Climate Change and Carbon:

What's in Stor(ag)e?

As the red rises in thermometers worldwide, MSU is positioning itself to play a leadership role in addressing emerging climate change issues and opportunities.

Whether you believe in prophecies that foretell of horrendous natural disasters signaling the "end of days" or that human activity is a major cause of global warming, scientific experts agree that the Earth's climate is changing.

Research shows that the world is now hotter than at any time during the past 1,000 years. Climate model projections summarized by the Intergovernmental Panel on Climate Change indicate that average global surface temperature will likely rise an additional 2 degrees to 11 degrees F by 2100.

Like global temperatures, average temperatures in the United States are on the rise. According to the U.S. Climate Change Science Program, the past decade was the warmest in more than a century. Along with temperature, increases in the number of heavy precipitation events and changes in snow cover have also been observed. Climate trend data paint a similar picture for Michigan and the Great Lakes region *(see box on page 25)*.

Scientific experts worldwide are predicting rises in sea levels, increased plant and animal extinctions, changes in species ranges, changes in agricultural yields, more intense and frequent storms, and increased drought, fire, flooding and heat waves if current climate trends continue.

"I was just shocked when I was in Scotland earlier this year and producers there were sharing with me what has happened in recent years as the winters have become warmer," said Steve Pueppke, director of the MAES and the Office of Biobased Technologies.

Scotland has a big potato industry. To keep their potato fields productive, producers rotate their potatoes with other crops such as carrots. In the past, winter frost killed the potato tubers left in the soil after harvest, but winters have now warmed to the point that these tubers survive and sprout the next year.

"We visited a field where farmers planted carrots and it was full of potatoes," Pueppke said. "It was astounding to see. This doesn't have anything directly to do with Michigan and we weren't even talking about climate change. This was just about, 'Look, my worst weed is my own potatoes because of the warmer winters.'"

The Heat is On

This is one of countless increasingly common examples of the kinds of changes occurring as global temperatures rise. So what's causing all the heat?

Scientific evidence shows that, since the beginning of the Industrial Revolution, there has been a steady increase in the emission of certain compounds known as greenhouse gases because of their ability to absorb and trap heat. As the concentrations of these gases — primarily carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20) — increase in the atmosphere, they act like a big blanket, trapping heat and increasing the average temperature of the Earth's surface over time. This process is commonly known as global warming.

Steve Pueppke is director of the MAES and the Office of Biobased Technologies (OBT). An OBT-commissioned report found that MSU has some strong climate change research programs and the potential to be a national leader in the area.

In the United States, greenhouse gas emissions come primarily from the combustion of fossil fuels in energy use. According to the Energy Information Administration, carbon dioxide has increased by more than 30 percent over preindustrial concentrations in the atmosphere, causing an enhanced greenhouse effect. During the past 20 years, almost 75 percent of greenhouse gas emissions have been produced from the burning of fossil fuels by automobiles and power plants.

"It is becoming increasingly clear that managing these emissions is critical if we want to slow global warming and reduce the amount of carbon entering the atmosphere," Pueppke said. "Four or five years ago, we weren't talking about carbon, and certainly not in agriculture circles. But as concerns about the agriculture industry's contribution to global warming began to surface, we started exploring how agricultural lands might also be used to capture and store carbon."

Tracking Agriculture's Carbon Footprint

"Until global warming, there wasn't a compelling practical reason to understand how carbon accumulation and disappearance affect the global carbon cycle," said Phil Robertson, MAES crop and soil scientist and director of the Long-Term Ecological Research (LTER) Program in Agricultural Ecology at the W.K. Kellogg Biological Station. "Before, most of the research on soil carbon dynamics was a local soil fertility issue."

The LTER is a unique, multidisciplinary research program that provides the knowledge and expertise required to look at agriculture from a whole-systems perspective, from fuel use to greenhouse gases, Robertson said.

