire rotations are an order of magnitude longer than historic rotations. They are more strongly linked to human ignition, detection, and suppression rather than the ecological factors that governed historic fire regimes.
- None-the-less, ecosystems that were historically highly fire-prone continue to burn far more than fire-resistant systems due to inherent flammability of living and nonliving fuels.

Introduction

The Great Lakes region is characterized by ecosystems born of significant glacial activity that ended 10,000 years ago, a substantial and growing population density characteristic of the East, and until recently, some confusion about how historic and modern fire regimes of the area fit together. Understanding the interplay between the landscape, human activity, and fire history is critical to managers who want more effective tools for restoration and management in a region where the wildland urban interface is not uncommon.

Enter Dave Cleland, a Landscape and Research Ecologist who works for both the Eastern Regional Office in Milwaukee, Wisconsin and the Southern Research Station in Athens, Georgia, USDA Forest Service. Cleland wanted a better understanding of natural disturbance regimes that affected landscape ecosystems in space and time. He also knew that researchers needed a more precise understanding of the terms "fire rotation" and "fire return interval."

He says, "fire rotation is the length of time necessary for an area equal to the entire area of interest (i.e., the study area) to burn (syn. fire cycle). This definition does not imply that the entire area will burn during a cycle; some sites may burn several times and others not at all. Fire return interval is the time between two successive fires in a designated area; i.e., the interval between two successive fire occurrences (syn. fire-free interval)."

Fire rotations or cycles usually are determined by calculating the average stand age of a forest whose age distribution fits a negative exponential or a Weibull function. In Cleland's research, fire rotations were determined by reconstructing historical fire boundaries across the entire study area, mapping landscape ecosystems that varied in both physical and biological properties affecting fire occurrence, and calculating fire rotations for each ecosystem type. Defining and using these terms allowed Cleland to map historic and modern fire regimes across a vast area while producing reliable estimates.

Originally the goal was to synthesize the literature, characterize the susceptibility of the area to fire, and map that to the different ecosystems of the region. But Cleland soon found that wasn't enough to address his questions. He says, "We started with what seemed like a simple proposal, and it mushroomed into something much, much bigger" than the proposal he first submitted to the Joint Fire Science Program (JFSP). To really do the job, he says the team "resorted" to the GLO Survey completed on the impetus of Thomas Jefferson in the 1800s.

Soon after the original JFSP proposal, "we got a lot more money from the Eastern Regional Office's Fire and Aviation staff, and formed partnerships with the Departments of Natural Resources in Wisconsin and Minnesota, which also funded GLO data development." Dr. David Mladenoff with the University of Wisconsin and Dr. John Almendinger with the Minnesota Department of Natural Resources lead the data development in those states.

"We had 11 people alone processing the data in Michigan for this project, along with concurrent data development in Wisconsin and Minnesota. It turned out to be the best data set I have ever worked with and it went way beyond the original scope of our intent," says Cleland. The data and results are now being used in a host of venues across the Great Lakes region and beyond.

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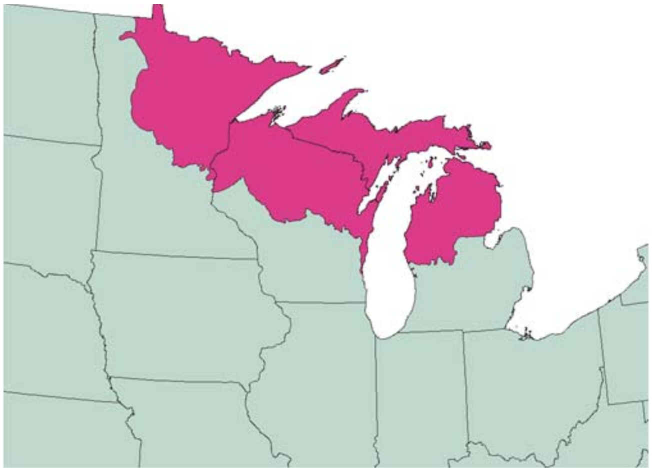
General Land Office Survey

The GLO Survey subdivided the United States into townships (36 square-mile units) and sections (square miles) to facilitate orderly sales and development of our nation. Cleland says, "We used the GLO data because we just couldn't use the available literature to characterize fire in this region due to limitations associated with the size and description of study areas, confusion between reported fire rotations versus fire return intervals, and widely varying estimates for analogous communities."

