momentum

Institute on the Environment • University of Minnesota

GROWING, GROWING, GONE...

Using and losing land to feed a growing world

FORESTS UNDER FIRE

CARGILL'S *balancing act*

POINTS OF NO RETURN

Q&A *eco-nomics with* GRETCHEN DAILY

THE LAND ISSUE

The *Other* Inconvenient Truth

It's taken a long time, but the issue of global climate change is finally getting the attention it deserves. There is now widespread acceptance of the need to confront energy security and global warming. We finally acknowledge that our addiction to fossil fuels, which has been harming our national security, economy and environment for decades, must end.

Unfortunately, this positive shift in the national zeitgeist has had an unintended downside. Climate change has become the poster child of environmental crisis, complete with its own celebrities and campaigners. But is it so serious that we can afford to ignore equally serious environmental issues, such as the rise of infectious disease, the collapse of fisheries, the ongoing loss of forests and biodiversity, and the depletion of global water supplies?

For the record, I'm no climate change skeptic. I earned my Ph.D. in atmospheric science and wrote my thesis on ancient climate change, but even I worry about our collective fixation on global warming at the expense of other issues. Learning from the research my colleagues and I have done over the past decade, I fear we are neglecting "the other" inconvenient truth: *a global crisis in land use and agriculture that could undermine the health, security and sustainability of our civilization.*

Our use of land, particularly for agriculture, is absolutely essential to the success of the human race. But we are pushing our agricultural systems to the limits. Continued population growth, changing dietary preferences, rising energy prices and increasing needs for bioenergy sources are putting tremendous pressure on our natural resources. And it's likely we'll need to double, perhaps triple, global agricultural production in the next 30 to 40 years.

Already, the area we use for agriculture is nearly 60 times larger than that of all the world's cities and suburbs, leading to major ecosystem losses and biodiversity decline. Plus, we're facing a severe decline in freshwater resources resulting from agriculture. Across the globe, we use 4,000 cubic kilometers of water per year, withdrawn from our streams, rivers, lakes and aquifers. Of this, 70 percent is used for irrigation, the single biggest use of water on the planet. At the same time, industrial fertilizers and other agro-chemicals have fundamentally upset Earth's chemistry.

Ironically enough, our land use practices are also one of the biggest contributors to global warming. Of the three most significant manmade greenhouse gasses, 30 percent of the total comes from land use and agriculture. That's more than the emissions from all the world's cars, trucks, trains and planes, or the emissions from all electricity generation or manufacturing.

Even in circles of well-informed scientists, the notion that our land use and agricultural practices rival climate change as a global environmental threat often comes as a big surprise. Clearly, we need to begin a larger national conversation about this issue, on par with the recent efforts of the climate change community and Al Gore.

That's exactly what we intend to do with *Momentum*: Start a conversation. The magazine may be small, but we're not short on quality material. In this issue, our writers delve into everything from the Green Revolution—past, present and future—to the early warning signs of environmental tipping points. After reading, we hope you'll visit our revamped magazine site, **environment.umn.edu/momentum**, for additional content.

Providing for the basic needs of 9 billion-plus people, without destroying the biosphere in the process, will be one of the greatest challenges our species has ever faced. It will require the imagination, determination and hard work of countless people from around the world. But the first step is admitting we have more than one problem.

Jonathan Foley

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Look for an extended version of "The *Other* Inconvenient Truth" at Yale Environment 360 (e360.yale.edu).

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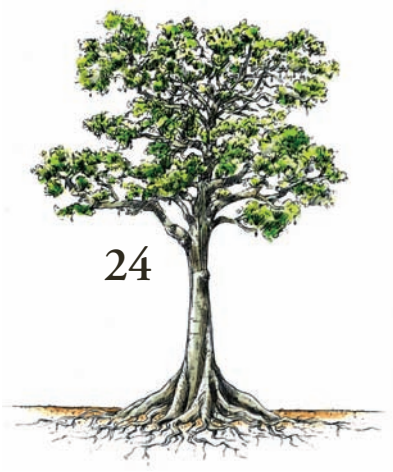
on the cover
Montana-based photographer **FOREST WOODWARD** is a recent graduate of the University of North Carolina and the youngest student ever to attend the Rocky Mountain School of Photography. His work has appeared in *National Geographic*, *Men's Health*, *Prevention Magazine* and many other publications. Visit **forestwoodward.com** for more info.

DEPARTMENTS



FEATURES

Look and Listen

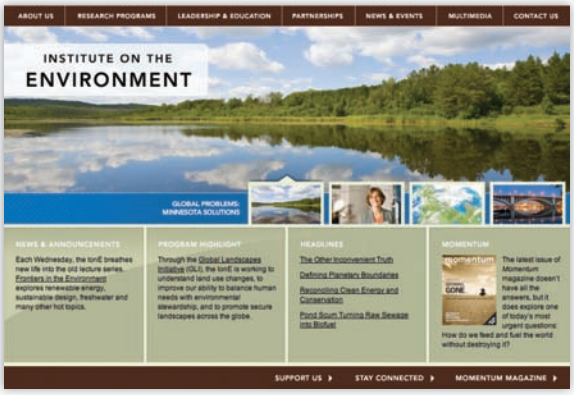
TIPPING POINTS PRIMER
Get the gist of "planetary boundaries" from the IonE's Jon Foley, who provides context on the recent *Nature* study that made global news headlines.

RIVER REFLECTIONS
Three regional river experts, including the IonE's Pat Nunnally, discuss the past, present and future of the Mississippi.

Extreme Home Makeovers

Ta-da! Announcing major upgrades to the look, feel and content of the Institute on the Environment and *Momentum* Web sites. The new sites incorporate a smarter design, easier navigation, more dynamic content, enhanced sharing features and thought-provoking blogs. Explore our refurbished Web homes at...

environment.umn.edu



environment.umn.edu/momentum

BE SOCIAL & WIN!

On Nov. 18, we'll enter all of our followers (at **twitter.com/UMNIonE**) and fans (at **facebook.com/UMNIonE**) into a random drawing for cool prizes, including a 2010 **Blue Sky Guide** coupon book, 1-pound bag of **Peace Coffee** and a stainless steel IonE tumbler ($35 value; three winners) and a gift bucket of environmentally-safe household cleaners from **Mrs. Meyer's Clean Day** ($60 value; one winner).

A User's Guide to Earth

Over the past century, human activity has changed the environment more than any natural process in Earth's recent history. As a result, many of our planet's climatic, geophysical, atmospheric and ecological systems could tip into unknown territory. In the article "**Planetary Boundaries: A Safe Operating Space for Humanity**," published Sept. 24 in the journal *Nature*, 28 of the world's top scientists attempt to quantify safe biophysical boundaries, outside which Earth can no longer function in a stable state. The University of Minnesota's Jonathan Foley, director of the Institute on the Environment (IonE), and Peter Snyder, an IonE associate fellow, are among the contributors. While the boundaries aren't 100 percent definitive, they do serve as a preliminary road map. The authors hope the next generation of scientists will refine and expand on their ideas. See **page 26** for a related story.

Science is in Our Nature

Groundbreaking research can't break much ground if it stays in the confines of the lab. That's where highly cited journals like *Science*, *Nature* and *PNAS* come in. Just a fraction of the articles submitted to the journals are accepted for publication, each one subject to intensive peer review. For the few scientists who make the cut, global attention is in the cards. Despite such fierce competition, members of the IonE community have published some 30 papers in these journals in the past three years. Not to toot our own horn (well, maybe a little), but this track record shows the University of Minnesota isn't joking around when it comes to environmental research. Just a few influential studies recently co-authored by our staff and fellows include:

Planetary Boundaries: A Safe Operating Space for Humanity
Nature, 9.09

Beneficial Biofuels: The Food, Energy and Environment Trilemma
Science, 7.09

Climate Change and Health Costs of Air Emissions from Biofuels and Gasoline
PNAS, 2.09

Star Quality

Now more than ever, decision makers around the world are embracing sustainable business models. So it's an opportune time for the IonE to embrace the innovation of private enterprise and other thought leaders. The IonE's new **NorthStar Consortium** is leveraging the resources and expertise of corporate, nonprofit, university and government participants to address land use, water, energy and climate, and production-consumption issues. In the coming year, these partners will identify shared challenges and opportunities across organizations, along with the technologies and strategies needed to make sustainable change.

Part of a broader NorthStar Initiative for Sustainable Enterprise (NISE), this ***Continued on page 5...***

PHOTO: PATRICK O'LEARY

SUNNY SIDE UP

For three weeks in October, University of Minnesota students made a home in Washington, D.C.—right in the heart of the National Mall. Of course, the historic hub didn't open its turf to any old house. This was the home of the future: An 800-square-foot masterpiece powered entirely by the sun. The U of M students represent one of just 20 university teams from around the world to gain a spot in the U.S. Department of Energy's **2009 Solar Decathlon**. For the past two years, young scholars from wide-ranging disciplines have been designing, planning and building what they've dubbed the ICON House. The name comes from the home's modified gable roof, which keeps the iconic house form while maximizing exposure to the sun. The students competed for points in 10 separate categories, ranging from architecture and engineering to appliances and net metering. The IonE provided $50,000 for this project; IREE provided $100,000.
solardecathlon.umn.edu

ARTIST STATEMENTS

What's your Mississippi River story? This is a question artist Anna Metcalfe, a collaborator on the IonE's River Life program, recently posed to teenagers from disadvantaged communities in Minneapolis and St. Paul. The University of Minnesota MFA graduate invited the youth to share their stories on paper outlines of boat shapes, which Metcalfe fired into a series of three-dimensional, ceramic story boats. After spending their summer near the Mississippi River Gorge, assisting local organizations with ecological restoration projects, the teens jumped at the chance to express their connection to the river in an artistic way. Metcalfe held workshops for the young storytellers, gathered their drawings and writings, and created nearly 60 clay boats in all. The collection is so exquisite; it's earned a showcase in the 2010 conference of the National Council for Education on the Ceramic Arts, taking place this spring in Philadelphia. For more, read "Navigating Our River Communities: Mississippi River Stories by Twin Cities Teens" at **www.riverstories.umn.edu**.

PHOTO: LAURA CORCORAN MAHNKE

MORE NEW FEATURES FROM TELLING RIVER STORIES

Steamboats and the Falls

Traveling the Red River Trails

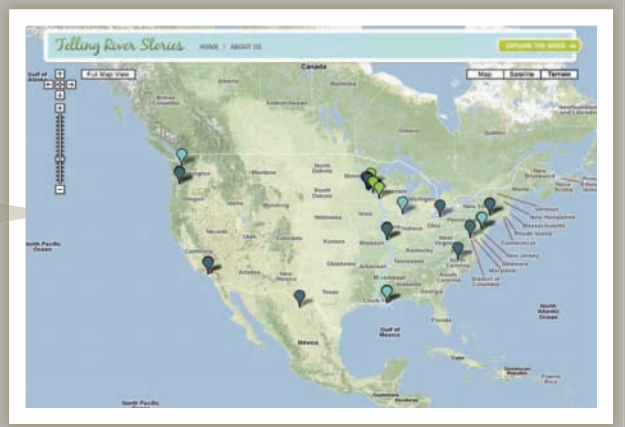
Interstate Park: A Haven for Mussels

Sugar Water: Biofuels and Poverty in Kenya

The Milwaukee Road Depot: An Emblem of the City

Streetcars and the Development of Minneapolis

Lake Pepin: Buttons, Ecology and the River



Continued from page 3...

consortium isn't just another committee on corporate responsibility. Instead, it will focus on whole systems, facilitate dialogue with a parallel research agenda, and generate new and actionable knowledge. As the consortium recognizes the key barriers to sustainable progress, a team of NorthStar fellows will translate these priorities into appropriate research. The goal is to develop frameworks, pathways or action plans within one year of each project's initiation. With significant resources from the University of Minnesota invested in this grand experiment, the stars are in our favor.
environment.umn.edu/northstar

A Major Minor

Housed within the IonE, the **Sustainability Studies Minor** is an up-and-coming undergraduate opportunity at the University of Minnesota. Since its beginning in 2006, the program has attracted more than 300 students and faculty from seven U of M colleges. The minor is open to students of all majors and explores issues from perspectives across the natural, social and applied sciences. The curriculum includes a core course titled "Sustainable People, Sustainable Planet," interdepartmental electives, and a project-based capstone course in which students address a community's environmental, social and economic sustainability from a systems perspective.
www.sustainability.umn.edu/minor

Erratum (i.e. oops)

In the previous issue's Noteworthy section, the *Momentum* magazine team overlooked an embarrassing error, which a careful reader pointed out. Referring to one of our resident fellow's environmental champions, we printed "Hero**ine**: Sigurd Olson" by mistake. Sorry about that. We all know Sig was the man.

PHOTO: IUPUI

Turning Over a New Leaf

Starting with this issue, *Momentum* magazine has upgraded to forest-friendlier paper. We're now using paper that relies on certification and designation systems in line with the highest environmental standards for the industry. The following Eco Audit spotlights just a few positive outcomes.