"With higher temperatures and longer growing seasons, there is even more potential for carbon to be lost from the soil as microbes turn soil carbon into CO_2," he said. "What we're ultimately trying to do is manage atmospheric climate change to keep CO_2 levels within acceptable limits."

Robertson said there are three principal approaches to reduce the carbon footprint of agriculture.

"One approach is to reduce the amount of fossil fuel and other carbon inputs used in cropping systems," he said. "We can do that by using biofuels instead of fossil fuels, using legume cover crops to reduce nitrogen fertilizer needs, using no-till practices to reduce fuel use, and by controlling pests with biocontrol measures rather than manufactured pesticides."

Carbon inputs also can be reduced by growing perennial rather than annual crops.

"Perennial crops such as hay and the cellulosic biofuel crops of the future have a very low carbon footprint," Robertson said. "They're planted once and then, once a year, they're harvested and fertilized, so there are substantially fewer inputs required in those systems."

A second way to reduce the carbon footprint of agriculture at the field level is carbon sequestration — the process of storing carbon, captured from the air, in soil.

"This can be done by using no-till to increase the amount of carbon held in soil," Robertson said. "We're not adding any more carbon to the soil; we're slowing down the decomposition of carbon-containing plant residues that are left in the field. Tilling the soil stimulates soil microbes to use residues quickly. By not tilling, we're slowing decomposition. We can also slow decomposition by planting legume cover crops whose leaves have more complex carbon molecules and so are difficult for microbes to break down. The bottom line is that carbon accumulates in the soil rather than being released into the atmosphere."

A third way is to reduce the non-CO_2 greenhouse gases that are produced in agriculture, Robertson said.

"Nitrous oxide is the principal one," Robertson said. "N_20 gas is produced naturally by soil bacteria and has 300 times the global warming potential of CO_2. In other words, keeping one ton of N_20 from going into the

atmosphere is equivalent to storing 300 tons of soil carbon from the standpoint of greenhouse gas management. So we can realize a big impact very quickly. N_2O loss can be reduced with better nitrogen management because it's mainly excess nitrogen in soil that bacteria turn into N_2O."

Methane is another non-CO_2 greenhouse gas produced in agriculture, but it's produced by animals rather than soil bacteria unless the soil is flooded.

"In both cattle and flooded soils, there are bacteria called methanogens that produce and emit methane as part of their normal metabolism. But because our soils are rarely flooded — we don't grow much rice in Michigan — we don't get much methane generation in Michigan field crops."

In fact, most of Michigan's cropland soils contain bacteria called methanotrophs that consume methane from the atmosphere rather than emit it, Robertson continued.

"Although this is cutting-edge research and still far from application, we know that, in most natural ecosystems, soil methanotrophs can take up a fair amount of methane," he said. "But when an ecosystem is cleared for agriculture, the soil's ability to consume methane is shut off — it's about 10 percent of what it was prior to being cleared. With research, we are trying to understand this lost methane consumption by asking what it is about agricultural soils that inhibits methanotrophs. Restoring a soil's lost capacity to consume methane could be another valuable way to reduce agriculture's carbon footprint."

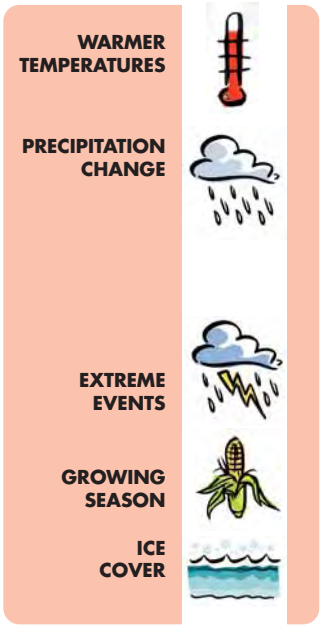
Phil Robertson's research through the Long-Term Ecological Research Program may help Michigan farmers participate in future carbon and greenhouse gas markets.