We used the GLO to map the boundaries of every fire that occurred across the 60 million acre study area in the mid-1800s. We also mapped wind, and openings (which are correlated with fire). This mapping effort gave us an accurate understanding of historic fires across this region."



The study area. Credit: Dave Cleland.

The researchers wanted to document changes in fire regimes in the area since European settlement. “An important initial facet of our research was to map categories of landscape ecosystems based on associations of ecological factors known to affect fire regimes,” says Cleland. “We addressed area effects on estimates of fire occurrence by studying fire regimes across a very large study area totaling 4,262,160 hectares. We reduced landscape heterogeneity by networking landscape ecosystems into fire regimes categories, and determined fire rotations within relatively homogeneous units. Also, we began to address long-term patterns by studying fires occurring in the early 1800s as well as modern fires.”

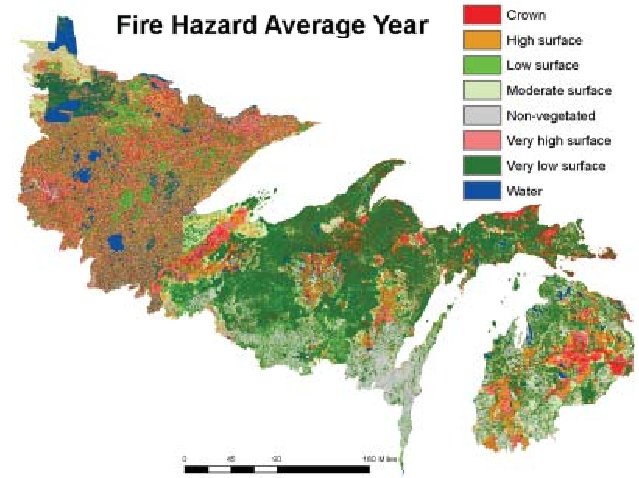
Next, the team compared the historic data to modern fire rotations. The GLO data gave a powerful look at fire in the past, but for modern fire rotations, the scientists went to the literature to compile detailed information on fire rotation categories. These ranged from short (less than 100 years) to long (greater than 1,000 years).

A vital aspect of the modern analysis was to “map categories of landscape ecosystems based on associations of ecological factors known to affect fire regimes,” according to the team’s 2004 *Landscape Ecology* paper. Thus, each fire rotation category is based on a careful ecological and physical analysis of the landscape itself, as well as its fire regime. With an understanding of the different fire regimes, researchers could then make precise measurements within these fire rotation categories. For each fire rotation category researchers were able to determine fire regime, fire intensity, ecosystem and forest type, soil and geology, fire return intervals, and fire rotation.

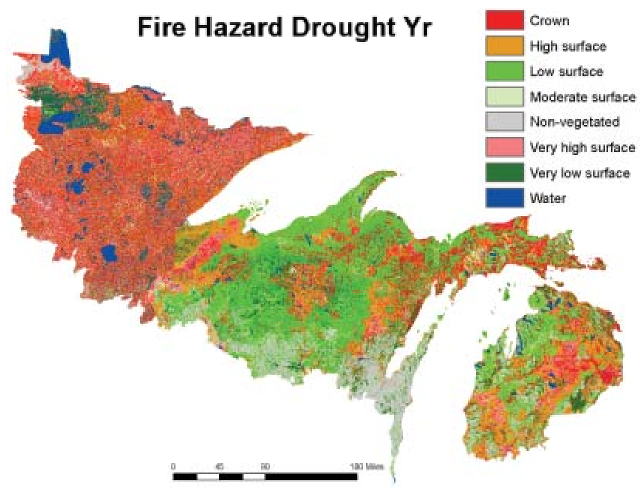
Predicting catastrophic fires

“The single most important result of this work, are the maps produced by this project that predict the likelihood of catastrophic fire,” says Cleland. Embedded in these maps, are a rich array of data and meaning now available to scientists, managers, planners, policy makers and more.