NEW LEAF PAPER®
ENVIRONMENTAL BENEFITS STATEMENT
of using post-consumer waste fiber vs. virgin fiber

Momentum saved the following resources by using New Leaf Reincarnation Matte, made with an average of 58% recycled fiber and 33% post-consumer waste, processed or elemental chlorine free, and manufactured with electricity that is offset with Green-e® certified renewable energy certificates:

12	Trees
2,296	Gallons of Water
6	Million Btu of Energy
578	Pounds of Solid Waste
880	Pounds of Greenhouse Gases

Calculations based on research by Environmental Defense and other members of the Paper Task Force.

www.newleafpaper.com

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NONSTOP ENERGY

How do we provide sustainable fuel, food, fiber and freshwater to a global population of 9 billion people in our lifetime? That's one of nearly 20 urgent questions we'll explore during **E3 2009: The Midwest's Premier Energy, Economic and Environmental Conference**, taking place **Nov. 17** at the Saint Paul RiverCentre. The National Renewable Energy Laboratory's Larry Kazmerski (pictured above), a photovoltaics pioneer, will offer the keynote presentation this year. Other new highlights include "Green on the Ground" workshops and a lunchtime panel discussion with representatives from the Natural Resources Defense Council, the National Corn Growers Association, Monsanto, Natural Resources Canada and the University of Minnesota. Presentation topics range from biomass, wind and geothermal power to smart grids, low-carbon fuel standards and geoengineering. Hosted annually by the IonE's Initiative for Renewable Energy and the Environment, in partnership with lead sponsors Faegre & Benson and Piper Jaffray, the conference brings together scientists, movers and shakers, and policymakers from across the Midwest and beyond to share the latest buzz in renewable energy. Net proceeds support U of M students working on leading-edge energy projects.
www.iree.umn.edu/e3

Environment 2.0 by EMILY GERTZ

For the techies, technophobes and everyone in between, we've gathered a few shining examples of how Web 2.0 can enhance environmental discourse—from spreading awareness to inspiring action.

JOSHUA LEVY, the online campaign manager for media reform group Free Press, describes himself as a "writer, editor, filmmaker and Web strategist exploring the intersections of technology, politics and activism." A former boss describes him as "one of the most insightful thinkers on the topic of improving government and politics in an interconnected age." During the 2008 presidential election, major mainstream news outlets referenced Levy's commentaries, published at techPresident.com, on how the campaigns were using social networking. • Levy answered his phone for this interview during his lakeside vacation in Vermont. When we expressed surprise that he'd picked up, he said, "We're never completely disconnected, are we?"

Emily Gertz What trends in social media are you seeing right now in the environmental field?

Joshua Levy Two or three years ago, if you called in a social media strategist to advise your organization, they would say, Well, try 10 of these services. That got really annoying really quickly. What's happening now is people are tending to focus in on Twitter and Facebook, and maybe MySpace in some cases, and some other sites depending on the organization. When it comes to environmental stuff, that's definitely what I've been seeing. … They're trying to build numbers on those communities. But more than that, they're really drawing people in on the activism that's going on, and getting people involved and engaged.

EG Why do you think certain social networking services are emerging as the leaders?

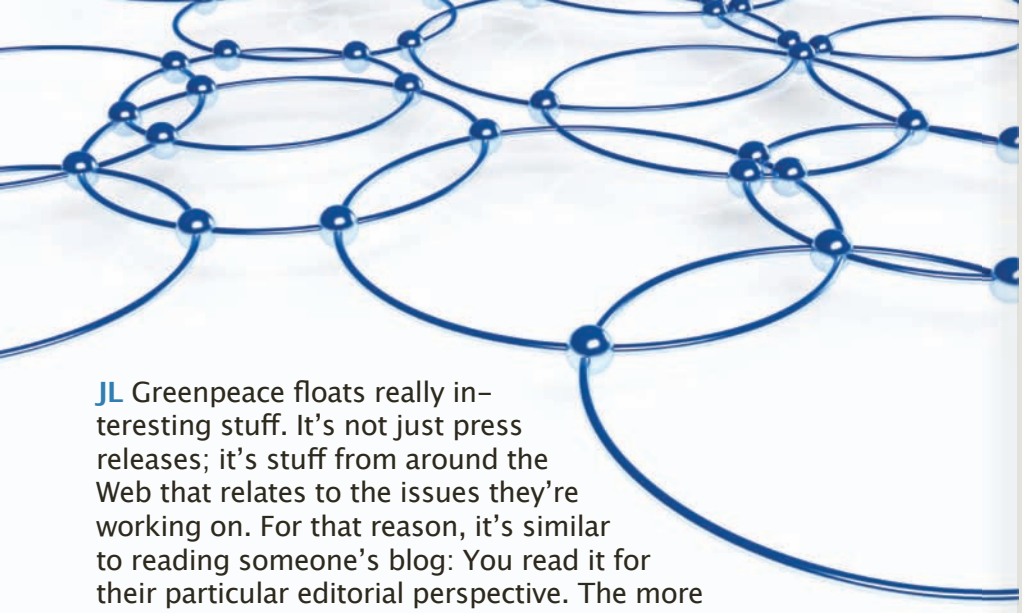
JL Social networking trends change so quickly and the landscape changes so quickly … so people have learned from the spaghetti-on-the-wall approach: They see that it's a lot of investment of time and not a lot of return. They understand that to get the most bang for your buck, [you must] drill down with a couple of core services.

EG That suggests the human element is still key, that there needs to be someone who's analyzing what works and what doesn't.

JL Absolutely. The human element is the thing that makes all of these services tick. Without it, they don't work. You can set up a Facebook fan page, and automate a feed into it, and not keep it up at all, and it's going to grow very, very slowly, if at all. But if you have a human being there, selectively choosing which articles—either from their organization or outside the organization—to post and link to and highlight, that shows a curatorial nature that people are more interested in and more likely to follow.

"**A little while ago I was very skeptical of what Twitter could do for me as a reporter.** But I've seen how it's become a place where political reporters are trading notes, tips and ideas. … In a real newsroom, you're trading ideas over a wall or across the desk with your editor. Twitter's become a kind of global newsroom for reporters across beats, to see what each other are covering. For climate and environmental reporting in particular, this year we have a lot of action on the Hill. Twitter, Facebook—all of these information-sharing sources—help people gather and collaborate in a way you couldn't before."

KATE SHEPPARD, Environmental Reporter, Washington, D.C.



JL Greenpeace floats really interesting stuff. It's not just press releases; it's stuff from around the Web that relates to the issues they're working on. For that reason, it's similar to reading someone's blog: You read it for their particular editorial perspective. The more successful people are learning how to do that. And also, they're learning how to engage with individuals as activists. One thing I've been doing at Free Press is reaching out to the most active people—members of our [Facebook] fan pages who comment the most, who "like" the most posts. I reach out to them to spread the word on our campaigns. So, people have learned to utilize the network, as the capital-N network has matured.

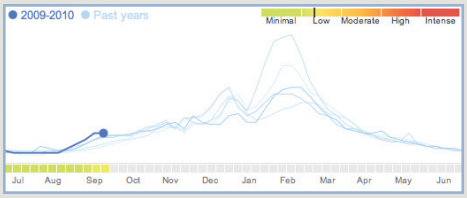
EG In some circles, there's a belief that faceless communication is a problem. How do you respond to the social media cynics?

JL I think any environmental organization of any reasonable size has an e-mail list. Each organization is better or worse at cultivating names and generating action with those lists. But those e-mail lists, which are basically Web .05 as far as the technology is concerned, to me, are the most nameless, faceless aspect of online advocacy. It's the dinosaur of online advocacy, and it's the one most likely to be thrown out the window these days. People are not innovating with e-mail. They're innovating elsewhere, in spaces that are much more personal, and that are full of unique, interesting and undiscovered ways to connect to individual activists—to figure out what those specific people are interested in and how they can use those specific skills to help.

EG What's the take-home message, then?

JL I think the smartest advocacy groups across the board—not just in the environmental movement are those who understand that Facebook is not a mass medium at all. It's not a place where nameless, faceless people come to join your cause. It's the opposite: It's a place where individuals … are coming on board. The smart people are figuring out how to bring those people on in new ways. Rather than just engaging them in "clicktivism," they're finding out other ways to get those people to volunteer, or to get them to help crowdsource campaigns or engage in offline activities. It's really encouraging that social media are being used this way. And I think we're really at the tip of the iceberg.

EMILY GERTZ is a journalist, editor and professional blogger who lives and works in Brooklyn, N.Y. She has covered environment, technology and science issues for *Dwell*, *Scientific American*, *Popular Mechanics*, Grist, Worldchanging and more.



Tracking Disease in Real-Time

In late 2008, Google launched the Flu Trends Web site, a component of their Labs program. Available in English and Spanish, the site skims Google search data for patterns that indicate geographic concentrations of the flu-struck. The site displays what it finds in maps and graphs, which provide a snapshot of up-to-the-minute influenza activity around the world.

As Google notes on the site, "We've found that certain search terms are good indicators of flu activity." So, if a high volume of people in Queensland, Australia or Queens, N.Y., suddenly begin performing searches on terms like "flu symptoms," "vomiting" or "body aches," Google can infer that a flu outbreak is occurring in those locations. Of course, not everyone who searches for "flu" has the bug, but taken together, Google search data on flu terms almost perfectly matches the data on actual incidents of flu from the Centers for Disease Control and Prevention.

While this methodology is solid enough to merit publication in the journal *Nature*, there is a hitch: This type of surveillance works well only if the particular disease hasn't made it into the news. Once word got out about the H1N1 outbreak in Mexico in April 2009, people without any flu symptoms started to do flu-based Google queries, totally skewing the Flu Trends results.

Eco-Nomics

Interview by MARY HOFF

What is nature worth? From one perspective, it's priceless. From another, it's not only valuable, but value-able as well. Stanford University conservation biologist **GRETCHEN DAILY**, who gave wings to the concept of ecosystem services in the 1990s, is working around the world to help policymakers recognize the economic worth of the benefits nature provides. A leading light in the ecology world, Daily co-founded the Natural Capital Project with The Nature Conservancy and World Wildlife Fund in 2006 as a mechanism for putting nature on the payroll. Her books, *The New Economy of Nature* and *Nature's Services*, have pioneered entirely new approaches to conservation. We caught Daily on her way to Hawaii, where her project team is reforesting pasture to help meet carbon sequestration goals, resulting from the state's 2007 climate law.

PHOTO: ELIN HOYLAND

WHAT DO WE MEAN BY ECOSYSTEM SERVICES? In a nutshell, it's all the benefits people get from natural systems. In a slightly bigger nutshell, a nice way to frame the answer is to imagine going to the moon. What would you need with you to make life possible and ideally fulfilling? First, goods—things we get from natural systems, such as food and medicines. Second, our life support system. Third, what makes life fun and fulfilling—all the cultural benefits we get, such as recreational opportunities and inspiration. Fourth, the preservation of options. There is so much we don't know, so we save more in anticipation of discovering new values.

In the past, people were a pretty small force, and getting enough of these benefits was easy. Today demand is at an all-time high, and the capacity of the biosphere to supply many services is being reduced drastically.

HOW CAN WE FACTOR THAT INTO ENVIRONMENTAL DECISION MAKING? We need to be able to pinpoint places on the landscape or on the seascape and say these places are really the most important for supplying these benefits, and if we were to invest in protecting them, we would get this return on the investment.

Up until recently we haven't been able to map out exactly the production of benefits like flood control or crop pollination and how that would change under alternative policies or pathways of development. But thanks to the brilliant work of a lot of people at the University of Minnesota and elsewhere, we have some new tools that let us do that. InVEST, which stands for Integrated Valuation of Ecosystem Services and Tradeoffs, lets you map out the production of benefits and ascribe value to them. You can say how much would it cost to purify water naturally, and how much would it cost to build a filtration plant to achieve the same goal? We're applying it now in the United States, China, Ecuador, Indonesia and Tanzania—places where major resource decisions are on the table that InVEST can really inform.

THIS IS NOT JUST CONSERVATION BIOLOGY, IS IT? Science is not the limiting factor. There are many other dimensions to these challenges, and no one discipline is going to get very far on its own. To protect Earth's life support systems is going to take people from a huge array of disciplines to raise awareness of and quantify human dependence on nature. We need to go beyond biodiversity to encompass all the benefits people care about.

SOME ARGUE NATURE SHOULD BE PROTECTED FOR ITS OWN SAKE, WITHOUT HAVING TO BASE ITS VALUE ON ITS CONTRIBUTION TO HUMAN WELL-BEING. HOW DO YOU COUNTER THAT? If nature were being protected for her own sake, there would be no worry. But around the world nature is being liquidated—at accelerating rates. Moreover, in rich and poor countries alike, conservation is often seen as the passion of a small minority, in conflict with most people's needs and aspirations. Changing this situation requires two things: first, shining a light on nature's tremendous but often invisible values; and second, demonstrating how these values can be mainstreamed into resource decisions to benefit both people and nature.

WHAT GIVES YOU HOPE? If you look at the statistics, you despair. But if you look at the spirit of all the people engaged in this movement, from so many different walks of life, you see a real awakening to the values of nature and growing power—that the conservation movement has never had before—to mainstream these values into the decisions of individuals, communities, corporations and governments. This brings me hope. Q&A

Visit **naturalcapitalproject.org** to learn more.

MARY HOFF is a science writer specializing in natural resources, environment, health and sustainability. A regular contributor to *Minnesota Conservation Volunteer*, she has also published in *Science World* and *National Geographic Explorer*, and has written numerous books for children on natural history and environmental topics.

Paradise Found

Say the word "Hawaii" and most people think sand, surf and sunsets. But look a little closer and you'll see pasture and rangelands that cover wide swathes of the islands' interior. The Nature Conservancy has been working for years in Hawaii to restore native areas of forest that have been uprooted by livestock grazing. In 2003, the Conservancy and the National Park Service jointly purchased the **KAHUKU RANCH** (pictured), transferring all 116,000 acres to Hawaii Volcanoes National Park in the largest private conservation transaction in the state's history. A sprawling natural wonder, the ranch contains ancient archeological sites, lava f ows, and unique mesic, wet and sub-alpine forests. Ranging from about 2,000 to 13,000 feet in elevation, almost to the summit of the Mauna Loa volcano, the area is home to dozens of endangered plant and bird species including the Hawaiian hawk, Hawaiian bat and rare songbirds. Such major efforts have protected the state's most fragile ecosystems—ensuring a future beyond high-rise hotels and cocktails on the beach.