Robertson's research may help Michigan producers enter the carbon and greenhouse gas market of the future. In the next few years, he believes that Michigan growers will have the opportunity to participate in a "cap and trade" carbon system — a regulatory program that will limit new CO_2 emissions to those that can be offset by credits for carbon storage or greenhouse gas avoidance elsewhere. These credits could be earned by farmers practicing no-till, for example, and then sold to CO_2-emitting industries.

"Right now, there is a very active carbon market in Europe, where carbon trading is around $50 per metric ton today," Robertson said. "And as the cap on emissions comes down in order to meet new national CO_2 targets,

PROJECTED CLIMATE CHANGES IN MICHIGAN

(from Union of Concerned Scientists Web site)



A 5 to 10 degree F rise in winter and a 7 to 13 degree F rise in summer temperatures by the end of the century are projected.

Although average annual precipitation may not change much, an overall drier climate is expected because rainfall cannot compensate for the increase in evaporation resulting from greater temperatures. Michigan may see drier soils and more droughts. Seasonally, winter precipitation is expected to increase by 5 to 25 percent while summer precipitation is expected to remain the same.

Extreme heat will be more common, and the frequency of heavy rainstorms will increase and could be 50 to 100 percent higher than today.

The growing season could be 8 to 10 weeks longer.

Declines in ice cover on the Great Lakes and inland lakes have been recorded over the past 100 to 150 years and are expected to continue.

Sustainable Michigan Endowed Project: Welcome to Integration Station

All aboard! The Sustainable Michigan Endowed Project (SMEP) is ready to help place Michigan on a sustainable track to the future.

SMEP was created in 2002 with an endowment from the W.K. Kellogg Foundation. Its purpose is to share the viewpoints, methodologies, projects, leadership, research agendas and policy analyses of its members, and to serve as a catalyst for multidisciplinary research that contributes to healthier communities, economies and ecosystems in the Great Lakes state. SMEP also provides seed grants to MSU researchers for Michigan-specific sustainability research.

Jeff Armstrong, dean of the MSU College of Agriculture and Natural Resources, directs SMEP, and Sandra Batie, MAES agricultural economist and Elton R. Smith professor of agricultural and food policy at MSU, is responsible for fund oversight and implementation. Armstrong and Batie are co-architects of the project.

"Once we received funding, it took a couple of years to get started because we promised the Kellogg Foundation that the SMEP executive committee would be composed of endowed chairs," Batie said. "When the money was requested, one other endowed chair and I were on faculty, so we had to wait until the rest of them arrived."

Six colleges — Agriculture and Natural Resources, Arts and Letters, Communication Arts and Sciences, Natural Science, Social Science and Veterinary Medicine — house SMEP faculty and staff members in 11 departments and the School of Journalism.

The first order of business was to get SMEP members on board and settled.

"First we had to get acquainted and get comfortable working together," Batie said. "Then we had to figure out what we meant by sustainability, how it relates to research and engagement, and how SMEP can link them in a way that makes a difference to Michigan's future through informing dialogue and debate around critical sustainability issues in Michigan."

SMEP member Dave Beede, MAES animal scientist who holds the C.E. Meadows Endowed Chair, said his work around the efficiency and environmental sustainability of dairy production — including animal nutrition and dairy industry carbon contributions — is greatly informed by his involvement in the group.

"With SMEP, there's the social part, the economic part, the environmental part and the ecological part, but, more than that, there's an integration of all these aspects in our thought processes," Beede said. "Some of the research that SMEP members are doing and what they are thinking about are mind-bending. I pick up a lot of good ideas. SMEP provides the opportunity to think about and frame issues in the context of Michigan that you might not otherwise have."

Following two years of building upon its collective common ground and the discovery of insights within the group, SMEP turned its attention to how it could deepen its and others' understanding of the sustainability concept and make its work more cohesive. To date, the group has convened a number of dialogue sessions and three academies to further inform its efforts, both within and outside of the MSU community.

One of the areas that SMEP focused on to increase understanding of the complexities of sustainability is the bioeconomy.