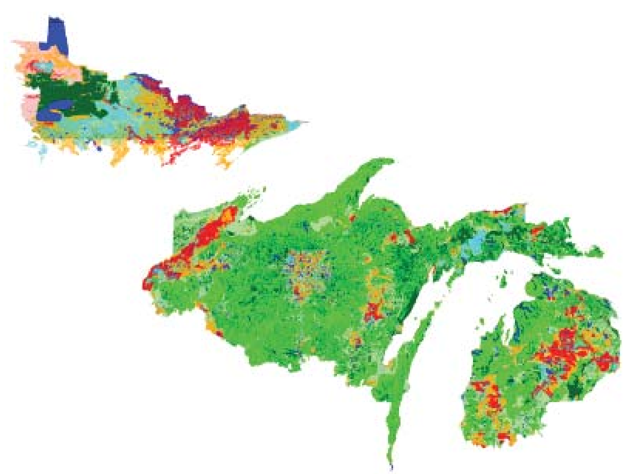
The maps depict historic fire regimes using the six fire rotation categories color-coded across a given region. With this, researchers can show data on the location and occurrence of modern fires. They can also create maps showing modern fire rotations and compare those to historic fire rotations. As a result, researchers can now predict the present-day likelihood of fire by coupling information on historical fire regimes with current landcover.



Likelihood of catastrophic fire in an average year. Credit: Dave Cleland.



Likelihood of catastrophic fire in a drought year. Credit: Dave Cleland.



Historical fire regime across the region. Color-coded areas signify different fire rotation categories. Credit: Dave Cleland.

Cleland and his colleagues have clearly shown that modern day fire rotations are much, much longer than historic rotations. Historic rotations ranged from periods of only a few decades for fire-prone systems, up to a more than a thousand years for the more resistant forest types. But they found that each of the categories today had rotations that were an order of magnitude longer than their historic equivalent. They write in their 2004 *Landscape Ecology* paper, "When averaged among all landscape ecosystems, fire rotations increased from ~250 years in the past to ~3,000 years in the present." This stunning change has important implications for humans and ecosystems alike.

The data suggest that the main explanation for the longer rotations typical today, is humans. Indeed, says Cleland, "We can't analyze the modern data without including information on fire suppression." Human activity including, ignition, detection, and suppression has extended the length of the fire rotations far beyond what they were when they were determined primarily by ecological factors. Curiously, the pattern of the most fire-prone to the most resistant still holds true. That is, ecosystems that were historically highly fire-prone continue to burn more often than fire-resistant systems due to the inherent flammability of living and nonliving fuels.

What does this mean for the people and ecosystems of the Great Lakes region? According to Cleland, "Our models show that these maps are the most important predictor of the risk of large fires." What's more, he adds, "some of these systems used to burn with great intensity, and in cases where fuels are the same, still do. The most severe fires burned every 50–100 years, releasing the energy equivalent to a detonated nuclear bomb. Today, these same areas are being suppressed to burning every 1,000–5,000 years. This is really important to understand and address in a landscape that still has plenty of fuel and dense human populations."

Beyond this, he adds, "The maps are used for much more than understanding fire. They can predict habitat, soils, vegetation, and more."