PHOTO: ADRIEL HELSEY

GROWINGPAINS

HOW DO WE FEED THE WORLD WITHOUT DESTROYING THE PLANET? AS THE POPULATION APPROACHES 9 BILLION, WE NEED SOME ANSWERS—AND FAST.

STORY Naomi Seck **PHOTO** Wallace Rollins

LET'S START WITH SOME QUESTIONS:

1. Which is the single-largest human use of land in the world?
a) Cities
b) Suburbs
c) Farms and pastures

2. Which human activity contributes the most greenhouse gas emissions?
a) Agriculture
b) Manufacturing
c) Transportation

3. Which aspect of agriculture contributes the least greenhouse gas emissions?
a) Growing rice
b) Raising livestock
c) Transporting food from field to market

Jonathan Foley, Institute on the Environment director, put these same questions to a room of environmental studies graduate students. They got them all wrong.

Like many people with far less environmental savvy, they thought the answers were: (A) and (B) for question No. 1; anything but (A) for question No. 2; and (C) for question No. 3.

This may come as a surprise, but agriculture covers almost 60 times more land surface than urban and suburban living space. When you include land deforested for farming, agriculture is responsible for approximately 30 percent of the world's greenhouse gas emissions, while transporting food accounts for just 10 percent of those emissions.

There is nothing humans do that transforms the world more than agriculture. The spread of agriculture is the single biggest shock ecosystems have seen since the end of the last ice age. And there's nothing humans do that is more crucial to the survival of our species.

"It's the 'other inconvenient truth,'" says Foley. "It's a bigger rearrangement of the world than anything that's happened with climate change."

Here's the dilemma: As the world anticipates a few billion more people in the next few decades, we'll need to do even more of it.

A TALE OF TWO FARMS

Kevin Paap and his wife, Julie, are fourth-generation farmers on their land in Minnesota. As Paap says proudly, he drives down the same driveway as his great-grandfather did on his way to farm the same land.

When Paap's great grandfather claimed his homestead back in 1899, he grew a variety of grains and vegetables, raised some cows, and had some chickens running around. He and his wife and kids cultivated some 160 acres, probably with the help of a rudimentary plow, some horses and other basic tools.

In a lot of ways, it's a farm Sebastian Mbengue would recognize.

Mbengue farms the land in a small village in Senegal, the westernmost country in West Africa. He and his wife grow millet, mostly, one the first grains ever cultivated and one of the hardiest. Millet can practically grow out of sand dunes. That's a good thing, because Senegal can be pretty dry at times.

They also keep up a mango grove and grow cassava and a brood of chickens. Last year, tomatoes fetched a good price at the market, so this year Mbengue, along with everyone else he knows, planted tons. But the price bottomed out, and you can't make back the money needed to transport them to market. So he gave them away by the bucketfuls to his sons, daughters, sisters and friends living in the city.

In Mbengue's part of Senegal, the rains typically start in July and keep on through September or October. His family has been farming in this village for at least as many generations as Paap's in Minnesota, and he learned when to plant and how to judge from his father.

There is nothing humans do that transforms the world more than agriculture.

Mbengue doesn't add much to his fields besides the rain and the seeds, weeding and plowing. He doesn't irrigate, even though the land is dry, and he doesn't use fertilizer or pesticides.

An agricultural advisor from the Israeli embassy once compared farming this way to gambling in a casino. Every year, Mbengue stakes his family's livelihood—and, collectively with all the farmers, food for everyone to eat—on things entirely outside of his control. The rains could stop or there could be too much. There could be a pest infestation. The prices could drop.

Much of this is true everywhere. Paap doesn't irrigate his fields, so he relies on the rain, though Minnesota typically gets more than Senegal. And he doesn't set the prices for his crops, corn and soybeans any more than Mbengue does.

But there is a world of difference between Paap's farm and the one Mbengue and his great-grandfather ran, or even from the farm Paap started a couple decades ago.

For one thing, Paap's farm, which he and his wife run with the part-time help of their two college-age sons, is more than 500 acres, instead of 160. That's thanks in no small part to sophisticated machinery, including a combine harvester. Invented in the 1800s, the first combines allowed farmers to cut stalks and separate grain in one pass.

Since then, they have become significantly more impressive. When Iowa farmer David Miller was growing up, combines could harvest 80 to 100 bushels an hour. Now, Miller says, there are combines that can harvest up to 4,000 bushels an hour, and a single farmer can do work that took 15 men even 30 years ago.

And the GPS on Paap's tractor isn't there to give directions. The tractor minutely tracks data on the yield across his 500-plus acres, storing the information for the following year. The tractor's computer then helps him calculate how much fertilizer to apply the following season across his fields, based on the previous year's yield. Where the yield was lower, the soil is probably a bit weaker, which means the yield will most likely be low again, and that means he needs less fertilizer in those spots.

So, with today's technology, Paap can localize and put the fertilizer where it's likely to do the most good.

There's another technology that is even more finely-tuned, says Peter Scheffert, director of agricultural development and financial assistance for Minnesota's Department of Agriculture. Using satellite imagery, Scheffert says "green-seeker" technology monitors the growing plants on the field. Rather than relying on last year's harvest, this technology analyzes the color of the leaves to see where there's a deficiency, and where the fertilizer might be needed right then.

Paap has also benefited from decades of seed improvement. His seeds have been bred and genetically modified to resist certain pests and to thrive in his soil environment. While his grandfather in the 1940s might have harvested an average of 50 to 100 bushels of corn per acre, and his father in the 1960s may have seen an average yield of up to 150 bushels an acre, Paap's harvests reach an average of 170 to 200 bushels an acre.

GREEN REVOLUTION: PART 1

The roots of Paap's modern farming mostly began in the 1940s. The world population was booming and people worried it wouldn't be possible to grow enough food. The old solution to making more food had always been to cultivate more land. But by the 20th century, most of the best land had already been cultivated—and adding in the marginal and less fertile land wasn't very effective.

Robert Zeigler, director of the International Rice Research Institute, says researchers were predicting widespread famine. "There were books written about that when I was in university, [which said] we should give up on Asia because there was no way they could possibly feed themselves."

Earlier in the century, chemists had unlocked processes crucial to increasing crop yields: synthetically fixing nitrogen into fertilizer.

In the 1940s, the Rockefeller Foundation began investing in research to increase crop yields even further. They started in Mexico with wheat. Norman Borlaug, who later won the Nobel Peace Prize for his efforts to solve the food crisis, bred stronger, pest-resistant, higher-yielding wheat that turned Mexico from a net importer of wheat in 1943 to a net exporter by 1958.

India and Pakistan were headed for famine in the 1960s, until University of Minnesota alumnus Norman Borlaug created higher-yield wheat varieties. Winner of the 1970 Nobel Peace Prize, Borlaug died Sept. 12, 2009, at 95.

Researchers tried to do the same with other staple crops around the world. By breeding better seed varieties and improving agricultural practices, rice yields have doubled or tripled across Asia in the past 40 years.

"Yields were very low for rice in Asia," Zeigler says, and efforts to improve them with fertilizer weren't helping. "Farmers put fertilizer on crops, and they wouldn't respond, they would just grow tall and leafy and then fall over and rot."

He says the IRRI got to work on breeding "rice varieties that were relatively short, so that when we added fertilizer, instead of growing tall, they added more grain."

As yields improved, the price of rice dropped, making food more affordable. And the increased yields improved profits for farmers, which helped develop the rural economy and helped more children go to school.

Higher yields have decreased environmental pressures as well. "By increasing our yields, doubling and tripling, we have reduced the amount of land that's required to produce the food we need," Zeigler says. "It's pretty clear in Asia that the great increases in productivity in rice have taken pressure off the most fragile land."

For example, the practice of growing upland rice on steep slopes, where you can get a lot of soil erosion, has dropped off. "In some of the most environmentally vulnerable areas, we've seen a reduction of agriculture because production in more favorable lands is much higher," says Zeigler.

This is the same revolution that has happened in the United States, where the entire economy of agriculture has changed radically.

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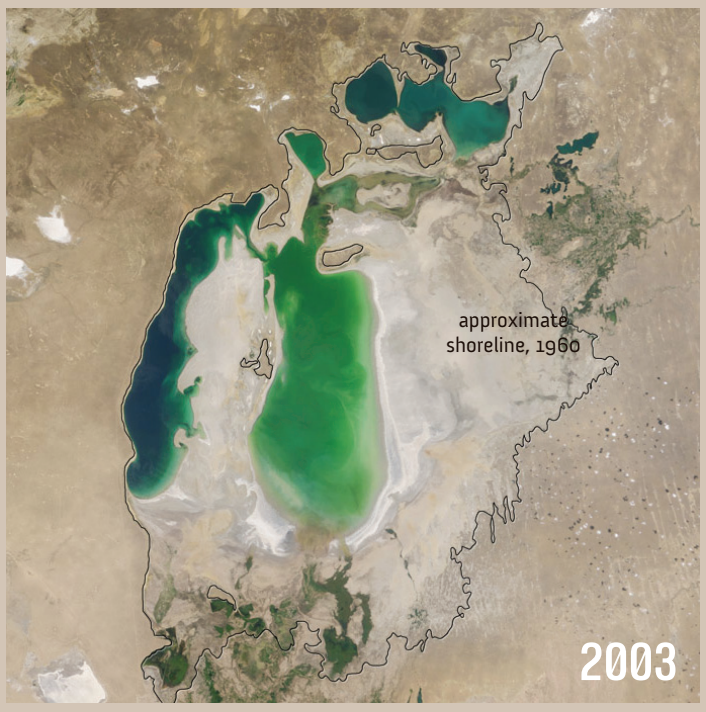
PHOTO: TEXAS AGRILIFE RESEARCH



FROM IRRIGATION TO EVAPORATION

Across the globe, we use 4,000 cubic kilometers of water per year, withdrawn from our streams, rivers, lakes and aquifers. Of this, 70 percent is used for irrigation, the biggest use of water on the planet. As a result, many large rivers have greatly reduced flows and some routinely dry up.

Case in point: Throughout the first half of the 20th century, the Aral Sea was the world's fourth-largest lake. In the 1960s, the Soviet Union began a massive irrigation project in what are now Kazakhstan, Uzbekistan and Turkmenistan, diverting water from the rivers that feed the sea to irrigate farmland.

Although irrigation made the desert bloom, it devastated the lake. As its water levels dropped, the lake split into smaller pieces: the Northern (Small) Aral Sea and the Southern (Large) Aral Sea. The Southern Aral Sea further split into eastern and western lobes, and by August 2009, almost nothing remained of its eastern lobe.

As the lake dried up, fisheries and the communities that depended on them collapsed. The increasingly salty water became polluted with fertilizer and pesticides. The blowing dust from the exposed lakebed, contaminated with agricultural chemicals, became a public health hazard. The dust blew off the lakebed and settled onto fields, degrading the soil. Croplands had to be flushed with larger and larger volumes of river water. The loss of the moderating influence of such a large body of water made winters colder and summers hotter and drier.

In a last-ditch effort to save some of the lake, Kazakhstan built a dam between the northern and southern parts of the Aral Sea. Completed in 2005, the dam was essentially a death sentence for the Southern Aral Sea.

Images and content: NASA Earth Observatory

AUGUST 16, 2009

Continued from page 13…

As corn, wheat and soy yields have increased, prices have dropped, which means the average profit per acre has stayed around $50 per acre since the 1950s, says the Department of Agriculture's Scheffert.

Over that same period, the American cost of living increased dramatically, as did the cost (and sophistication) of the tools needed to farm at modern levels. That meant farms had to be bigger to make a living, and because the better technology lessened the manpower required, it was possible to boost farm size.

And thus, you end up with the story of the Paap farm, which has tripled in size in the past century. Or even Miller's farm, about 400 acres of corn and soybeans, which he attends to on weekends and evenings while also working full-time as the director of research and commodity services at the Iowa Farm Bureau.

Agricultural researchers like Stanley Wood of the Consultative Group on International Agricultural Research come to a conclusion perhaps startling to those who decry modern agriculture's impact on the environment: "This increase in productivity has actually saved huge amounts of land from conversion [to agricultural use]," says Wood.

In fact, about a billion hectares of land has avoided being converted.

"If you think about what the yields of cereals were in the early '60s, and if you look at the world's production of food now, if we took the yields and applied them to production today, we'd require more land than is on the planet to feed everybody," says Wood. "We'd need five times as much land."

PROBLEMS LOOMING

While the Green Revolution averted crisis in the 20th century, researchers are far from sanguine about the prospects for the 21st.

For one thing, we are feeding vastly more people, so "the relative number of hungry people has been going down, but the absolute number hasn't declined much," explains Tom Tomich, director of the University of California Sustainable Agriculture Research and Education Program.

> "Agriculture is responsible for about 30 percent of greenhouse gasses, bigger than all other human activities, more than all the world's transportation, or all the world's electricity, or all the world's manufacturing."

Moreover, says Tomich, the huge increases in food production have come with an environmental cost. "We have used more and more water for irrigation," he says, "more and more fossil fuels"—which not only run tractors, but are used intensively to create fertilizer, of which we are also using more and more.

