S. HRG. 106–905

CARBON CYCLE RESEARCH AND AGRICULTURE'S ROLE IN REDUCING CLIMATE CHANGE

HEARING

BEFORE THE

COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY UNITED STATES SENATE SUBCOMMITTEE ON RESEARCH, NUTRITION AND GENERAL LEGISLATION

ONE HUNDRED SIXTH CONGRESS

SECOND SESSION

ON

CARBON CYCLE RESEARCH AND AGRICULTURE'S ROLE IN REDUCING CLIMATE CHANGE

MAY 4, 2000

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THURSDAY, MAY 4, 2000

U.S. SENATE,
SUBCOMMITTEE ON PRODUCTION AND PRICE
COMPETITIVENESS, OF THE COMMITTEE ON AGRICULTURE,
NUTRITION, AND FORESTRY,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2:01 p.m., in room SR–328A, Russell Senate Office Building, Hon. Pat Roberts, (Chairman of the Subcommittee,) presiding.

Present or submitting a statement: Senators Grassley, Kerrey, and Johnson.

OPENING STATEMENT OF HON. PAT ROBERTS, A U.S. SENATOR FROM KANSAS, CHAIRMAN, SUBCOMMITTEE ON PRODUCTION AND PRICE COMPETITIVENESS, OF THE COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY

The CHAIRMAN. The Subcommittee will come to order.

I have an opening statement, a brief opening statement, and then we will get right to the witnesses. A special good afternoon and a welcome to today's hearing.

Given scientific uncertainties about the magnitude, the timing, the rate, and the regional consequences of climate change. What are the appropriate responses to the problem in regards to world decisionmakers? The administration has decided that the Kyoto Protocol, which mandates the United States to cut its energy usage 7-percent below 1990 levels with little or no developing Nation participation, may be the appropriate method.

I am not going to open up a debate about the treaty or climate change, but, obviously, I think all of us are interested in finding a solution, more especially those of us that have the privilege of representing agriculture. One component of a solution is croplands, soils, and forests that can soak up carbon dioxide. We will hear today from the leader of NOAA, the Agency that reports that crops, soils, and forests have the ability to absorb most if not all of the carbon dioxide emitted through fossil fuel emissions. Let me repeat that: crops, soils, and forests have the ability to absorb most if not all of the carbon dioxide emitted through possible fuel emissions.

Is there a sensible solution to climate change that has benefits for agriculture as opposed to pursuing a different kind of strategy—

it might be diplomatic, but it also might be highly regulatory—that may impose harsh unforeseen consequences on the United States?

I have introduced legislation that will promote agricultural research in the area of climate change while giving producers and policymakers a better understanding of the link between the carbon cycle and agricultural best management practices.

This bill, S. 1066, the Carbon Cycle and Agricultural Best Practices Research Act, would authorize the Department of Agriculture to conduct needed research on the mechanics of storing carbon in soil and to perform research that will better define agriculture's ability to solve climate change. Why? Agriculture may have the ability to store 200-million tons of carbon annually or the equivalent of 307-million-tons-of-coal, and that is, to put it mildly, a lot of carbon. For a regional perspective, a large utility in Kansas uses about 10- to 11-million tons of coal annually.

The research focuses on best management practices such as conservation tillage, efficient fertilizer application, intensive crop rotations, and increased cover crops. These practices actually reduce soil erosion and reduce the fuel costs, they improve soil fertility, they improve water quality, and they increase production. For this reason, the promotion of conservation practices in agriculture remains a win-win opportunity—and I don't know how many other positives I mentioned there, but we could list the same number of wins after each one—in regards to everyone.

With that in mind, I am pleased to welcome the panels here today and look forward to hearing about agriculture's role in mitigating greenhouse gases. Now, today's panelists include representatives from our Government agencies, leading carbon cycle researchers, and also agriculture producers who have embraced best management practices. Unfortunately, because we are in the middle of the planting season, one of the producers that was invited to testify, Mr. Clark Woodworth, from Sterling, Kansas, America, could not make the trip to Washington, and I would like to submit his testimony for the record at this point.

