



United States Department of Agriculture
Forest Service



Science

FINDINGS

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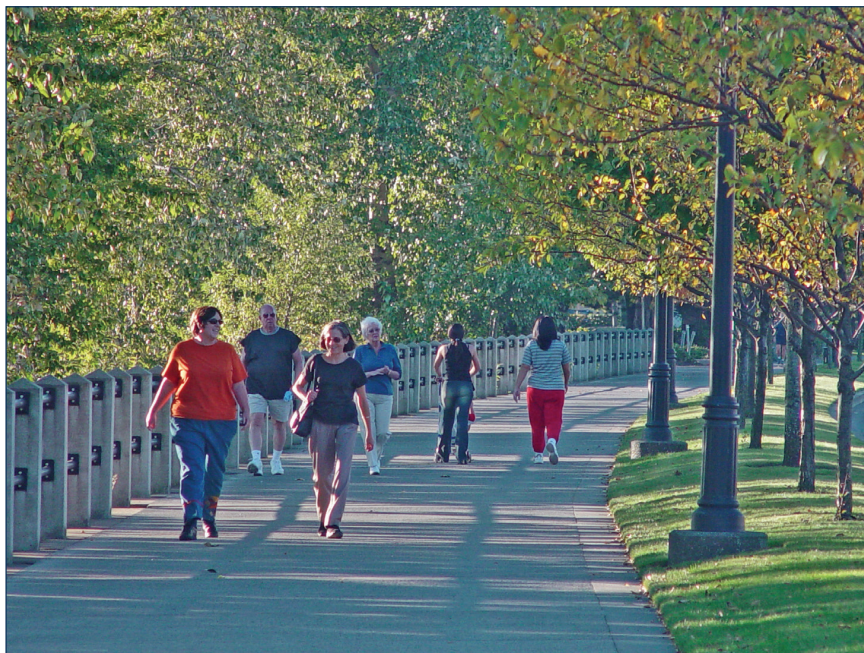
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"Science affects the way we think together."

Lewis Thomas

Exploring Connections Between Trees and Human Health



Guy Kramer

New research shows a connection between tree health and human health.

*"Life on earth is inconceivable
without trees."*

—Anton Chekhov

Beginning with the earliest cultures on Earth, humans have revered trees. Poets, philosophers, and painters celebrate trees in their writings and art, and some version of the "tree of life" has been used in religions throughout the world to metaphorically represent ideas about life and death. We enjoy trees for a variety of reasons and intuitively understand that their presence is good for us, but can we quantify the relationship between trees and human health?

In recent decades, access to nature has been correlated with a striking number of mental and physical health benefits in humans. Recent studies in the health field have shown, for example, that being in nature reduces the biological markers of stress, relieves symptoms of depression, and increases white blood cell counts. Walking in a forest reduces heart rate and cortisol levels. Although these studies support the health benefits of nature in general, few studies have focused specifically on trees.

Can the impact of trees on our lives be measured? Under what circumstances might they be essential to human health and survival?

IN SUMMARY

Humans have intuitively understood the value of trees to their physical and mental health since the beginning of recorded time. A scientist with the Pacific Northwest Research Station wondered if such a link could be scientifically validated. His research team took advantage of an infestation of emerald ash borer, an invasive pest that kills ash trees, to conduct a study that gets closer to a definitive connection between the loss of trees and increased human mortality.

Researchers analyzed data on demographics, tree loss from the emerald ash borer, and human mortality from lower respiratory disease and cardiovascular disease for 1990 through 2007. Results showed that the spread of the emerald ash borer across 15 states—first recorded in 2002—was associated with an additional 15,000 deaths from cardiovascular disease and an additional 6,000 deaths from lower respiratory disease. Human mortality increased the longer emerald ash borer was present and killing trees. Deaths occurred at higher rates in wealthier counties, where more trees are typically found in urban areas.