If you put all the world's pastures in one place, they would cover Africa.

Where do statistics like that come from? The Institute on the Environment's new Global Landscapes Initiative, for one.

"We're stepping back to look at the globe as a whole, which really isn't done anywhere else," says Jonathan Foley, IonE director and head of the initiative.

Scientists and researchers are using satellites, censuses and other data to map the world's landscapes in a new way—looking at who is using which land for what, how many trees grow there, and how many bushels of wheat they harvest.

Then they take that data to figure out what it all means, with long-range observations and computer modeling. Foley calls it "future-casting."

"What if we do end up with 9 billion people who want to eat like Europeans and Americans? How much land would be required? How much productivity?"

At the same time, economists are working on ways to price out land use intangibles. Sure, Foley says, you can calculate corn profits by subtracting the costs to fertilize, plant and harvest from the market price. But what about the things we don't put prices on?

"How much carbon is this ecosystem storing and what is that worth?" he asks. "What about biodiversity, what might that be worth?"

To find out, Foley says the GLI researchers are working closely with leaders in the industry, non-governmental and policy arenas. Makes sense, since these are the people who will take the GLI's work and run with it.

The Institute on the Environment's Foley says one of the most worrying issues is growing water scarcity. "We have basically dried up most of the Aral Sea to irrigate what used to be the Soviet desert to grow cotton," he says. "The Colorado River doesn't flow into the ocean anymore," because so much is diverted along the way for irrigation. Underwater aquifers are being used up. Ninety-five percent of Lake Chad has disappeared since the late 1960s.

"Agriculture already uses vastly more water and has changed the water cycle of the planet more than climate change ever will," Foley says.

At the same time, agriculture is a major contributor to climate change and will suffer as an industry from the consequences.

Slash and burn agriculture, especially in the rainforest, emits a high level of carbon dioxide. Agriculture is also responsible for some of the highest human-caused emissions of methane and nitrous oxide, which are even more potent greenhouse gases than carbon dioxide.

As rice stalks decompose in the flooded conditions that allow many rice varieties to thrive, large amounts of methane get released into the atmosphere. Ruminant animals such as cows, which digest grains in a series of stages in several stomachs, also emit a significant quantity. Nitrous oxide, another powerful greenhouse gas, is released from over-fertilized fields.

When you weigh the amounts by the degree to which each gas warms the environment, Foley says, "agriculture is responsible for about 30 percent of greenhouse gasses, bigger than all other human activities, more than all the world's transportation, or all the world's electricity, or all the world's manufacturing."

Perhaps equally worrying are the trends in yield growth. After the dramatic increases of the late 20th century, some of the staple cereal crops seem to be reaching the limits of their potential.

Zeigler says, at least where rice is concerned, "we're predicting about 20 years from now we'll have squeezed about all we can out of our current technologies."

All of this is true now, as we work to feed a global population of more than 6 billion. But estimates indicate the population will grow by another 50 percent by about 2060.

And if current consumption trends continue, says Wood, not only will every one of those people need to eat, but they will probably be eating a higher proportion of meat than today's population. Raising equivalent amounts of food from livestock requires a higher degree of grain production than if humans were to eat the grain themselves.

"If you take into account both of those things," Wood says, "maybe you need to grow 60 or 70 percent more food than we currently do."

GREEN REVOLUTION: PART 2

Foley says this is potentially a bigger problem than climate change,

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and wonders why it gets talked about far less. "We may be able to adapt to a warmer world, even if we decide to keep using fossil fuels, but we can't say 'nah, we're not going to grow any more food,' or say to the next billion or so people born on this world, 'nah, you're not going to eat.'"

Still, Tomich remains fairly optimistic. "As a species we've demonstrated a great ability to invent and innovate." The key moving forward, he says, is collaborating rather than competing as individuals.

Take the slowing yield growth, for instance. David Lobell, a food security and environmental researcher at Stanford University, points out that "it's often the leading edge—the highest yielding areas—that bump up first against any sort of yield potential." For rice, that's clearly in Asia. But in other parts of the world, notably in Africa, yields are still well below their potential.

> Not only do the crops have the potential to feed more people, but they could do so with a lower impact on the environment.

"There are promising technologies [in Africa]," says Lobell, such as the development of a rice that is much improved for desert environments. More important, he says, is the development of markets and incentives to apply fertilizer, which could increase yields.

But even in Asia, "the 'maximum yield' is subject to change as technology improves," says Lobell.

Zeigler says the IRRI is developing new rice hybrids they think have the potential to significantly improve yields in the next two decades. And, looking even further down the road, the IRRI is working to modify the photosynthetic system of rice from the evolutionarily older C3 process to capture sunlight to the newer C4 process used by maize and sugarcane. Zeigler says this would increase yields by anywhere from 40 to 50 percent.

Many researchers say these kinds of crop advances, many of which can only come about through genetic modification, are absolutely crucial to prevent the looming crisis. Not only do the crops have the potential to feed more people, but they could do so with a lower impact on the environment.

Higher yields will continue to mean less land needs to be converted to agricultural use. But by modifying the seed varieties, grains can be developed to use less water as well. And they can be developed to use less fertilizer more efficiently, meaning less would need to be manufactured and less runs off into water sources or turns into nitrous oxide in the environment.

Foley shares the concerns of a lot of people about genetic modification. "The regulation of these new GMOs [genetically modified organisms] is probably not what it should be," he says. "It would be nice if there were partnerships between private entities and watchdog groups to make sure these things are used wisely." Still, he says the possibilities are very interesting.

Beyond seed varieties, there have been significant advances in crop management that have helped farmers minimize their negative impact on the environment.

One is the GPS technology that leads to less waste. Another is something called "no-till" or "minimum-till" where, for the first time since agriculture began, farmers are forgoing the plow. Instead of digging through the soil at the beginning of every growing season to turn over the soil and get rid of weeds and last season's leftovers, farmers are leaving the ground cover be—or disturbing it far less. It preserves more moisture in the soil, which decreases runoff and keeps the soil rich so it needs less fertilizer.

For more and more farmers today, good business and good environmental practices go hand in hand.

"We in agriculture will take second place to no one in our commitment to land, air, water and the care for livestock and of our families," says Paap. "We've got a vital stake in respecting and protecting our environment, for ourselves and future generations, while at the same time remaining a leader in feeding the world."

NAOMI SECK is a Washington, D.C.-based freelance journalist who covers a wide range of global environmental topics. She is a frequent contributor to Voice of America and has also reported for *The Christian Science Monitor*, *The Economist*, *CNN Traveller* and more.

ANCIENT WISDOM, UPDATED

In Ancient Rome, the most famous statesmen proudly called themselves farmers, and many happily shared their knowledge in books for the average Joe.

In one particularly well-known example, which Iowa State University historian David Hollander recalls, Cato the Elder explained how to make the most profit as a farmer: "Raise cattle."

What, he imagined someone questioning, is second best?

"Raise cattle not as well."

And third?

"Be a lousy cattle farmer."

These days, cattle farming may or may not be the most profitable, but from an environmental standpoint, it has some of the highest impacts.

This doesn't mean we shouldn't do it at all, says the Institute on the Environment's director Jonathan Foley, since some lands are particularly well-suited to raising livestock and not much else.

But from a consumer standpoint, says Carnegie Mellon researcher Chris Weber, if your goal is to minimize your personal carbon footprint, one of the best ways is to eat less beef and dairy.

A lot of people think you should eat locally to reduce your carbon footprint, says Weber, but if you look at the data, which he did, it doesn't bear out.

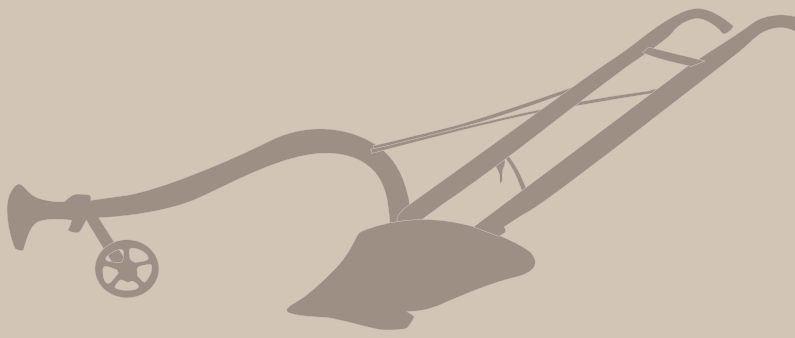
"If you were to completely localize your diet, you would reduce household emissions something like eliminating 1,000 miles a year driven in a 25 miles-per-gallon car," he says.

"But if you switch, one day a week, all your calories from red meat or dairy to vegetables, it would be like driving 1,200 miles a year less."

That's because cows and other ruminant animals emit methane as part of their digestive process. Plus, cows eat more calories of grain to make the equivalent number of calories of meat, which means more grain has to be grown around the world.

But if you love your steaks, know that, from a carbon-emissions perspective, grass-fed cattle are on equal footing to grain-fed.

"Although you're cutting out emissions associated with making the grain," says Weber, "cows that are eating grass actually belch more, so more methane is released from that. Plus they have to live longer to get to the weight needed to slaughter."



HISTORY LESSON

Before agriculture, people were mostly hunter-gatherers. About 10,000 years ago, that all began to change. And another 5,000 years after that, almost everyone lived in settled, agriculture-based communities.

Today only a few pockets of hunter-gatherer societies remain in the world.

And yet, "some studies suggest that, for the average person, after the switch to a settled agricultural lifestyle, some aspects of their life were distinctly worse," says Iowa State's David Hollander. "The average hunter-gatherer had a much broader, diverse diet than someone in a settled agricultural environment, and general health seems to have declined."

The whys of societal change are always multifaceted. "But it seems one thing that's going on is that people, given the choice, would rather have the more secure food sources than the better diet," says Hollander.

And if you define the success of a species by its proliferation, agriculture seems to have been a pretty good idea. By one estimate of the world's population, in 130,000 B.C., there were about 100,000 people. In 10,000 B.C., there were about 7 million. Then agriculture was invented, and by 81 A.D., there were about 300 million people in the world.

Perhaps agriculture wasn't the reason for the rapid increase in population growth. It could be the other way around: Agriculture was invented because there were more people in the world.

Either way you look at it, the average ancient farmer needed a lot more land to produce the same amount of food as the modern farmer—and the average hunter-gatherer needed even more land than that.

Today, with 6 billion people and rising, we should probably be glad our ancient ancestors picked up the plows.

A NEW WORLD MAP

Humans have completely transformed the natural world. Let's adjust our maps—and our mindsets—accordingly.

BY CHAD MONFREDA
Maps and data provided by Erle Ellis

Any ecology student could tell you what biomes are: vegetation types, such as grasslands and tropical rainforests, that ecologists use to map the planet. But there's a problem. Biomes don't exist. Or rather, biomes exist only at the discretion of nearly 7 billion people trying to live their lives on a crowded planet. ¶ Invert that ancient image of invasive humans chopping away at the edges of a pristine nature. The era has long since moved from the *Holocene* to the *Anthropocene*. Nature is now embedded within a matrix of human-altered croplands, pastures, towns and cities. These anthropogenic biomes—"anthromes" for short—offer a fresh way of seeing our planetary pastiche. ¶ By combining data on land cover, land use and population density, researchers from the University of Maryland, Baltimore County, and McGill University have visually captured 21 anthromes, ranging from urban settlements and irrigated villages to remote deserts and other barren lands. Using these data, we've zoomed into particular anthromes in seven countries, spanning six different continents, to show how human and natural landscapes have become one.

CHAD MONFREDA is a doctoral student at Arizona State University, where he studies biodiversity and global environmental governance. He's also a freelance writer who researches global land use and covers sustainability science for WorldChanging.com. **ERLE ELLIS** is an associate professor at the University of Maryland, Baltimore County, where he directs the Laboratory for Anthropogenic Landscape Ecology. In collaboration with McGill University's Navin Ramankutty, Ellis coined the term "anthromes" in the article "Putting People in the Map," which appeared in *Frontiers in Ecology and the Environment* in 2008.