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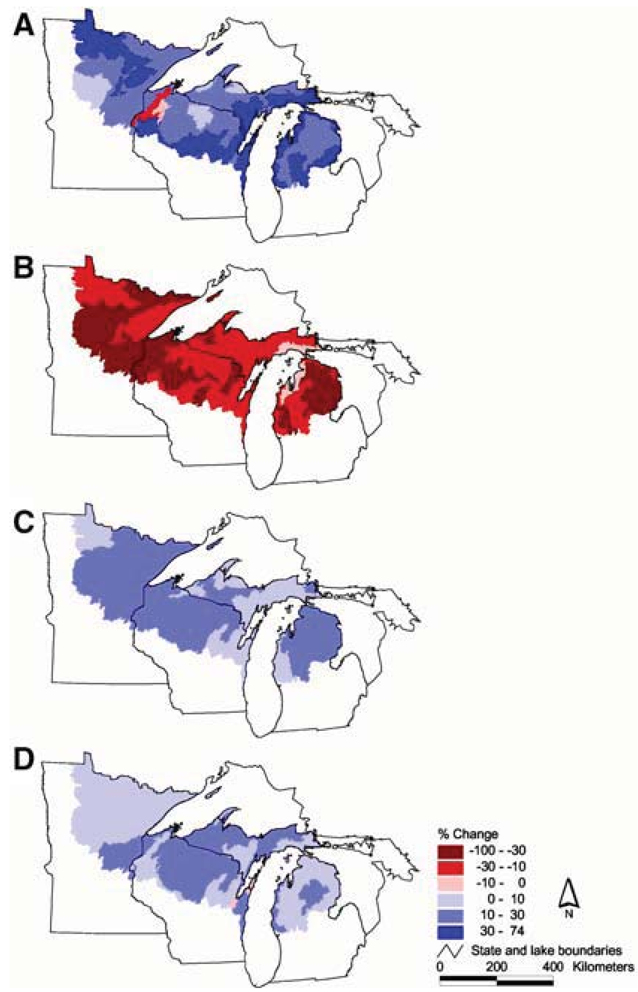
Meaning beyond the maps

Cleland and his colleagues now have a veritable treasure trove of research papers that—at their core—use the JFSP data described above to understand more about the region's ecosystems and to help clarify what the historic and modern fire regimes mean for the people of the area.

For instance, in a paper titled, Assessing Fire Risk in the Wildland-Urban Interface (WUI), published in 2004 in the *Journal of Forestry*, the researchers use these data to determine what areas of the WUI within the study region are prone to severe wildfire. They wanted to link this understanding to data on the numbers of people and houses within what they determined to be high risk areas. Cleland points out that, "There is often an assumption in fire research that everything always happens in the west (fire risk). But really, there is a small but significant percentage of the east where fire hazard is a real problem, and given the high levels of human development in primary and seasonal homes, high risk to people."

Another key story relates to the link between humans and fire. In their 2007 paper in the *International Journal of Wildland Fire*, Cleland and Brian Sturtevant, show how human presence is the major present-day driver of fire disturbance in northern Wisconsin. What's more they show that the biophysical factors of each area determine "whether those fire starts become large fires." They write, "Our results have implications for both ecological restoration and the management of fire risk within historically fire-prone systems currently experiencing rapid rural development."



The maps above show the changes in ecoregion characteristics in the northern U.S. Great Lakes region between pre-Euro-American land use and the present.

Map A shows the change to more open vegetation with the exception of the Bayfield Sand Plain and Bayfield Till Plain in western Wisconsin.

Map B shows the change and declining dominance of conifers throughout the region.

Map C shows the change and increasing dominance of aspen in the region (combined *Populus tremuloides* and *P. grandidentata*).

Map D shows the change and increasing dominance of maple in the region (combined *Acer saccharum* and *A. rubrum*).

Credit: *Landscape Ecology* 22/7/(2007), 1089-1103. Schulte et. al. Figure 3.

Meanwhile, there's the story about lake-effect snow of the Great Lakes region, published by the *Journal of Ecology* in 2007. Scientists Paul Henne, Feng Sheng Hu, and Cleland, found that lake-effect snow is the strongest dictator of abundance and type of forest vegetation. This relates to climate change since predicted change includes warmer weather and less lake-effect snow. Thus, they conclude, "Snowfall reductions will probably cause a major decrease in the abundance of ecologically and economically important species."

In addition, in a 2007 issue of Landscape Ecology researchers Lisa Shulte, David Mladenoff, Thomas Crow, Laura Merrick, along with Cleland, discuss the disheartening evidence for homogenization of the Great Lakes landscape. They found a dominance of broad-leafed deciduous species that had replaced conifer species. These data show a clear and striking change in ecosystem structure today relative to pre-European influence. The researchers also emphasize that this change will affect future ecosystem conditions and ecosystem services.

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Spontaneous ignition

The GLO-based mapping of historical fires is, says Cleland, "Something no one has ever done before. This analysis was very complicated, but it is a new and important contribution. Now, because of it, we have a host of folks using both the data itself and its meaning, in many different places."