Although the study doesn't establish causation, it does suggest a link between trees and human health. This information can be applied to a range of fields including public health, urban forestry, and urban planning.

So far, only three studies have tried to answer these questions, and Geoffrey Donovan, a research forester with the Pacific Northwest Research Station, has conducted two of them.

Donovan's first study, which found a link between trees and human health, was published in *Health & Place* and discussed in a *Science Findings* article in 2011. It found that women with more trees around their homes were less likely to have underweight babies and raised some profound questions in Donovan's mind about the nature of our relationship with trees. He began to frame a second study that would get closer to establishing a cause-and-effect relationship between humans and trees.



KEY FINDINGS



- The spread of the emerald ash borer, which poses no direct threat to humans but has killed more than 100 million trees in the United States, was associated with an additional 15,000 human deaths from cardiovascular disease and an additional 6,000 deaths from lower respiratory disease.
- Human mortality increased the longer emerald ash borer was present in a county, consistent with the progression of the insect infestation. Infected trees typically die within 2 to 7 years.
- More human deaths occurred in wealthier counties, where trees usually are more abundant.

CONTROLLED EXPERIMENT CONUNDRUM

Unfortunately, scientifically proving that trees enhance human well-being is exceptionally difficult, primarily because of the serious obstacles scientists confront when trying to design a controlled experiment.

Let's say a researcher wants to prove that a certain medicine reduces blood pressure. He or she selects 100 people and gives half of them the medicine and half a placebo. If people in the treatment group have significantly

lower blood pressure a reasonable assessment is that the drug works. Now imagine trying to design a similar study to determine whether trees improve human health. You might build 100 houses, plant trees around half of them, and wait 50 years for the trees to grow to maturity. Unfortunately, you would need to find ways to control for numerous social and economic influences that could shift and change over the period of the study, and—more significantly—prevent the study participants from moving during those 50

years. Clearly, an experiment of this sort is completely impractical.

For a long time, Donovan just could not find a realistic scenario in which a controlled study would work. Then one day, he realized that it might work better to reframe the question.

"You just need to see the problem differently," he says. "Rather than looking at the effect of trees on health, what about looking at the effect of loss of trees on health?"

NATURAL EXPERIMENTAL DESIGN

Once Donovan turned the question on its head, he saw that he might be able to take advantage of the aggressive spread of an invasive pest.

The emerald ash borer is a metallic green beetle native to East Asia that hitched a ride on wooden pallets or packing materials and landed in North America sometime prior to 2002. The beetle kills ash trees by burrowing into the inner bark, making it impossible for water and nutrients to reach the tree's crown. All infested trees die within a remarkably short period of time: 2 to 7 years.

"It doesn't matter if they're stressed or healthy," says Donovan. "They're all going to die—it's a ferocious thing." Between 2002 and 2010, the emerald ash borer was responsible for the death of more than 100 million trees in 15 states in the United States.

Although the emerald ash borer has no direct effect on human health, Donovan wondered if its environmental impact was indirectly affecting human health. For the purposes of this study, the insect was a convenient, fast-acting tree killer. Within a short period,

residential streets lined with mature ash trees had little to no tree cover. Because the natural environment changes significantly and quickly where the emerald ash borer takes hold, it eliminated the need to wait decades for trees to grow and then see what happened after they were gone.

"Rather than wait 50 years for a tree to grow, I had to wait only 5 years for a tree to die," he says. "Straight away, you've dealt with the problem of change over time."

The emerald ash borer also alleviated the other significant study design problem: accounting for complex demographic variables that could confound a study's findings.

"One of the problems you get when you do any type of work with trees—and this isn't just human health, it could be house prices or energy and anything—is that you get a nice tree/nice neighborhood effect. So the nicest neighborhoods tend to have nicer trees. Nicer neighborhoods also tend to have people who are richer, better educated, and a whole lot of other things," says Donovan. "It gets kind of tricky, which is why not many people are doing this type of research."