ANTHROMES AROUND THE WORLD

- **DENSE SETTLEMENT:** Region with compact urban development and human population
- **VILLAGE:** Dense agricultural settlement, e.g. rice, irrigated, cropped, pastoral, rain-fed
- **CROPLAND:** Annual crops mixed with other land uses and land covers
- **RANGELAND:** Residential, populated or remote land for livestock grazing; minimal crops and forests
- **FORESTED:** Forest with low human population and agriculture
- **WILDLAND:** Forest, desert, etc. with low or no human population

BRAZIL'S WILD FRONTIER

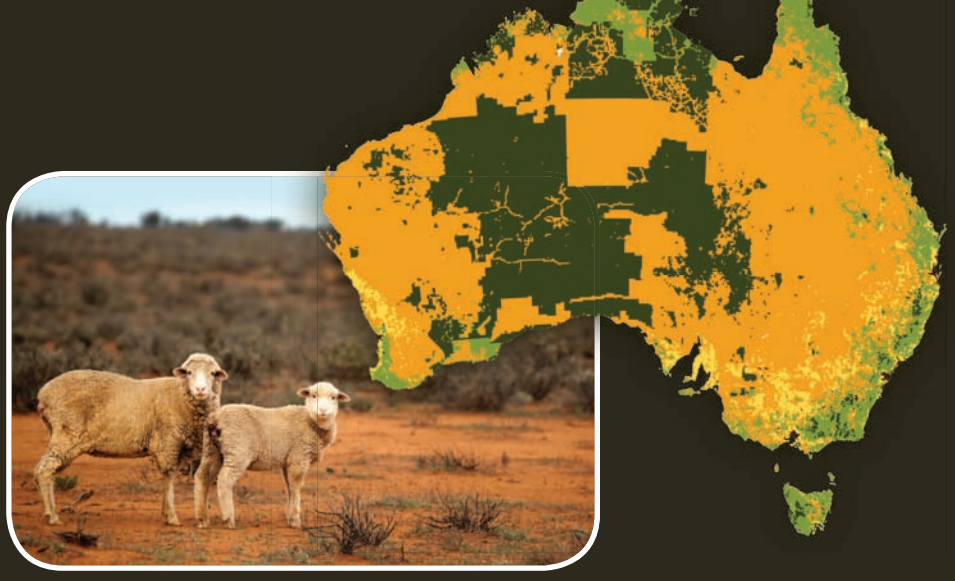
No ecosystem on Earth carries more ecological and symbolic value than the Amazon rainforest. And no country better illustrates the complexities of managing the biosphere in the 21st century than Brazil. Remote and wild forests cover one-third of the country, occupied by the occasional settler or indigenous community with few ties to the central government in Brasília. Like the bygone age of America's Wild West, the Brazilian Amazon presents a vast, promise-filled frontier to an emerging global power. But unlike the United States during its ascent, Brazil must negotiate a host of new political, economic and ecological tradeoffs clamoring for attention across multiple scales. The Amazon provides critical ecosystem services in the form of global carbon storage, regional climate regulation, local flood control and an extraordinary wealth of biodiversity—all contending with growing demands for timber, soy, beef and biofuels from regions like Europe and China. Weighing heavily on these tradeoffs is Brazil's imperative to develop and retain sovereignty over its domestic resources. Will Brazil follow the lead of the American frontier? Or might it take another course?

PHOTO: RICARDO FUNARI

INDIA'S GRAIN POWER

One-half million villages sprawl across every corner of rural India, where seven in 10 Indians dwell in some of the longest cultivated and most densely populated landscapes on the planet. India is home to one-quarter of all the world's villages, and nearly one-half of all **rice villages.** Running along the fertile Gangetic Plain from Punjab to the Bay of Bengal, these ancient rice villages are home to 250 million people—making them the most populous anthrome in any single country. Over millennia of intensive land use, India's villages have evolved into a finely textured bio-cultural tapestry. Today, however, India's unique knowledge and genetic resources face new challenges in a world where intellectual property carries the promise of big money. Most notorious is the case of neem, a tree whose traditional medicinal properties led to patent claims in the United States and Europe. Public outcries of biopiracy and neo-colonialism led to a drawn-out series of legal disputes and the eventual revocation of certain patent claims by the European Patent Office. PHOTO: MELISSA ENDERLE

AUSTRALIA: ADAPTING DOWN UNDER

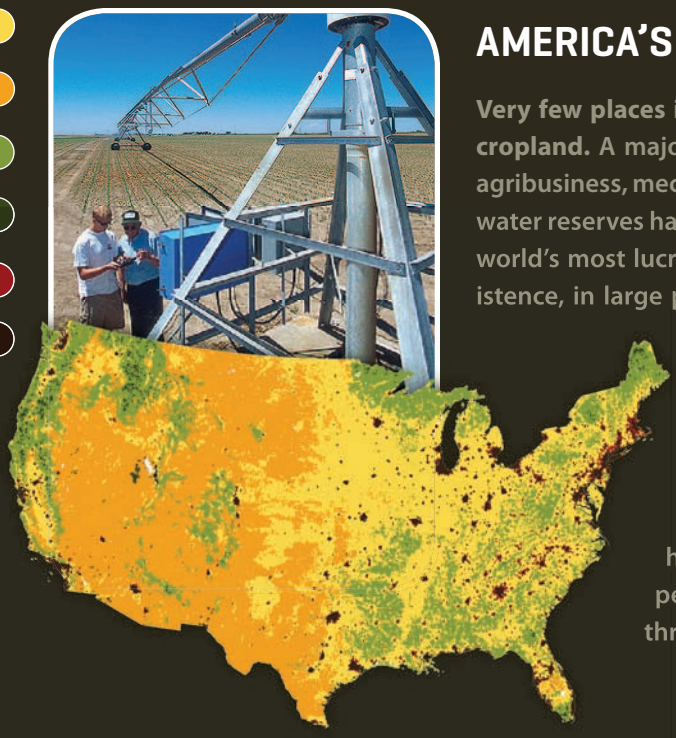


The harsh, unpredictable climate of Australia's vast interior makes it one of the least densely populated countries in the world. While 62 percent of Australians dwell in **urban anthromes** like Sydney, Perth and Melbourne, less than 300,000—roughly 1.5 percent of a population of 18 million—spread themselves thinly across the 4.2 million square kilometers of **remote rangelands** that span half the continent. But the absence of humans does not mean an absence of human influence. Aboriginal people have used fire to manage Australia's vegetation for at least 40,000 years. And, in the past 150 years, ranchers have used self-replicating machines called sheep and cattle to capture thinly dispersed plant cellulose and convert it into meat, hides and wool valued at $2 billion per year. No other technology comes close to fire and livestock in its power to enable a small population to transform vast swathes of land. In the past 30 years, however, Australia's remote rangelands have entered a period of profound cultural and economic change. Tourism now rivals the economic returns from livestock, and mining far exceeds them, forcing aboriginal and ranching communities to adapt yet again.

CHINA'S BURGEONING CITIES

The greatest migration in our civilization's 10,000-year history is now under way in China. A "floating population" of 150 million—mostly young, mostly rural and making up 10 percent of the country—is seeking out newly-found urban opportunities. Already, Chinese rivers and coastlines host almost one-quarter of the world's **urban and densely settled anthromes**, where half of the world's cranes and new concrete are busily building the most significant human habitats of the 21st century. But cities are more than concrete and steel. They are also key nodes in a global exchange network of goods, services, people and ideas. Rising cities little known to most westerners, like Guangzhou, Shenzhen and Tianjin, are helping to reconfigure anthromes the world over: Both domestically, as farm-workers abandon traditional, labor-intensive agriculture, and internationally, as regions as far-flung as the rainforests of Borneo and Brazil rush to supply China's mounting demands for feed, fuel and fiber.

AMERICA'S FADING BREADBASKET



Very few places in the world are devoid of people and rainfall but rich in cropland. A major exception is the High Plains of the United States, where agribusiness, mechanized agriculture and the discovery of enormous groundwater reserves have transformed low-productivity rangelands into one of the world's most lucrative breadbaskets. These **remote croplands** owe their existence, in large part, to the Ogallala Aquifer, which supplies about 30 percent of the nation's irrigation water to grow one-fifth of its wheat, corn, cotton and cattle. Yet this anthrome—just 50 years old—may be short lived. Severe overdraft of the Ogallala has led to cropland abandonment in some places and a 9 percent loss in water storage overall. While center-pivot irrigation and other conservation techniques have substantially reduced overdraft of the Ogallala from its peak in the mid-1970s, the ultimate sustainability of this anthrome is at risk. PHOTO: AGRICULTURAL RESEARCH SERVICE

RWANDA: MAN VS. NATURE

One of the most densely populated countries in the world, Rwanda is also one of the most biodiverse. **Dense settlements** comprise one-quarter of the country, and villages occupy the rest. Ironically, there are no wild anthromes in this land awash with some of the richest biodiversity on the planet. Situated between the Great Rift Valley to the east and the Congolese rainforest to the west, Rwanda sits atop the Albertine Rift, a biodiversity hotspot home to more endemic mammals, amphibians and birds than anywhere else in Africa. Remarkably, human population densities here approach 750 people per square kilometer. The extreme convergence of people and wildlife speaks to the anthromes' major lesson: Nature now exists in pockets embedded in human landscapes, and any attempt to conserve nature must also address human well-being. But paradise this is not. Most Rwandans live in precarious conditions, in a country riven by civil war, where violent conflict has has led to an increase in unsustainable practices like the **bushmeat trade.** PHOTO: SAREL KROMER

UNITED KINGDOM: GOD SAVE THE GREEN

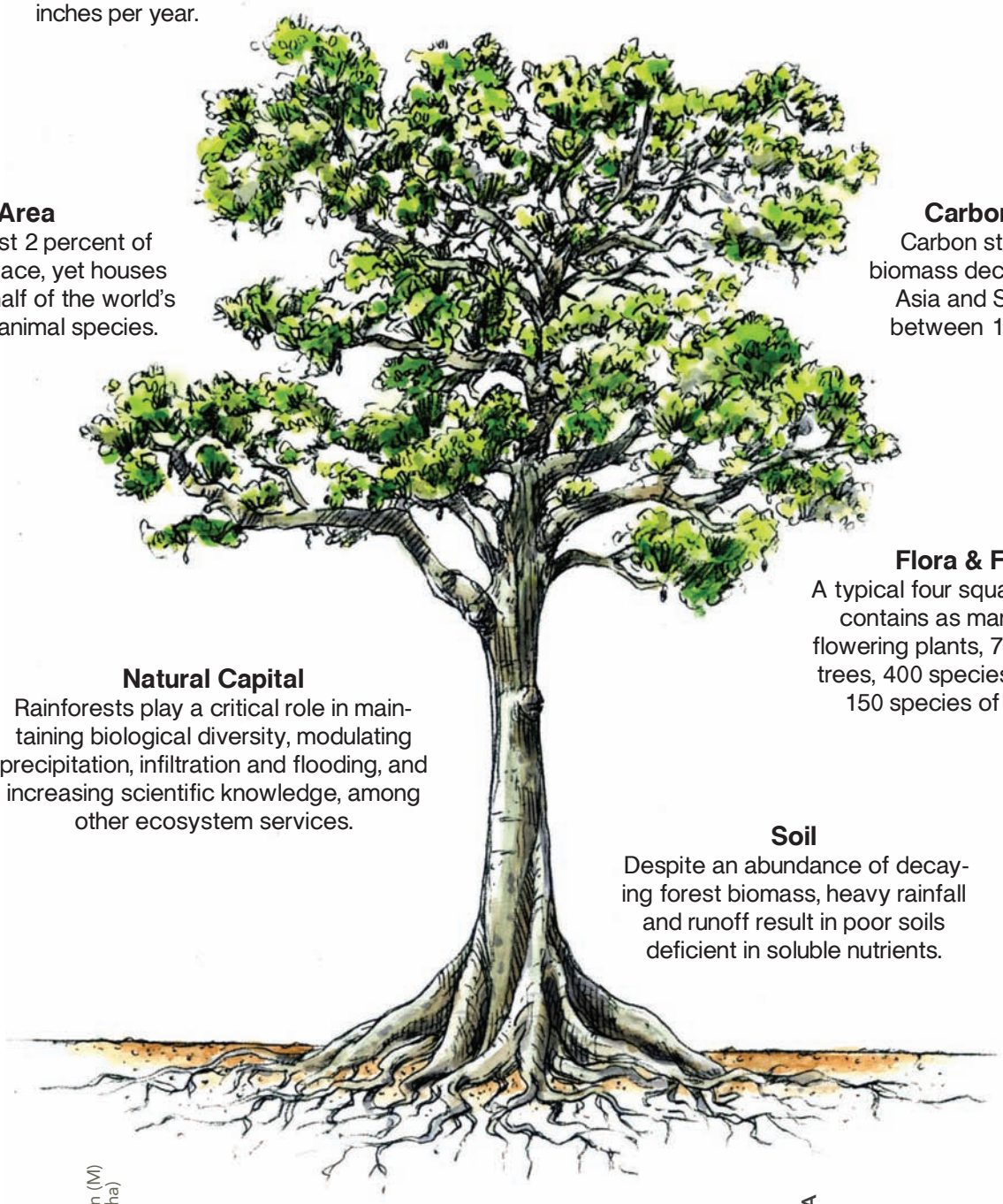
British economist John Maynard Keynes once quipped, "The inhabitant of London could order by telephone, sipping his morning tea in bed, the various products of the whole earth." Although Keynes was talking about the British Empire, the same could be said of the United Kingdom today: The island nation imports 40 percent of its food from abroad. Free from the pressure of feeding its entire population from the **agricultural anthromes** that already cover three-quarters of the country, the U.K. can afford to preserve the picturesque landscape of hedgerows and rolling fields so integral to its national identity. Keynes' observation persists today because the country continues to reap the benefits of a global economy. But this can be a risky strategy—with some 20,000 jobs hemorrhaging from London's financial district, that great center of international banking and insurance. As the current economic crisis unravels these industries, the full impact on the U.K.'s landscapes remains to be seen. PHOTO: DAVID PEARSON (FLICKR.COM/ELHAWK)

INTO THE WILD

TROPICAL RAINFOREST

Nicknamed “the world’s largest pharmacy” because more than 25 percent of modern medicines originate from tropical rainforest plants.

Rainfall
80 to 450-plus inches per year.



Area
Covers just 2 percent of Earth’s surface, yet houses more than half of the world’s plant and animal species.

Carbon Storage
Carbon stored in forest biomass decreased in Africa, Asia and South America between 1990 and 2005.

Flora & Fauna
A typical four square-mile patch contains as many as 1,500 flowering plants, 750 species of trees, 400 species of birds and 150 species of butterflies.

Natural Capital
Rainforests play a critical role in maintaining biological diversity, modulating precipitation, infiltration and flooding, and increasing scientific knowledge, among other ecosystem services.

Soil
Despite an abundance of decaying forest biomass, heavy rainfall and runoff result in poor soils deficient in soluble nutrients.

