PNW
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Science FINDINGS

INSIDE

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"Science affects the way we think together."
Lewis Thomas

MORE RAIN, MORE DROUGHT: WILL THE FORESTS THRIVE OR DIE?

Flooding is expected to increase in many areas under most climate change scenarios, and has already drawn the attention of insurance companies in the United States, where disaster payouts have increased over the last decade.

Conversation overheard at a water fountain:

Man: Hey, that global warming stuff. Should I believe that, or is it just another crock?

Woman: You better believe it, buddy. The insurance companies do.

At any gathering, formal or informal, of people discussing global warming and climate change, there are guaranteed to be doubters. Even taunters.

The evidence, however, is starting to mount. "The overwhelming majority of scientists agree that the planet is warming, based on various key indicators. Emissions of greenhouse gases from fossil-fuel combustion and tropical deforestation could warm the earth by 1.5 to 3.5 degrees Celsius, or more, within the next century," says Ron Neilson. "But a very vocal minority believes just as firmly that the error range is too great to make any definitive statements."

Neilson is long past the stage of querying the truth of global warming. A bioclimatologist with the PNW Research Station, he is lead author of one of the three models in the world designed to grapple dynamically with the unimaginable complexity of tracking and predicting climate-driven vegetation change patterns for the whole planet.

IN SUMMARY

Global Warming: Is it real or not? Ron Neilson, PNW Research Station bioclimatologist, has been studying the phenomena for about 25 years. He also is the lead author on one of three models in the world designed to track climate-driven vegetation change patterns on the planet.

Neilson's findings, featured in this issue of "Science Findings," may be able to assist land managers to prepare for global warming impacts. Neilson and his colleagues developed a model called the mapped atmosphere-plant-soil system (MAPSS).

The MAPSS model can simulate changes in vegetation distribution and runoff under altered climate and carbon dioxide concentration. Key findings from Neilson's work reveal that the Pacific Northwest is an area of uncertainty.

Other key findings reveal that there is a shifting of vegetation to the north, dieback of boreal forests, and continued warming temperatures that have the potential to strain water resources. Future forest management plans should take into account the range of possibilities under climate change scenarios.

He has several analytical and technological reasons for feeling the confidence he does in the value of climate change modeling. But one of the more compelling reasons, and certainly the most gratifying, has evolved out of work he did 25 years ago as a graduate student tromping through the woods and the desert compiling field data.

"The model and that old empirical data on vegetation, climate, and runoff characteristics came up with almost exactly the same predictions about distribution of certain kinds of vegetation," he says. "And remember, that field work was of course very localized. The model matched up with it even though it was running across the entire continental landscape."

KEY FINDINGS

- The MAPSS model can simulate the changes in vegetation distribution and runoff under altered climate and carbon dioxide concentration. It simulates both type of vegetation and density, for all upland vegetation from deserts to wet forests.
- Overall patterns include a shifting to the north of vegetation, some dieback of boreal forests, particularly along edges of interior grasslands, and a grim outlook for the Eastern United States as an area that will likely suffer negative impacts under global warming. There are few "no change" areas within the United States, and the Northwest is an area of uncertainty.
- Early stages of global warming could see increases in productivity and density of forests worldwide, as increased carbon dioxide acts as a fertilizer. Continued elevated temperatures, however, could strain water resources, in time producing drought-induced stress and broad-scale dieback, with associated wildfire increases.
- Increased carbon sequestration from more productive vegetation growth could be offset by pulses of carbon into the atmosphere from increased wildfire.

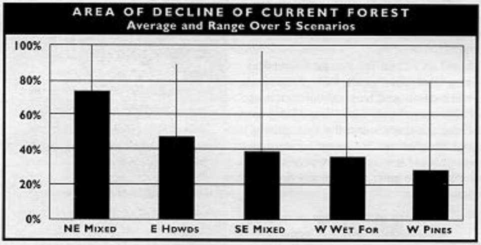
ARE WE SURE THE GLOBE IS WARMING?

Let's back up briefly to the accepted evidence—the mostly accepted evidence.