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Debbie Miller, Bugwood

The emerald ash borer, native to East Asia, was first confirmed in North America in 2002.

In medicine, the most respected type of clinical trial is a randomized control trial, and fortunately for Donovan, the emerald ash borer's haphazard spread mimics this method.

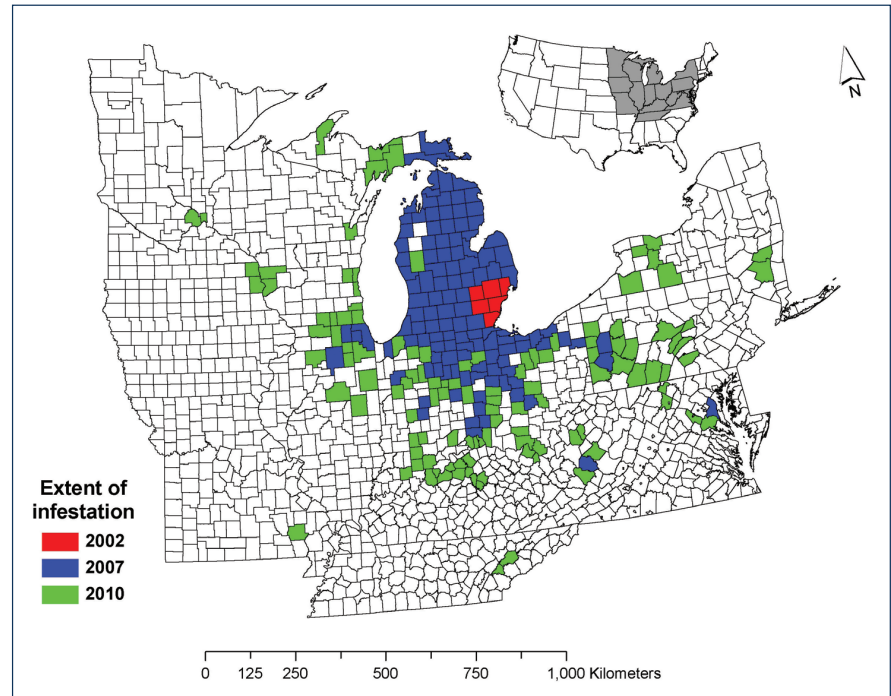
"This insect moves fairly quickly and erratically. It flies to the next tree, but also it's transported by firewood," he says. "For our study, this was fantastic because its spread isn't correlated to demographics; it's not correlated with income, with race, or with education. I realized that we had a unique opportunity."

Donovan and his multidisciplinary research team collected data on the spread of the emerald ash borer from the Agricultural Plant and Health Inspection Service, and on tree cover from the U.S. Geological Survey. Demographic data for 1990 through 2007 came from the U.S. Census. Through the National Center for Health Statistics, the team compiled data on human mortality for the same time frame in states where the emerald ash borer had devastated ash populations; the longer time frame allowed the team to see what changed as the emerald ash borer was introduced and tree mortality increased.

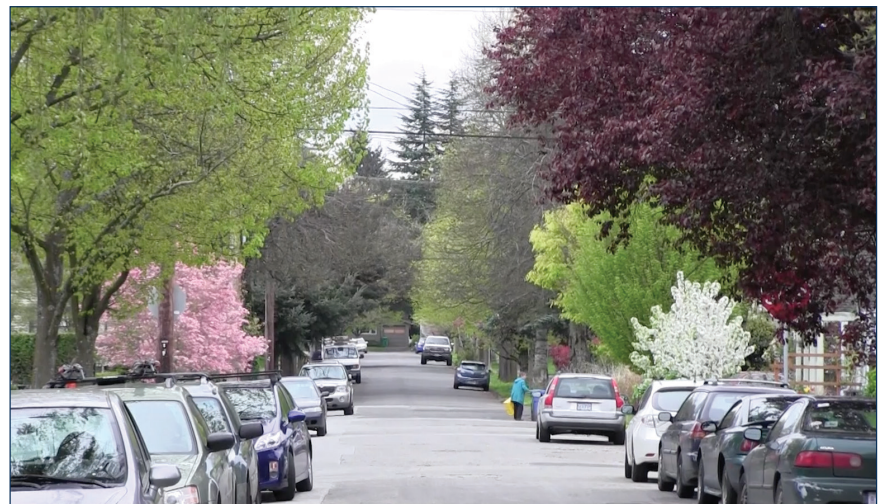
The study focused on two causes of human death that perhaps could be affected by trees: lower respiratory disease and cardiovascular disease. Poor air quality and stress are risk factors for both diseases, and trees can improve air quality and reduce stress.