RUSSIA 809 million (M) hectares (ha)

BRAZIL 478M ha

CANADA 310M ha

USA 303M ha

CHINA 197M ha

While forests cover 30 percent of Earth's total land area, there are only two major, intact virgin woodlands: the northern boreal forest stretching from North America to Scandinavia and across Russia, and the tropical rainforests of Central America, South America, Africa and Southeast Asia. Both play distinct roles in shaping our global environment.

compiled by TODD REUBOLD
illustrated by RUSSELL CHARPENTIER

BOREAL FOREST

The term "boreal" originates from Boreas, the Greek god of the north wind. "Boreal forest" is typically used to refer to the central and southerly part of the biome, while "taiga" is often used to describe the barren northern areas of the Arctic tree line.

Natural Capital

In the Canadian boreal forest, the economic value of water filtration, flood control and carbon storage is more than double that of traditional industries such as forestry, mining, hydropower, and oil and gas extraction.

Flora & Fauna

Mainly coniferous trees such as larch, spruce, fir and pine; inhabited by woodpeckers, hawks, moose, bears, weasels, lynx, fox, wolves, deer, hares, chipmunks, shrews, bats and other animals.

Rainfall

7-29 inches per year.

Area

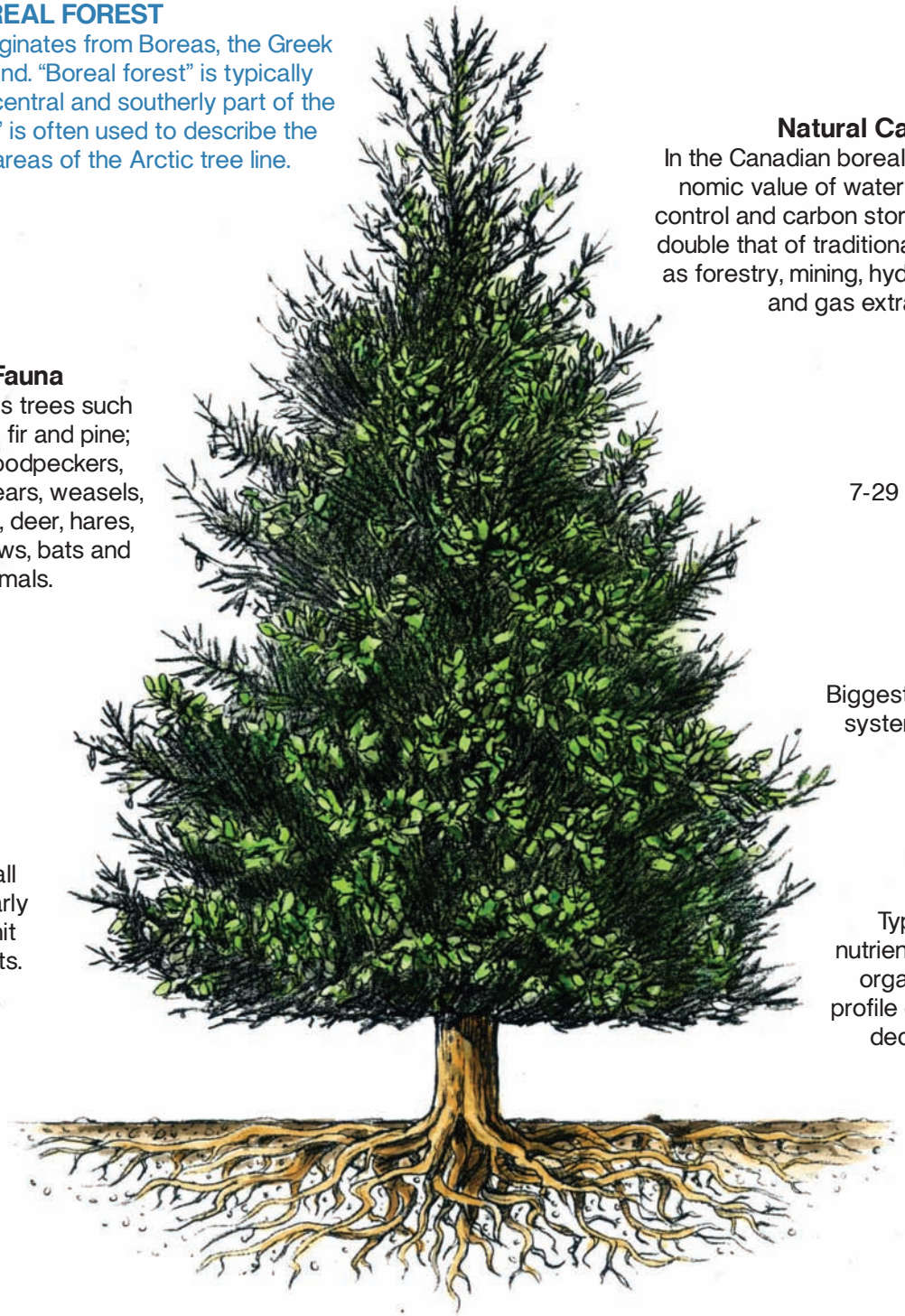
Biggest terrestrial ecosystem in the world.

Carbon Storage

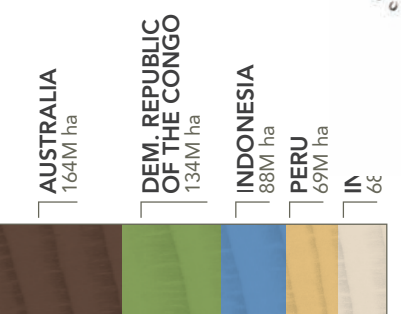
Holds 22 percent of all terrestrial carbon—nearly twice as much per unit area as tropical forests.

Soil

Typically thin and nutrient-poor, lacking the organically-enriched profile of more temperate deciduous forests.



SOURCES: Encyclopedia of Earth, Food and Agricultural Organization of the United Nations, International Boreal Conservation Campaign, Nature Conservancy, Pembina Institute, Wikipedia



TOP 10 COUNTRIES WITH THE MOST FOREST AREA IN 2005


GLOBAL
WARNINGS

SCIENTISTS ARE ON A QUEST TO PREDICT SUDDEN SHIFTS IN ECOSYSTEMS, BEFORE WE REACH THE POINT OF NO RETURN. BY BRANDON KEIM

The Sahara is probably the most iconic desert on Earth, evoking visions of desiccated landscapes dominated by scraggly shrubs and naked soil.

But it wasn't always that way. Just 6,000 years ago, the Sahara was lushly vegetated and nourished by frequent rainfall. Within the course of a few centuries (or a few decades, depending on the study), everything changed. The rains dried up, plants withered and the modern Sahara emerged.

For most of the 20th century, scientists had no idea how to explain this. Evidence of a radical shift—provided by fossils, sediment deposits and abandoned villages—was overwhelming. According to standard ecological theory, however, such a massive change shouldn't have happened so quickly. The most popular explanation was that slow and subtle shifts in Earth's orbit changed solar radiation levels, causing a drop in rainfall patterns. But computer simulations of the shift failed to replicate the speed at which this had taken place.

Meanwhile, researchers were baffled by a more contemporary puzzle in the Sahel, a band of arid grasslands that cross Africa beneath the Sahara. Starting in 1969, the Sahel experienced a devastating drought, one that continues today. Whereas most other droughts around the world last for just a few months, this one has lasted for three decades, repeatedly reaching new lows in rainfall.

In the past, many scientists attributed this to changing sea surface temperatures and tropical circulation patterns. But changing temperatures alone couldn't account for the drought's unprecedented severity and duration.

It was only when ecologists developed new models describing interlocking relationships among land, vegetation, atmosphere and oceans that things started to make sense. Suddenly they could reproduce the Sahara's rapid desertification and the Sahel's record dry spell.

Out of this work—along with research on polluted ponds and damaged coral reefs—came a new theory of ecosystem change: Transition doesn't need to be linear and gradual. Rather, it can take place rapidly and unpredictably. Ecosystems can exist in "alternative stable states," with only a nudge needed to flip them from one to the other.

Today, scientists believe these so-called critical transitions can take place in many different ecosystems. But even if they happened only in arid and semi-arid lands, there would be plenty of reason to pay attention. Such lands cover some 40 percent of the world's surface and support a billion people. As ever more water is diverted to grow crops and more animals are put out to pasture, the nudges are many and strong. And greenhouse gas pollution and climate change are only adding to the pressure.

"We don't know where the thresholds are," says Marten Scheffer, an ecologist at the Netherlands' Wageningen University. "But we know they're there and that we cross them."

ECOSYSTEMS ON THE EDGE

To many people, the term "tipping point" suggests *The Day After Tomorrow*-style ice storms, or Malcolm Gladwell's examples of Hush Puppy sales and crime in New York City. But there are tipping points, or "critical transitions," in ecosystems, too.

The dynamics of critical transitions are very different from those of traditional ecological theory, in which change is supposed to happen more or less gradually, in a straightforward and fairly predictable way. Sometimes that's true, but not always.

Scientists first noticed these transitions in lakes and ponds, where nutrient pollution quickly turned clear waters that once supported a rich ecosystem into oxygen-starved, algae-dominated soup. Other critical transitions are visible in coral reefs (where overfishing can rearrange the food chain in ways that leave reefs vulnerable to disease), as well as on land in tundra, grasslands and jungles.

Many ecologists now think that critical transitions can be found almost anywhere. The science is still maturing, but certain basic patterns appear to be universal. Shifts follow a period in which parts of an ecosystem, such as water and nutrient availability, vegetation patterns or animal populations, are altered. On the surface, the system doesn't seem to change, but what was formerly a stable arrangement becomes internally unbalanced.

New feedback loops—between, for example, a new plant species and local climate—kick in. Suddenly a relatively small impact, like a wildfire or a few seasons of heavy grazing, can produce long-lasting changes. The ecosystem seems to be drawn toward some other configuration.

When it arrives, this new configuration is as stable as the old one. And if the transition in question involves an ecosystem important to us, such as farmland that turns to desert, that one-way trip is bad news.

Scientists are now trying to flesh out their models with real-world details, applying numbers to concepts and mapping the boundaries between states.

This is hard work, says Marten Scheffer, a Wageningen University ecologist and regime shift pioneer. "Do we understand what's happening? In theory, yes, but in practice, there's a problem: We don't know the signals very well yet," he explains.

"If you see it too late, your system can shift in a way that's difficult to recover."

FROM THEORY TO PRACTICE

Today, scientists are trying to figure out how to handle these critical transitions. One approach acknowledges the possibility of thresholds to guide land management strategies. If strategies needed to be calculated from scratch for each region, the task might be impossible. But a set of generic models, called typologies, might sketch the parameters of any arid system.

"We try to get lots of data from where thresholds have clearly been crossed, and understand where the threshold and the system were when that happened," says Brian Walker, an ecologist at Australia's Commonwealth Scientific and Industrial Research Organisation. "Then you can say, 'I'm in a semi-arid rangeland in Africa, and this is what I should be watching out for.'"

Many of the world's semi-arid rangelands behave in much the same way, with their states determined by feedback loops among water, vegetation, soil and climate.

The findings of Walker and his colleagues are now used to guide grazing and fire prevention patterns at test sites in South Africa and Southeast Australia. Although those tests may prove successful, applying the approach elsewhere may prove tricky.

"When you get to the field, you have to deal with particular ecological patterns. You have to deal with the technology and methodology that's available for collecting data. You have to deal with the reality of sampling, and figure out how you're going to use those samples and analyze them," explains Craig Allen, a research ecologist with the U.S. Geological Survey who's studied transitions in the American southwest.

In addition to typologies, scientists need early warning signs: something to tell them if their plans aren't working or if a system is in danger of tipping. Theoretically, this is possible. According to models and real-world testing, a system that's approaching a critical transition should lose its equilibrium in mathematically verifiable ways.

When approaching a critical transition, a slightly unusual season can be followed by dramatic changes in plant cover. At one time, these changes would have reverted back to normal, but instead they linger. Lines on graphs that chart the system become jagged. The center no longer holds.

"Up until about five years ago, we thought that regime shifts were essentially unpredictable. They were like accidents waiting to happen, and would catastrophically come out of nowhere. There was no possibility of predicting them or dealing with them in advance," says Steve Carpenter, a professor and early warning sign expert at the University of Wisconsin-Madison.

Carpenter says the availability of early warning indicators could provide enough advance notice to take action and prevent crossing the threshold. The best examples come from systems that have been studied for decades, where researchers can compare new readings against historical baselines. But such thorough datasets are the exception, not the rule.

"For many circumstances, the time needed to detect variance is too long," says Walker. "You cross the threshold before you've detected it."

A CRITICAL TIMESAVER

Given that detecting thresholds could take decades, researchers are looking for a shortcut—namely, indicators that can be applied to any arid region and require the ecological equivalent of a thermometer under the tongue.

The most promising of these is changing vegetation patterns. The beginning of a grassland's transition to desert is marked by localized outbreaks of relatively sparse shrubs. Where soil once held by the grass' roots had acted like a sponge, water no longer penetrates. Wind blows faster over bare ground, piling eroding earth at the base of shrubs, which require more of the system's water.

As the shrubs spread, the desertification accelerates. Patches of grass shrink and become even more vulnerable to local change. They suffer "micro-extinction events." Bare soil between bushes is dark, where the grassland soil had been beige. Ground-level temperatures rise, making water evaporate even faster. Soil is blown into the air. If enough ultra-fine dust particles enter the local atmosphere, they disrupt rain formation, which requires water molecules clustering around particles of larger size.

Scientists believe this phenomenon is responsible for the unusually long Sahel drought.