"We've worked very hard to understand sustainability and its various elements," Batie said. "You can't think about sustainability in any great level of detail unless you have a specific topic, so we picked the bioeconomy."

Last fall, 90 experts from academia, industry, state government and non-governmental organizations attended a bioeconomy academy in Plymouth, Mich., to discuss how Michigan might restructure itself as a strong, emerging, sustainable bioeconomy and to address the question "What are the key issues of a bioeconomy that would place Michigan on a more sustainable trajectory?"

Attendees heard presentations and

the value of practices such as carbon sequestration will increase, and one source of those carbon credits is likely to be agriculture.

"We need to ensure that Michigan farmers have opportunities to enter the carbon trading market when it becomes available," he continued. "Reducing methane emissions from cattle and dairy operations is one opportunity. Soil carbon sequestration is another opportunity, and we're working to provide the science needed to allow N_2O credits to become another."

By working now to curb heat-trapping emissions, Robertson is confident that Michigan agriculture can help reduce both the pace and the magnitude of global warming and be more successful in adjusting its agricultural, environmental and socioeconomic approaches to cope with the changing climate.

"Even incremental decreases in the emissions of CO_2 will bring benefits," he said.

Carbon Storage: Acres of Opportunity

One way to increase the amount of carbon that agricultural land can sequester or store is through tillage management. Several methods of tillage are used in crop production: conventional tillage, minimum or reduced-tillage, and no-till.

MAES crop and soil scientist and Extension forage specialist Doo-Hong Min has spent the past three years studying the effect of various tillage practices on carbon sequestration and greenhouse gas reduction in forage-based dairy systems.

participated in scenario building and open space forums where they discussed issues such as envisioning Michigan's bioeconomy in a global context, defining Michigan's role as a steward of the Great Lakes, developing a carbon framework for a Michigan bioeconomy and examining the meaning of rural regional sustainability.

"It was clear at the end of this academy that sustainability has to be an ever-increasing part of every business decision maker's approach to the world," said Chris Peterson, MAES agricultural economist who holds the Nowlin Chair of Consumer Responsive Agriculture. "As the population grows and resources become more stretched, each and every one of us is going to bump into limits that will be increasingly hard to escape unless we are working together and really focused on sustainability.

"Beyond the bioeconomy, it is also clear that major food firms and agrifood businesses in the world are evolving strategies to be more sustainable," continued Peterson, who is also the director of the MSU Product Center for Agriculture and Natural Resources. "Having SMEP here at MSU provides the opportunity to create new relationships with these corporations to help them accomplish this."

"I don't know of anywhere else in the nation that has anything like SMEP," Batie said. "It's a high-powered think tank that's multidisciplinary and involves people who do extensive engagement and research who then come together and relate it to Michigan. It certainly has implications nationally, internationally and globally, but the SMEP framework starts with Michigan and works outward."

"SMEP has brought together a constellation of top faculty members strategically focused in key areas of sustainability," Armstrong said. "The synergy and impact of this collective expertise have been enormous, as these academic stars have collaborated and cultivated scholarship across departments, disciplines and colleges."

But is there a way to measure SMEP success?

"SMEP can consider itself successful when there is a richer civil discourse about sustainability on campus and between campuses, businesses, governments and non-governmental organizations," Peterson said. "In part, SMEP's success can't be measured until we can look back 10 years from now and ask if Michigan a more sustainable place than it would have otherwise been by what we did."

Batie agreed.

"SMEP's success will depend on the long-term engagement of all stakeholders in the process to develop a feasible approach to conserve the natural environment while stimulating a sustainable business environment. That's the ticket."