For starters, the results are now being used by the Michigan Department of Natural Resources for forest planning, by the wildlife division for wildlife planning, for fire hazard mapping, by the Wisconsin Department of Military Affairs, and to improve the Course Scale assessment (for which Cleland wrote almost 2-dozen models). What's more, the LANDFIRE project is using these data as inputs into spatial modeling and as a quality control check point.

Based on the results of this work, Cleland also provided guidance to The Nature Conservancy's Global Fire Initiative, and data to the National Park Service and the Fish and Wildlife Service. Data are also being used by the Northern Research Station in the National Fire Plan-funded restoration ecology and silvicultural research. Cleland also, used these JFSP-funded results to teach journalists in a program sponsored by Institutes for Journalism and Natural Resources for the past three years.

Cleland recognizes the scope and magnitude of the results of this research. Many people and programs are benefiting from it. "This study got bigger and bigger, and more and more important and complicated. But it was rather life-shortening," he concludes with a wry grin.

Management Implications

- This research gives a depth of perspective uncommon today. The results invite managers, planners, scientists, policy-makers, and others, to understand with great depth and precision the historic and recent human-induced changes to a landscape.
- Fire risk in the eastern U.S. is important to understand and utilize in planning and management efforts.
- This study offers an abundance of data and meaning to help managers, planners, and others across the country (and in the east in particular), to understand changes in fire regime from pre-European times to the present.
- Management efforts must account for major changes to the landscape, fire regimes, and ecosystems themselves, as well as how they will look in the future given historic deviations from the pre-European era.

Further Information: Publications and Web Resources

Assessing Fire Risk in the Wildland-Urban Interface, Robert G. Haight, David T. Cleland, Roger B. Hammer, Volker C. Radeloff, and T. Scott Rupp. October/November 2004, *Journal of Forestry*.

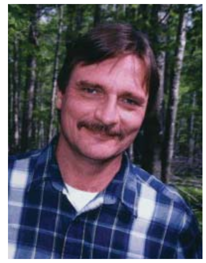
Characterizing historical and modern fire regimes in Michigan (USA): A landscape ecosystem approach, David T. Cleland, Thomas R. Crow, Sari C. Saunders, Donald I. Dickmann, Ann L. Maclean, James K. Jordan, Richard L. Watson, Alyssa M. Sloan and Kimberley D. Brosofske, Landscape Ecology 19: 311–325, 2004.

Lake-effect snow as the dominant control of mesic-forest distribution in Michigan, USA Paul D. Henne, Feng Sheng Hu, and David T. Cleland *Journal of Ecology* 2007.

Homogenization of northern U.S. Great Lakes forests due to land use. Lisa A. Schulte, David J. Mladenoff, Thomas R. Crow, Laura C. Merrick, David T. Cleland, Landscape Ecology, DOI 10.1007/s10980-007-9095-5. http://treesearch.fs.fed.us/pubs/12663

Human and biophysical factors influencing modern fire disturbance in northern Wisconsin, Brian R. Sturtevant and David T. Cleland. International Journal of Wildland Fire, 2007, 16, 398–413.

Scientist Profiles



Dave Cleland is currently the acting National Vegetation Ecologist with the Washington Office, USDA Forest Service. He was a Landscape Ecologist with the Eastern Regional Office, Milwaukee, Wisconsin, and a Research Ecologist with the Southern Research Station's Center for Forest Disturbance Science, Athens, Georgia, when this research was conducted. His interests are developing and applying knowledge of ecological patterns and processes at national to local scales for research, management, and policy applications.

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Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

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JFSP *Fire Science Brief* is published monthly. Our goal is to help managers find and use the best available fire science information.

Learn more about the Joint Fire Science Program at *www.firescience.gov*

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Joint Fire Science Program

Manager's Viewpoint

WRITTEN BY MANAGERS FOR MANAGERS

January 2009

Characterizing Historic and Contemporary Fire Regimes in the Lake States

Written By: Tom Remus

> **Purpose of this opinion piece**
>
> *Manager's Viewpoint* is an opinion piece written by a fire or land manager based on information in a JFSP final report and other supporting documents. This is our way of helping managers interpret science findings. If readers have differing viewpoints, we encourage further dialogue through additional opinions. Please contact Tim Swedberg to submit input (timothy_swedberg@nifc.blm.gov). Our intent is to start conversations about what works and what doesn't.