Global temperature records take us back as far as 200 years in Europe, with some local sites, with fewer instruments, stretching even further. Tree rings take us back several thousand years. Ice cores and deep ocean sediments reach beyond that.

"There is excellent evidence in instrument and tree ring measurements that the planet is warming, that it is hotter than at any time over the last 2,000 years," says Neilson. "In fact, we are currently heading towards the highest temperatures since the last deglaciation, which occurred during the thermal maximum of around 5,000 years ago." He notes that there is clear evidence also of other expected results of global warming, such as increases in rainfall and cooling of the upper atmosphere as a result of the heat-trapping greenhouse effect below it.

What's causing this? "It could be natural variations, internal oscillations in weather patterns or variations in solar output, or it could be human-induced greenhouse effects. The current thinking is that it's probably about 50 percent each—natural versus human-induced," Neilson says. Then he adds, wryly, "That thinking is based on data, not political expediency."



Dark blocks show average area of decline of current forest cover in five regions of the United States. Vertical "whiskers" show the possible range of decline areas.

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VIEW FROM THE CRYSTAL BALL

Supposing, then, we accept the premise and agree that the planet is warming. Now what? International scientific studies have been underway for some years, and at least in the United States, insurance companies really do want to know what's going on. They've noticed the increase in their disaster payouts. Electric utilities have questions. And now Senators are asking.

Neilson presented recent findings in 1996 for a Roundtable Discussion on Local and Regional Effects of Global Climate Change, for the Environment and Public Works Committee, at the invitation of Senator Joseph Lieberman (D-Conn). He was asked to address several key issues: What specific regional impacts become apparent under simulations? How well, really, can we simulate these local effects of climate change on forests and native vegetation? Do different models produce consistency about potential effects? and How useful are the models for multisector assessments involving water, agriculture, wildlife, industry, and urban areas?

"That the policymakers are even asking these questions is encouraging," says Neilson, "but they absolutely do not like uncertainty. I try to address this by aggregating data to the levels of management unit they recognize, and by trying to find patterns, to extract a larger synthesis from seemingly disparate pieces of information."

Patterns. Under all potential future climate scenarios, forests are projected to shift northward into currently nonforested areas. Vegetation mass as a whole, and thus the Earth's carbon stocks, would likely increase in the beginning, acting as a so-called negative feedback to global warming. If climate change is rapid enough, however, simulations through time suggest that there could be widespread boreal (Northern, predominantly conifer) forest dieback along its southern edge, especially next to interior grasslands.

"Such dieback could inject large amounts of 'salvage' timber into the global marketplace or, if left on the land, could cause massive fires and possibly large injections of carbon dioxide into the atmosphere, a positive feedback that would exacerbate global warming," Neilson told the committee.

Although there are significant differences among the many simulations run, they all suggest there are few "no change" areas in the United States, he said. And all simulations show growing amounts of forest susceptible to drought-induced dieback as temperatures increase.

The other most notable pattern, he added, is that within the temperate zone, the Eastern United States seems to be the most sensitive large region on the planet to potential negative impacts from global warming.

And the good news?

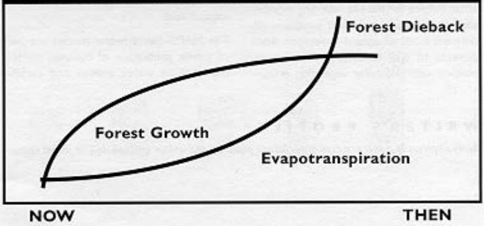
"Regional to local 'winners' and 'losers' are most easily displayed by looking at maps of change in vegetation density, which is simulated via leaf area," Neilson explained. "The Lake States appear to suffer under all simulated scenarios, as does much of the Eastern United States, particularly the Appalachian axis. With the exception of Florida, the Southeast could be at considerable risk. Consistent 'winners' seem to be the central valley of California, the Southwest deserts, and Florida. The Northwest is quite uncertain."

A closer look at the Northwest and its uncertain future illustrates well the larger questions of uncertainty in dynamic modeling.