According to studies in the Sahel, Africa's Kalahari Desert and rangelands around the Mediterranean, all this produces telltale patterns of vegetation patch size and shape. In a healthy system, these can be plotted on an orderly curve. As the likelihood of transition increases, data points fall off the line. Aberrations can be seen by the naked eye.

"The spatial indicators we're working at are the only class that requires a snapshot in time, meaning that spatial patterns suffice to know that one is approaching a regime shift. That's what makes it so appealing," says Max Rietkerk, a geoscientist at the Netherlands' Utrecht University.

The most advanced test of spatial indicators is taking place in the U.S. southwest, where scientists with the Long Term Ecological Research Network are studying the boundary between Great Plains grasses and shrub-dominated desert. So far, the results are mixed: Aerial imagery has failed to match patterns to desertification, but this might be a shortcoming of low-resolution images rather than the approach itself.

Some LTER researchers are taking a similar approach but on a smaller scale, comparing hand-measured variation in hectare-sized plots. "If we start to see bare patches forming, and they get big and we see erosion out of those patches, that's a good indicator that we're losing resilience," says Brandon Bestelmeyer, a research ecologist with the U.S. Department of Agriculture. "We don't know how close we are, but we're closer than before."

> "UP UNTIL ABOUT FIVE YEARS AGO, WE THOUGHT THAT REGIME SHIFTS WERE ESSENTIALLY UNPREDICTABLE. THEY WERE LIKE ACCIDENTS WAITING TO HAPPEN, AND WOULD CATASTROPHICALLY COME OUT OF NOWHERE."

Researchers have tentatively observed similar spatial patterns in other ecosystems, from bogs to tundra and coral reefs. It's not certain yet whether they indicate critical transition as clearly as they appear to in grasslands. But it's at least possible that the patterns could someday serve as a universal indicator of tipping points.

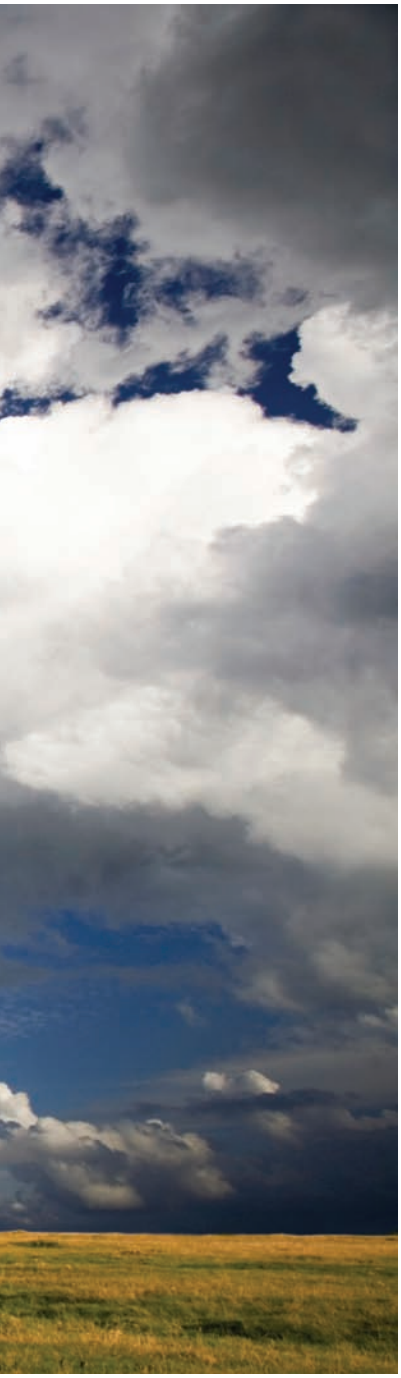
"I *hope* there are universal early indicators. If we have to figure this out for every system, then we're up a creek without a paddle," says Aaron Ellison, a forest ecologist at Harvard University. "If we have to spend 30 years on a system that we want to manage in some way, they'll all be gone before we have a chance."

BRANDON KEIM is a Brooklyn, N.Y.-based freelance journalist specializing in science, technology and culture. He's a frequent contributor to Wired.com's award-winning Wired Science blog. His work has also appeared in the *The Christian Science Monitor*, *USA Today*, *Seed* and many other publications.

Nature's Bank Account

Money doesn't grow on trees, so how do we put a monetary value on nature?

by STEPHEN POLASKY



The best things in life are free—an evening with friends, a summer day at the lake, hiking in the forest on a crisp autumn morning. But just because these things are free doesn't mean we can take them for granted. Maintaining relationships with people and maintaining the environment both require thoughtful action and investment. If we want these "best things" to remain, we need to focus on what builds our communities and nourishes our environment at the same time.

In the past few centuries, humans have dramatically transformed the planet, in good ways and bad. Our quality of life has improved with increases in food production, as well as better health care and education. Yet, humanity has not invested sufficiently to maintain environmental quality. Deforestation, expanding deserts, emergence of dead zones in coastal waters, loss of biodiversity and climate change are just a few consequences of our collective failure to properly care for the environment. And either we, or our descendents, will pay the price.

Environmental degradation causes harm to people by damaging health, reducing productivity and jobs (as seen with the collapse of fisheries), and potential large-scale disruptions from climate change. Some of these damages are hard to quantify, such as reduced quality of life when local lake water becomes clouded with algae, or when a favorite natural area is developed. Even so, these values are real and vital.

Most prices we pay for goods and services do not reflect the full impacts of our production or consumption choices on the environment. Before we can see what fundamental changes are needed to fully sustain the environment, we must begin to incorporate the value of nature in our economic and political decision making. This presents three complex, albeit surmountable, challenges.

First, we must recognize that we don't always know the environmental costs of our actions. For example, chlorofluorocarbons were promoted as a cheap and effective chemical for refrigeration and a propellant for aerosol cans. Not until 40 years after their discovery were CFCs linked to destroying the ozone layer that shields Earth from ultraviolet radiation.

Second, we must translate our actions—and the intended or unintended results—into environmental values we can compare with other values, such as increased income or jobs. Economists have already made great progress in valuing certain environmental benefits. For example, we can infer the value of nature to homeowners by analyzing how housing prices increase with access to lakes, a scenic view or other environmental amenities.

And third, we must bring the values of nature to bear in our decision-making processes. Innovative public policies, such as incentive-based regulations, and private initiatives, such as environmental certification, harness market forces for environmental protection, showing it is possible to protect the environment—even in a rising economy.

In spite of the challenges, we've already seen how progress on both the environment and the economy can be made. Following the passage of the Clean Air Act in 1970, emissions of major air pollutants in the United States were cut in half by 2005, while the economy nearly tripled in size. The Clean Air Act made reducing air pollution a priority, helping to usher in new technology and smarter policies to improve the environment within a growing economy.

Our understanding of the links between human actions and environmental impacts has improved rapidly in recent years. What we need now is to account for a broader range of nature's goods and services in our daily choices. By accounting for the natural world, we can preserve the best of both worlds: a better environment *and* a better quality of life.

STEPHEN POLASKY is a professor of ecology and environmental economics at the University of Minnesota and a resident fellow of the Institute on the Environment. He leads Accounting for Nature, an IonE research project focused on changing economic activities to ensure long-term sustainability while meeting the near-term needs of people.

Branching Out

Peter Reich is planning for the future of our boreal forests with science *and* society in mind.

by GREG BREINING

Smart investors assemble a diverse portfolio to weather uncertain times. Likewise, scientists are beginning to consider how northern Minnesota's boreal forest can be managed to withstand changes in climate, economy and population.

University of Minnesota professor Peter Reich, one of the world's top forest ecologists, is guiding such an effort with a generous grant from the Institute on the Environment. During the next four years, Reich and a team of ecologists, economists and other scientists will work with several community groups to imagine the future of the northern forest and consider how best to prepare for changes.

"What's the range of possibilities that are plausible?" asks Reich. "And given those possibilities, what can we do as a society to maintain the best quality of the environment and sustain economic vitality at the same time?"

Timing is crucial because Minnesota's forests face rapid transformation. Most ominous is climate change. As average temperatures climb, southern species creep northward. Exotic species and new forest pests take root.

Depending on moisture, Minnesota's northern forest could veer toward open oak woodlands or dense, shade-loving hardwoods. How would either development affect, for example, a timber industry dependent on pulpwood species such as aspen? How will tourism fare when the forest changes? What happens to forest species as timber companies sell off land?

These are the sorts of changes Reich hopes people will anticipate. "Even if you can't predict the future, you're set up as well as possible to be in the best situation possible."

A leading authority on tree physiology and the carbon cycle, Reich has worked in a variety of forests—from boreal to tropical. For 15 years, he has studied the ecology of oak savannas and the response of plants to changes in climate and atmosphere at the U of M's Cedar Creek Ecosystem Science Reserve.

Though Reich describes himself as a "basic science guy," undertaking projects that are clear-cut in design, the outlines of his most recent effort are much less straightforward. "It's not strictly a scientific project," he says. "It's a project trying to link science and management and economics."

Why the focus on the boreal forest? For several reasons, says Reich. For starters, people of northern Minnesota are especially dependent on forest industries such as logging, paper and tourism.

Moreover, the state sits at the edge of the northern forest biome, where the landscape grades swiftly from conifers to hardwoods to prairie and farmland—the sweep of change you'd see in traveling from Nova Scotia to Texas. In this zone of abrupt change, scientists expect the most dramatic shifts due to climate.

Finally, the boreal forest tugs at Minnesotans' identity. "It's an iconic, cultural, almost spiritual entity for the people of Minnesota," says Reich. "For all those reasons it seems like an important thing to study."

Key to preparing for a volatile future, Reich says, is strengthening the resilience of the forest ecosystem: the ability of the forest to adapt or bounce back from disturbance or change. For example, as climate drives northern species such as moose from the Boundary Waters Canoe Area Wilderness and allows southern species such as red maple to spread northward, should we let species migrate and adjust on their own? Or should we transplant southern species or even exotic species that are better adapted to a warmer climate?

"If climate change happens as anticipated and a lot of the species that are common now don't do well in 20, 40, 60 or 80 years, how do you maximize resilience of the forest? That's the kind of discussion we need to have—what do you want the Boundary Waters to look like in 50 years? And how do you get there?"

To consider these questions, Reich is developing a four-pronged process:

First, analyze "past trajectories that got us to where we are today and that might give hints as to what the future will hold."

Second, gather a variety of citizens to envision the range of plausible scenarios of the forest and society in the future.

Third, get stakeholders to consider "the things that must happen to make us better off given that range of future possibilities."

And fourth, "try to implement some cross-ownership, landscape-scale management initiatives."

Although initially, Reich would be satisfied simply to get citizen and professional groups engaged in a conversation that would continue indefinitely, he says it's also important to get different groups working together to make the forest more resilient in the face of threats such as fire, climate change, fragmentation and invasive species.

"When I'm dead and gone—hopefully not right away—it would be nice if there was a northern forest that's healthy and vibrant. Probably a different forest … but with people living there and making a living and maintaining environmental quality. No one would disagree with that. It's like apple pie and the American flag."

GREG BREINING is a St. Paul, Minn.-based travel, science and nature writer. His articles have appeared in *The New York Times*, *Audubon*, *National Geographic Traveler*, *Minnesota Conservation Volunteer* and many other publications. He's also the author of several books on travel and the environment.

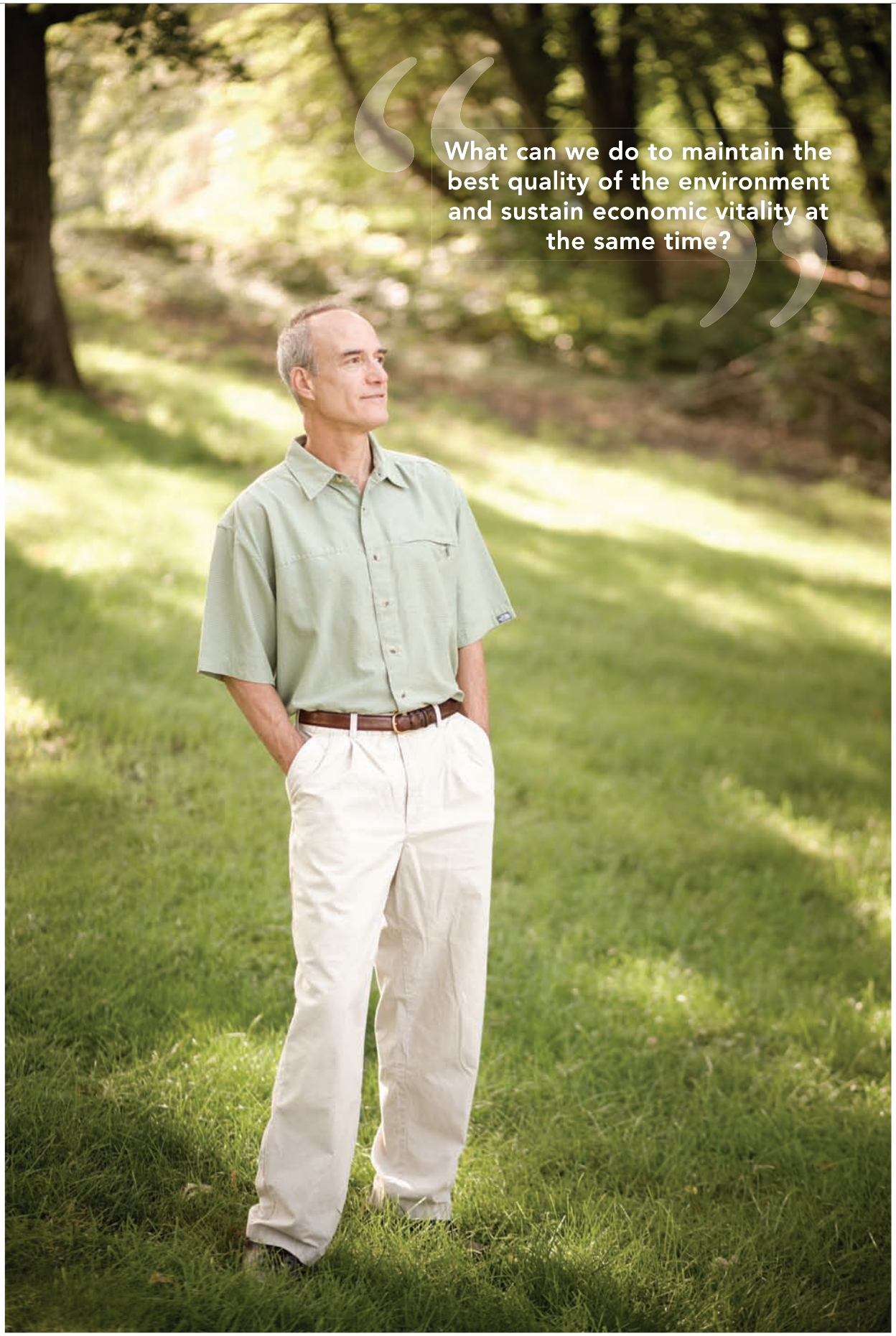


PHOTO: JOSH KOHANEK

Giant Steps

After taking some hard shots from critics, Cargill has bounced back with big strides toward sustainability.

by DAVID MAHONEY

As anyone familiar with folklore knows, it's not always easy being a giant. Cargill, the nation's largest privately owned company and a colossus of global agribusiness, has certainly suffered its share of slings and arrows on account of its size. With food production and trading operations scattered across the developing world, the Minnesota-based company has been a target of activists concerned about the effects of industrial-scale agriculture on endangered ecosystems.