Problem

In recent years, the role of landscape-level fire history and modern fire potential has taken on a sense of urgency. Today, a unit land manager usually has a good idea of where on the landscape—and under what conditions—fires and catastrophic fires will occur. However, at the same time, land managers are increasingly asked to justify their fire management decisions. This study on Characterizing Historic and Contemporary Fire Regimes in the Lakes States contributes additional information to the Great Lakes Ecological Assessment (http://www.ncrs.fs.fed.us/gla/) and provides another broad-scale tool for unit and regional land managers to help make appropriate decisions on a landscape level.

Application by Land Managers: Identifying Fire-Prone Areas to Assist Planning and Decision Making

This research project by David Cleland benefits land managers by including historical data (General Land Office Survey) and modern human interactions on the land. Previously, most forestry-project planning has been done on a stand-by-stand basis. Thus, models (such as LANDFIRE) have such a large spatial coverage that drilling down to the project level is difficult. We, as managers, often go into our project-level planning and implementation feeling that these types of broad-scale datasets are too coarse for our necessary level of work. Inevitably, the data always seem to reinforce our "gut feelings."

So, while the General Land Office Survey might have some short-comings—being on a section line of separation and a snapshot in time—I feel it provides historical data that often confirms our suspicions and anecdotal information. Thus, reinforcing the "gut feelings" that surface when we view today's ecological conditions.

Fire risk assessment in the Great Lakes region is complicated by the complexity and spatial diversity of fire regime change, influence of glacial geology, and, to a lesser degree, post-settlement land use.

The Fire Regime Condition Class concepts are applicable in this region. However, they are not driven by altitude or topography, but by the overlapping glacial substrates left by overlapping glacial epochs. While good fire dendrochronological research exists in some locations (for instance, Boundary Water Canoe Area, Itasca State Park, Minnesota), this broad-scale research product identifies fire-prone areas in a manner that land managers can use in planning processes and other decision-making ventures.

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Forest site conversions happened on a huge scale throughout the Great Lakes region with the logging practices of the 1800s. Conversion of vast tracts of fire-dependent pine species to early successional species (such as aspen) has exacerbated the influence of fire-suppression practices on skewing the fire return interval.

While this might not increase the risk of catastrophic fire in all cases, it does have ecological and social implications. An example of a social and economic concern is how do we convert short-lived/low-value species to long-lived/higher-value species that are more suited for drier sites? When fire return intervals have become “off course,” this can be difficult to achieve.

Common Conundrum Faces Fire Managers

The historical role of lightning fires across the landscape proves to be a common conundrum facing fire managers who wish to reintroduce fire for ecological benefits. The number of lightning fires in this Great Lakes region in modern time pales compared to the human-caused fire count.

If left unchecked, what would the cumulative effect of these human-caused fires be?

If left unchecked, what would the cumulative effect of these human-caused fires be?

Even though fires started by Native Americans apparently were more common and had more influence on the land than lightning, this question remains an interesting one. Many Native American land fire managers have postulated that the number of historic ignitions—or possible fire starts—were similar to today. In other words, historically, fires started by Native Americans occurred across the landscape, but generally were more frequent around areas of settlement and habitation. Additionally, just like today, these fires’ intensity, severity, and ability to increase in size and area would be contingent on the site’s dryness. Thus, Cleland’s point holds true—then and now. The historical fire return interval would therefore be shortened even more.

Manager Profile

Tom Remus graduated with a B.S. in Forestry from the University of Minnesota in 1985. He started his wildland fire career in the early 1980s with the National Park Service in a variety of seasonal positions. In the early 1990s, he began working for the Minnesota Department of Natural Resources. In 2002, he became the Regional Fuels Specialist for the Bureau of Indian Affairs' Midwest Region. In 2008, he accepted his current position with this agency as regional Fire Management Officer.

The information for this Manager's Viewpoint is based on JFSP Project 98-1-5-03, Characterizing Historic and Contemporary Fire Regimes in the Lake States; Principal Investigator was David Cleland.