"You put people in a natural environment and blood pressure and heart rate go down, as does salivary cortisol, which is a stress hormone," says Donovan. "It sort of makes sense that the sudden removal of trees would have the opposite effect."

After collecting the data, the team used fixed-effects regression models to estimate the relationship between county-level mortality rates



Counties where the emerald ash borer was detected in 2002, 2007, and 2010.



Frank Vanni

Urban trees purify the air, modify ambient temperatures, reduce storm water runoff, and generally make cities nice places to live. This is the first study to examine links between the sudden loss of urban trees and human health.

and trees lost to the emerald ash borer. The models accounted for potential confounders such as education, income, and race. The models also included a linear time-trend to account for broad trends in mortality—improved medical technology, for example—that would not be captured by demographic variables. A 1-year lag of mortality rate also was included to address temporal autocorrelation—a statistical consideration when a

single variable (in this case, mortality rate) is analyzed at different points in time.

Finally, a variable denoting the amount of ash-canopy cover in a county was included—if the presence of the borer has a negative public-health effect, then one would expect the presence of ash trees to have a positive effect, especially in counties not yet infested.

Results showed that the spread of the emerald ash borer across 15 states was associated

with an additional 15,000 deaths from cardiovascular disease and an additional 6,000 deaths from lower respiratory disease. Human mortality increased the longer the emerald ash borer was present in the environment and killing trees. Deaths occurred at higher rates in wealthier counties, where more trees are typically found in urban areas.

Donovan is careful to point out that the study's results don't prove causation. Instead, he says these results show a strong association. "Similar methods helped scientists understand how cholera spreads and identified a link between cigarette smoking and lung cancer," he says. "Sometimes it's impractical or unethical to conduct randomized controlled experiments; in these cases, observational research can provide valuable insight."

Neither does the study provide direct insight into how trees might improve mortality rates related to cardiovascular and lower respiratory-tract illness, but it does suggest that plausible factors might include improved air quality, stress reduction, increased physical activity, and more moderate temperatures. Further research might reveal these details.

"You're dealing with degrees of proof," he says. "There are a lot of questions to be answered, and this is not the final word."