MANAGEMENT IMPLICATIONS

- Integrated assessments of climate change across management sectors (agriculture, industry, forestry, urban planning, and others) are crucial to preparing for global warming effects. Various alternative futures ought to be considered to maintain management options.
- With global warming and the possibility of international greenhouse gas emissions control treaties, the forest management mission could expand further to include carbon sequestration.
- Shifting distributions and changing productivity of forests would alter regional forest markets and affect the global forest marketplace. National and regional economies could be altered, with national and global workforce effects.
- Long-term forest management plans are constructed under the assumption of a stable climate. Future expectations within these plans need significant modification to accommodate the range of possibilities under climate change scenarios.

GETTING FROM NOW TO THEN: POSSIBLE THRESHOLDS



Early global warming may increase productivity and density of vegetation in certain areas, but at the point where vegetation outstrips its own water needs, drought-induced dieback could begin and eventually reach large proportions.

TO THRIVE OR TO DIE? THAT IS THE QUESTION

Suppose the planet's increase in carbon dioxide—one of the causes of global warming—acts first as a fertilizer for forests. Logically, they would love it, and expand. But then imagine that their increase outstrips the available water resources, and they start to die back. This is called a threshold response—the point at which the forest changes from increased productivity to rapid drought-induced dieback. Such landscape-scale stress would increase susceptibility to fire and disease, and the eventual loss of forest cover could far outweigh the early gains.

"Notably, the areas most susceptible to this phenomenon are the Northwest and the Southeast, the two biggest timber-producing areas in the country," Neilson points out. Once again, "salvage" timber and widespread fire would become critical issues.

It's not completely clear, however, that this will happen, he says. In such areas with high winter rainfall, but dry summers, the water runoff-vegetation relation is more complex. Both can increase, largely because of the offset of their seasons of activity. Thus in the Northwest, the timing of rainfall could be a variable that alters the outcome of the eternal competition between water resources and biotic resources.

The link between vegetation and water, naturally, is inalterable. Simulations show that under continued warming in the West and Northwest, if forests begin to decline, they would use less water. In combination with less snow formation and earlier melt, this could result in increased winter flows with possible flooding. Neilson points out these changes in annual runoff also could have profound implications for the availability of water for irrigation, domestic uses, electricity generation, and freshwater fisheries.

The reason Neilson and his colleagues can even make these surmises about water in an area of regional uncertainty such as the Northwest, is that the models they are using today have the vegetation processes fully coupled to the hydrologic processes. Things under the hood, it seems, are getting pretty complicated.

TOO MANY VARIABLES, OR NOT ENOUGH?

Behind all the maps and the simulations is a biogeography model constructed by Neilson and his colleagues, called the mapped atmosphere-plant-soil system (MAPSS). The MAPSS model simulates the distribution of all upland vegetation on the Earth, based on climate and soils, and relies on current knowledge of both vegetation and hydrologic processes. For example, it tracks the physiological effects of elevated carbon dioxide on the water use efficiency and productivity of plants.

Given an average climate, Neilson explains, MAPSS calculates the type of vegetation that can exist on a site, its density in terms of leaf area per unit ground area, and a water balance for the site, including monthly soil moisture and runoff. It simulates 45 different kinds of upland vegetation from deserts to wet forests, and has been coupled with two other vegetation ecosystem modeling and analysis project (VEMAP) models that are then able to be truly dynamic over large areas, and through time, one of them all the way from 1895 to 2100.

"MAPSS challenges the long-standing assumption that models cannot operate across large scales. Models have historically been built for very small scales. The early ones grew vegetation and included some nutrient cycling, but they couldn't move vegetation around, MAPSS can," says Neilson.

Not only that, it provides internally consistent and published simulations at global, continental, and regional scales, the latter with a resolution of about 6 miles. A prototype version of the model is bringing it down to a resolution close to the size of a football field.

The MAPSS-based hybrid models are part of a new generation of dynamic models that include water, energy, and carbon exchange between the atmosphere and the biosphere, and address the role of the biosphere in affecting climate change. It is one of the models in VEMAP, which was formed to closely examine the new models and apply them to U.S. assessment activities.

"The more variables you can incorporate into a model, the greater your confidence can be," Neilson says, "and yet the quest is always for the minimum amount of complexity that will still capture the processes you're modeling."