SMEP-funded Grants

Measurement and Interpretation of the "Heartbeat of the City" through its Acoustic Signatures — Stuart Gage, Department of Entomology

Integrating Ecological and Social Dimensions for Sustainable Management of Michigan's Jack Pine Resource — David Rothstein and Larry Leefers, Department of Forestry, and Deborah McCullough, Department of Entomology and Department of Forestry

Enhancing Michigan's Rural Communities with a More Sustainable Agricultural Sector — Suzanne Thornsbury, Department of Agricultural, Food and Resource Economics

Assessment of Environmental Variables and Anthropogenic Impacts to Microbial-induced Egg Mortality of Lake Sturgeon: An Imperiled Native Great Lakes Fish — Kim Scribner, Department of Fisheries and Wildlife and Department of Zoology, and Terence Marsh, Department of Microbiology and Molecular Genetics

Graduate Education in Sustainability: Socioeconomic Well-being in Michigan and the Genuine Progress Indicator (GPI) — Robert Richardson, Department of Community, Agriculture, Recreation and Resource Studies

::: Val Osowski

"This research is important to Michigan because alfalfa is a premium forage for the state's dairy industry and because there hasn't been any research done that looks at carbon change differences between no-till and conventional tillage practices in alfalfa-based forage systems," Min said.

Min planted four combinations of alfalfa and alfalfa-grass mixtures that are common Michigan livestock feed forages: alfalfa, festuolium (a combination of meadow fescue and either perennial ryegrass or Italian ryegrass), orchardgrass and timothy. Test plots were planted in 2006, and yield and soil-carbon change data were collected and analyzed in 2007 and 2008.

"The downside of carbon sequestration research is that it's not something that can provide definitive answers in two or three years — it takes decades or centuries to accurately discern how much carbon is being captured and stored long term. But we wanted to set a baseline to build upon in the future."

In other tillage studies around the country, researchers are finding that no-till definitely sequesters more carbon than conventional tillage practices, Min said.

"That makes sense because conventional tillage practices disturb the soil several times, oxidizing the soil organic matter and, in so doing, releasing a lot of CO_2 into the air," Min said. "In no-till situations, soil organic matter and crop residue are not disturbed, so the carbon in organic matter can be stored in the soil and become more stable over time. Research findings have

shown that no-till practices can help reduce carbon releases in agriculture by about 20 percent. Another benefit of no-till is that farmers can save a lot on fuel costs from reduced equipment use and further reduce the amount of carbon released into the air."

MAES forage scientist Doo-Hong Min conducts research on tillage practices and carbon sequestration at the Upper Peninsula Experiment Station in Chatham. In the future, he'd like to expand his research to collect greenhouse gases continuously during the growing season.

As a forage specialist, Min is also interested in carbon sequestration and grazing practices.

"With grazing, more carbon is sequestered in the soil because animals produce and deposit a lot of manure on pastures," Min said. "Grazing animals also serve as a natural mower, so there's no need for farm equipment or fossil fuel use in managing these pastures. Another benefit is that residual forage plant materials such as leaves, stems and roots die on pasture and are stored over time as a stable organic carbon in the soil."

Min and his team want to expand their research to include the monitoring of CO_2, CH_4 and N_20 emissions in no-till and conventionally tilled plots.

"We want to collect greenhouse gases continuously during the growing season using a chamber installed on the ground that has a vial and syringe that sucks up greenhouse gases leaving the soil," Min explained. "These gases are very changeable. That's why, rather than random or occasional sampling, we want to do continuous monitoring."

Although Min concedes that such an approach is expensive and labor-intensive, the ability to correlate soil carbon exchange with these other greenhouse gas emissions is critical to developing effective greenhouse gas reducing practices.

"With data from this type of research, we could develop mathematical models that show us whether a particular tillage or cropping practice was a significant contributor to the reduction of greenhouse gas emissions and/or sequestering carbon," he explained.

Whatever aspect of agriculture is being explored to help reduce greenhouse gas emissions into the environment, researchers from across many disciplines must work together to develop solutions and strategies that will be effective and sustainable, Min emphasized.

"In order to be successful, carbon sequestration research must be multidisciplinary and integrated," Min said. "Forage scientists, animal scientists, soil scientists, agricultural economists and rural sociologists are all part of addressing the issues we face. We have to look at the big picture rather than just a single aspect. That's very important."