SO FAR, NO CAVEATS

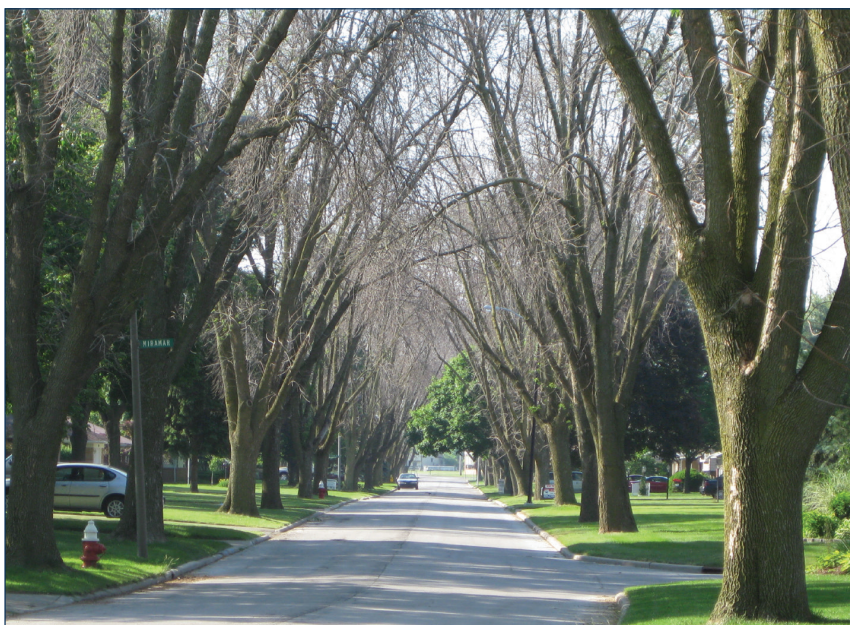
As with any good study design, once the model provided results, the team set about trying to disprove them. "Don't be gentle with your own results," warns Donovan. "I found a relationship where there could be one, but it's important that there is no relationship where I know there can't be one."

One of the ways he tried to "break" the model was to test the effect of emerald ash borer infestation on accidental death, because there would be no conceivable link between those events. Indeed, he found no connection. "Now, that isn't a control in a formal sense, but it's encouraging," he says.

People often ask Donovan whether the emerald ash borer preferentially attacks stressed trees, thinking that the factors that stress trees could also stress people and perhaps explain the higher human mortality rates. They also wonder whether, since mortality was higher in wealthier neighborhoods where pesticide use might be more widespread, humans might have accidentally poisoned themselves.



2006: A street in Toledo, Ohio, prior to an infestation of emerald ash borer.



2009: The same street in Toledo, Ohio, after the emerald ash borer arrived.

Donovan is clear, however, that neither concern is relevant to his findings.

"Some pests do preferentially attack stressed trees: pine beetles, for example. However, the emerald ash borer kills all 22 species of North American ash, and it kills virtually all untreated trees," he says. "I didn't control for pesticide use, but I don't think it was an

issue for two reasons. First, effective pesticide treatments hadn't been developed by 2007, so pesticides weren't out there much. Second, pesticide treatments are either injected into the trunk (these are most common and most effective) or applied as a soil wash; so there wouldn't be a lot of incidental exposure."

Dan Hermis

Dan Hermis

LIVABILITY OR SURVIVABILITY?

Few would disagree that greenery, especially trees, makes urban environments more “livable.” Trees cool the air, break the monotony of gray sidewalks and parking lots, reduce crime, increase property values, and provide many other benefits. But simply saying that trees make neighborhoods livable may be missing the point.

“I would argue that trees may make a city survivable, not livable,” says Donovan. “That’s what the results of this latest study suggest. There is something fundamental about the human condition and exposure to the natural environment; cities make that problematic, and perhaps trees are one way of allowing us to survive in these environments.”

Donovan’s study suggests that urban planners might increase survivability in cities by considering trees as an essential part of the environment, rather than an amenity. “Talk about trees and parks alongside transportation, infrastructure, law enforcement, and things like that,” he says. “Planting trees is an easy way you can modify the environment, so this study is very policy relevant.”

“The wonder is that we can see these trees and not wonder more.”

~Ralph Waldo Emerson



MANAGEMENT IMPLICATIONS



- The association between human health and trees is quantifiable, as demonstrated by examining the effect of tree death on human health. Entities such as public health agencies, urban forestry departments, and city planners can use this information in their decisionmaking.
- Trees are widely available, inexpensive, and offer many benefits including human health. Trees as such may be a cost-effective way of improving a city’s public-health infrastructure.
- All urban residents need to be well informed about the many benefits trees provide.



Northwest Natural

Planting and maintaining urban street trees are relatively inexpensive ways to enhance a city’s public-health infrastructure.

FOR FURTHER READING

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