In 2006, Greenpeace protesters upset over the destruction of Brazilian rainforest by soy farmers blockaded Cargill's soybean export terminal on the Amazon River in Santarém. Two years later, the Rainforest Action Network slipped a boat into a regatta on Lake Minnetonka, near the company's headquarters, rigged with a sail bearing the company's logo over the slogan "Biofueling Climate Change"—a disparaging reference to the company's role in exporting soy and palm oil from Brazil and southeast Asia (where palm plantations have also displaced rainforests) for biodiesel production.

Environmentalists may have reason to be wary of the company leaving big footprints on its far-flung stomping grounds. But it's also worth noting that Cargill has forged friendships in some unlikely quarters.

In 2004, Cargill joined forces with The Nature Conservancy on the Responsible Soy Project, a certification program that gives a seal of approval to "forest-friendly" Brazilian farmers. After the Greenpeace protest, Cargill announced it would no longer do business with soy farmers around Santarém who weren't in compliance with Brazil's strict forest code, which requires landowners to maintain natural vegetation on 80 percent of their land. The Nature Conservancy staff now supplies Cargill with information to ensure compliance on the part of individual farmers.

In Indonesia, on the island of Borneo, Cargill has teamed up with Fauna & Flora International to protect the forest habitat of the orangutan and other endangered species. The organization is surveying Cargill's palm oil plantation on the island for "high conservation-value forest." Once FFI completes this initial work, it will help Cargill develop a conservation plan for the habitat. Cargill has a similar arrangement with Conservation International in Papua New Guinea to protect the habitat of the Queen Alexandra's Birdwing, the world's largest butterfly.

Mark Murphy, Cargill's point person on environmental issues, acknowledges that the 2006 release of *Eating Up the Amazon*, a Greenpeace report that held Cargill's feet to the fire for its practices in

LEFT: An international producer and marketer of food, agricultural, financial and industrial products and services, Cargill employs 159,000 people in 68 countries. In an effort to reduce its footprint, the company has formed partnerships with more than a dozen environmental organizations. **ABOVE:** The Oro Province of Papua New Guinea is the only place in the world to find the Queen Alexandra's Birdwing. Cargill and Conservation International are working together to determine the habitat this endangered butterfly needs to survive.

Brazil, was "a tipping point" in the company's approach to perceived environmental threats in its supply chains. Although Cargill had already taken steps to prevent deforestation from soy production, Murphy says the Greenpeace report accelerated its efforts by putting pressure on big Cargill customers like McDonald's.

"Today, corporate responsibility is front of mind for consumers," says Murphy. "When Coke and McDonald's get pressure from consumers who want responsible products, they look to their suppliers. We're their suppliers. So we're feeling increasing demands from our customers."

An almost immediate response to the Greenpeace report was Cargill's active participation in negotiating an industry-wide moratorium on purchasing soy planted on newly deforested lands within the Amazon biome. Greenpeace, one of several environmental organizations that took part in the negotiations, has been surprisingly congratulatory of efforts made by Cargill and other soy traders to uphold and extend the moratorium.

Cargill and Greenpeace still have their differences, but Murphy says the relationship has significantly improved—so much that Greenpeace recently accepted an invitation to a Cargill management meeting to participate in a panel discussion about environmental impacts.

"I think Cargill is recognizing that we need to have dialogue with broader audiences to understand these issues better," says Murphy. "But Cargill is a house of 80 businesses, and our various businesses look at those issues in very different ways. We have to manage what is in the best interest of all those businesses. So we have to take a very balanced, thoughtful approach."

DAVID MAHONEY is a Minneapolis-based freelance writer who has contributed to a variety of national and regional magazines, including *Esquire*, *The History Channel Magazine*, *Delta Sky* and more. He wrote an article on the Institute on the Environment and its director, Jon Foley, for the January/February 2009 issue of *Minnesota* magazine.

Yielding Questions by MARK NEUZIL

This past summer, noted biofuel experts John Sheehan and Joe Fargione took part in a spirited debate over greenhouse gas emissions from land use change, with a focus on agricultural yield improvements. Hosted by the Environmental Protection Agency in Washington, D.C., the workshop helped inform the proposed revisions to the Renewable Fuel Standards (RFS) program. • "I wanted the EPA to acknowledge that if background yields improve faster than the demand for land and food, those yields can dramatically lower land use impacts," Sheehan says, citing biotechnology as a potential player. But Fargione is concerned that agricultural demand will outstrip yield increases, causing continued expansion of agriculture into remaining natural areas. • What follows are excerpts from the in-depth exchange between the two scientists.

"Let's look at the 16 billion gallons of ethanol that RFS would like to have occur by 2022. An assumption is that all this land is not marginal land but prime agricultural land. If no yield improvement occurs after 2007, the model suggests you are going to see a huge demand for land for agriculture.

It probably doesn't make sense to assume no yield improvement in the future. It will occur. And if you listen to Monsanto … it will be more dramatic than the historical trends. Even given growth in population and food demand, our model suggests there is a period out there around 2035 when the amount of land we need in agriculture could actually begin to decline. If you look at the annual emissions from carbon that are occurring from year to year, given historical yield improvements, the carbon debt from land clearing is much, much smaller and you actually pay it back sooner.

In a constant yield future, there's a huge carbon debt. In a historical yield case, you could see a payoff in 30 years.

[Joe and I say] completely opposing things, but it's the nature of the data analysis that it is very possible that we've come to completely opposing conclusions and they have to be worked out.

Joe is right that one of the fundamental issues is this pasture question. If you just limit yourself to cropland yield rate improvements relative to demand increases over time, it is very possible you will conclude we are not increasing fast enough to keep up. On the other hand, pasture efficiency improvements may take care of all that. There is no doubt in my mind—because I projected historical demand forward—that it probably underestimates demand. We need to work on both ends of this equation so we can come to some reasonable conclusion about what the actual trend is."

JOHN SHEEHAN
Scientific Program Coordinator
Institute on the Environment

"It makes a big difference what you assume yields will do. If you look at the historic data, global demands for food are increasing faster than yields, so global cropland is increasing at around 12.4 million acres per year. At present, biofuels are expanding cropland and that land has to come from somewhere.

Part of the discrepancy is that I was looking at cropland and [John] was looking at cropland and pasture. Demand is increasing faster than yields for cropland, but that may not be the case for pasture. If cropland is expanding into pasture, the issue becomes, 'is pasture made up by going into natural areas or not?'

One of the assumptions is how you project out yields for crops and how you project out demand. [John] projected out yields in oil crops exponentially. It's always a problem when you project out exponentially and it doesn't continue—you end up being really wrong as you project out further. For example, with corn yields, if you project out linearly from 1992 to 2007, you are off by 1 bushel per acre; if you project out exponentially, you are off by 100 bushels per acre. You over-project if you go out too far.

The other issue is the assumptions you make about demand. Human population will go from about 6 billion to 9 billion by 2050. So a 50 percent increase. But people are eating more meat, which requires more land, so food demand will approximately double. One of the big impacts … is what happens with meat demand in developing countries? [Some projections indicate food demand may triple.]

The fact that we have controversy and debate over what future yields might be isn't a reason not to address the issue."

JOE FARGIONE
Lead Scientist, North America Region
The Nature Conservancy

AUDIO
Visit us online to link to a complete recording of the EPA workshop, along with slide presentations from Sheehan, Fargione and some 20 other participants.

MARK NEUZIL is a professor in the Department of Communication and Journalism at the University of St. Thomas, St. Paul. He is a regular contributor to MinnPost.com and the author of five books with environmental themes.

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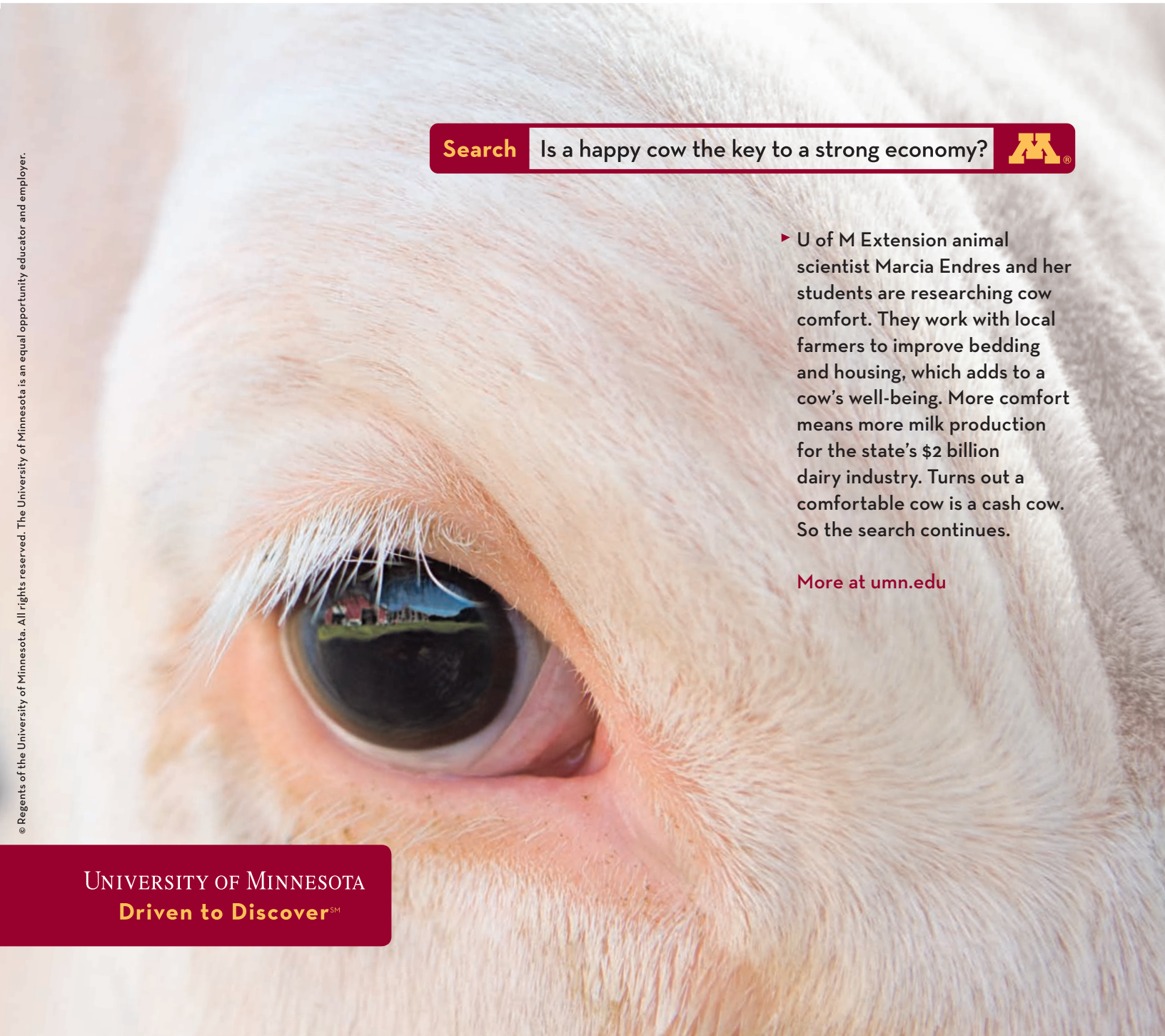

- U of M Extension animal scientist Marcia Endres and her students are researching cow comfort. They work with local farmers to improve bedding and housing, which adds to a cow's well-being. More comfort means more milk production for the state's $2 billion dairy industry. Turns out a comfortable cow is a cash cow. So the search continues.

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