A balancing act, indeed, and one that is constantly challenged to prove itself capable of supporting its claims. That's why the matchup with the field data from 25 years ago has been so important. Such models as MAPSS cannot hope to be credible without this kind of real-world validation. They also are vetted internally by large-scale comparisons with many different data sets.

WRITER'S PROFILE

Sally Duncan is a science communications planner and writer specializing in forest resource issues. She lives in Corvallis, Oregon.

RECOGNIZING FEEDBACK LOOPS

The MAPSS model assumes that maximum leaf area index is constrained either by the availability of water or by the availability of energy. The models work from such highly localized measurements as leaf area index, to suggest what might happen on a global scale through time. But they are designed to address the kinds of atmosphere/biosphere-level feedbacks that could have forests first thriving, then dying.

Coupling fully dynamic oceans and all their system processes with atmospheric models, for example, has allowed simulations to capture negative and positive feedbacks that play a critical role in the regional distribution of temperature and rainfall changes, Neilson says.

"The conclusion from our studies is that the feedbacks between the atmosphere and the biosphere could have profound influences on both systems. The nature of the feedbacks span the full range of processes from complex biophysics to physiological, structural and ecological processes."

Some simulations are programmed to show what the world will look like under an equilibrium condition in which there is double the current amount of carbon dioxide in the atmosphere. But how likely is an equilibrium condition?

Neilson and his colleagues recognize clearly that the biosphere's response to transient climate change could differ significantly from that simulated under equilibrium climates. "It's easier to build an equilibrium model than one that reflects the transition states during the process of carbon dioxide buildup. But although the planet is not likely to settle into an equilibrium state, simulating for something like a doubled carbon dioxide supply tells you what your end point tendency under climate change should be toward," he explains.

In one of its new dynamic versions, MC1 (MAPSS-CENTURY) has incorporated a wildfire model, in recognition of the huge role fire plays in carbon release, and in vegetation change. The fire component tracks the change in intensity and the spatial distribution of fires through time.

What's under the hood is indeed complicated, and it's only going to get more so, as processing speed and parallel processing continue to improve. Just imagine, then, what including such elements as insect infestation, dispersal of seeds, and vegetation establishment in their calculations will do.

CAN WE MANAGE FOR GLOBAL WARMING?

Can we really hope to model something as complicated as Earth's climatic systems, its vegetation and water systems, and get any kind of reasonable picture?

Global modeling teams always use more than one model for comparative purposes, Neilson points out. They do it for their own cross-checking purposes, but it also allows them to answer those policymakers when they ask whether there are consistent responses from different models in different regions of the country, under different scenarios.

Neilson believes the implications of the models as tools for planning futures must become a central management issue. "Managers can't afford to look at their own sectors exclusively any more. Integrated assessments are essential to try to deal with decisions about whether you grow trees to sequester carbon, for example, and then how you protect your water resources from drying up."

An alternative to this approach might be to use the landscape in some locations as a "carbon pump," moving wood from rapidly growing forests over short rotations into long-lived forest products, he suggests.

"The idea here is not that we as researchers can come up with definitive answers or recommendations. It's our role to present options—if you do this, that is likely to result—and wherever possible, start zeroing in, narrowing the uncertainties. That way, monitoring can be structured to detect early warnings of climate change, and research can be coordinated to help explore alternatives in managing resources."

Of course, there are multifaceted global implications. Neilson points out that shifting distributions and changing productivity of forests would affect regional forest markets within the global forest marketplace. National and regional economies could be altered.

Within this context, it is crucial to recognize that almost all regional plans are constructed on the assumption of a stable climate, he says. The Northwest Forest Plan and Interior Columbia Basin Ecosystem Management Project are two obvious examples.

"The expectations of future growth trajectories in the current plans would need significant modification, and balancing the management of these issues is not about to get any easier," says Neilson.

The growing power and complexity of climate change modeling needs continuing institutional support, he believes, to prepare us as well as possible for uncertain outcomes. After all, if the insurance companies are involved, you know we'll pay for it one way or the other.

"Ah, what a dusty answer gets the soul — When hot for certainties in this our life!"

George Meredith (1828-1909)

FOR FURTHER READING

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