A New Climate for Leadership

The sky is the limit when the topic is the complexities and nuances brought on by global climate change.

"The broad, disciplinary nature of climate change research requires that a wide range of expertise and institutional support be applied if MSU intends to strengthen its role in national and international climate research," Pueppke said. "MAES researchers have a deep expertise in plant and agricultural sciences across a wide range of specialties that can provide solutions to increase land-based carbon absorption and reduce carbon releases. If MSU is going to play a leadership role in climate change, we need to build on this capacity."

In early 2008, the MSU Office of Biobased Technologies (OBT) engaged Shepherd Advisors to gain a better understanding of the strengths and potential opportunities in climate change research for MSU, particularly as they relate to efforts to advance the bioeconomy.

"The OBT is increasingly exploring the roles of agriculture and the bioeconomy in addressing climate change solutions and seeking to better understand the role of MSU in addressing climate change challenges," Pueppke said.

Shepherd Advisors inventoried programs and leadership in climate change research, evaluated external stakeholders' needs and identified potential opportunities for MSU to become a stronger univer-

sity contributor in researching and finding solutions for mitigating and adapting to climate change. Its report, presented to the OBT in August, stated that MSU has strong competitive advantages in a number of research niches, such as regional impacts and modeling, integrated analysis and forecasting, human-natural systems and solutions/adaptation science. The report also stated that MSU has significant opportunities to address the solutions and management aspects of climate change scenarios and to help make climate change science understandable and applicable to real-world decision makers.

"MSU has a growing group of successful researchers that are carving out a niche to address the physical, biological and chemical understanding of climate processes, as well as the social, political and business applications that are critical to successfully adapt to and diminish the effects of climate change," Pueppke said. "The Shepherd Advisors report confirms that MSU has the potential to play a leadership role in addressing the solution and management aspects of climate change. The question now is how we further address this key issue for Michigan and the world."

Weathering Climate Change

To successfully navigate the opportunities and challenges posed by the changing climate, Pueppke believes it is essential to build on such research.

"The broad, multidisciplinary nature of climate change research requires a wide range of expertise and institutional support," Pueppke said. "We at MSU have made the argument that our 150 years of knowing how to work with the agricultural community positions us perfectly as something new comes down the pike. There is a lot of promise and potential in the research being done in the climate change and bioeconomy arenas that can contribute to Michigan's economy and help us adjust to the shifts that climate change brings about."

If climate change research is going to be effective and add value to Michigan's economic and environmental future, the results need to be disseminated to farmers and the public, Min said.

"If research is done only for its own sake, there isn't an appeal to a lot of people," Min said. "We need to get this information out. Otherwise, farmers will tend to farm as their ancestors did, and many of them won't change unless there is a compelling reason to move from these 'tried-and-true' practices. Disseminating this information will also help consumers understand why certain things are happening and to think more seriously about reducing carbon emissions from their cars or homes — it can have a domino effect on people's way of thinking."

Providing farmers with incentives to transition from conventional practices to more economically and environmentally sustainable practices is also critical in addressing climate change issues related to agricultural land use, Robertson said.

"Farmers aren't going to adopt new practices unless it makes economic sense, and it's not going to make economic sense unless there are some compelling incentives," Robertson said. "The bottom line is that if we are serious about promoting practices that reduce greenhouse gases in agriculture, we need to be serious about creating an infrastructure that pays for them as well."

There is credible evidence that our climate is changing and that if projected trends don't change, things will happen that have long-term impacts and will be extraordinarily difficult to undo, Pueppke said.

"What folks should be concerned about is that their children and grandchildren will have to deal with the consequences of climate change," he said. "On the list of things to worry about, we, understandably, tend to focus on the mortgage, gas prices and the war. That makes it a little tough to insert, 'By the way, the atmosphere is going to be too warm in 2070,' but we really need to keep that in mind. Reliable, science-based information on how climate affects Michigan's agricultural and bioeconomy industries currently will help us design and create new products and technology as we consider how to respond to future changes in climate."

::: Val Osowski