[The prepared statement of Mr. Woodworth can be found in the appendix on page 102.]

Let me welcome to the panel David J. Hofmann, who is the Director of Climate Change Monitoring and Diagnostic Laboratory at the National Oceanic and Atmospheric Administration, NOAA, in Boulder, Colorado; the eminent Chief Economist of the Department of Agriculture, Mr. Keith Collins; and Richard Stuckey, the Executive Vice President of the Council for Agriculture Science and Technology. The acronym for that is CAST, but the real acronym is that this organization has provided agriculture down through the years a very strong policy recommendation on behalf of sound science.

Let me remind all the panelists that your entire testimony will be submitted for the record. I would ask you to limit your statements to no more than 5-minutes so that everybody has ample time to be heard. We do have, as everybody knows, a tough schedule here in the Senate with the Appropriations Committee meeting and the education bill on the floor. And so if you could perhaps hold your remarks to about 5-minutes, it would be appreciated.

David, why don't you start off, please?

STATEMENT OF DAVID J. HOFMANN, DIRECTOR, CLIMATE CHANGE MONITORING AND DIAGNOSTIC LABORATORY, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, BOULDER, COLORADO

Dr. HOFMANN. Good afternoon. I am Dr. David Hofmann, the Director of NOAA's Climate Monitoring and Diagnostics Laboratory in Boulder, Colorado. Thank you, Mr. Chairman, for providing me the opportunity to testify before this committee on atmospheric carbon dioxide research and the important role that the terrestrial biosphere—the soils, trees, and plants—now appear to play in taking up human-produced carbon dioxide. I am honored to be here today and am grateful for your leadership in bringing attention to this important issue. My written testimony briefly reviews what we know about carbon dioxide uptake by the terrestrial biosphere which have been obtained from large-scale global atmospheric measurements which the NOAA laboratory I work for has been conducting for many years.

As you know, the burning of fossil fuels and conversion of forested land for agricultural use has caused an increase in the concentration of carbon dioxide in the atmosphere. One of the most famous environmental records comes from one of the observatories in our laboratory, the one in Hawaii at Mauna Loa. And having been a scientist for about 35-years and only an administrator for about five, I still have to have a chart in order to speak coherently. And Andrew Larkin is putting up some charts over there. You also have a copy on your desk that shows the Mauna Loa carbon dioxide record, and what you see besides the major increase from the 1957 period when the record began are these oscillations up and down, and this is evidence how the global biosphere, the terrestrial biosphere, takes up carbon in the summer, and in the winter it increases again.

[The information referred to can be found in the appendix on page 113.]

If you go to the same latitude in the Southern Hemisphere, you don't see these huge oscillations because they don't have the land there and the trees to the extent that we do in the Northern Hemisphere.

So that is very important evidence right off the bat that the terrestrial biosphere is important. But data such as these allow us to get a global picture of how carbon dioxide moves through a mobile system of carbon exchange. Carbon dioxide is exchanged between three major global reservoirs, and I show those with the next chart: the oceans and the land exchanging carbon with the atmosphere. And the little yellow blocks to the right show how much carbon is exchanged. The tallest one has about 90-billion tons of carbon, and that is exchanged between the ocean and the atmosphere. Next, the land exchanges about 50- or 60-billion-tons. And yet the human emissions are only about 8-billion-tons, the third block from the left, and the amount that the ocean and the lands actually uptake is only about half of that, about 4-billion-tons.

So the problem is that we have a system that takes up a lot of carbon, gives off a lot of carbon, but only keeps about 2-percent of it. And so the question is: How can we enhance this? Is there some way that we can do that?

Prior to about 1990, it was believed that the oceans played the major role in taking up about half of this excess human carbon dioxide and that the lands played only a minor role. In the last 10-years we have a lot of new information, new techniques. For example, not all carbon dioxide molecules are the same. Some of them have a heavy carbon atom, carbon-13, and plants don't like carbon-13. They discriminate against it. They like to take up ordinary carbon-12. But the oceans don't care, they take up 13, they take up 12. And so if we measure not only the carbon dioxide but the isotopic composition, about 8- in 1,000-molecules are carbon-13. We can fingerprint the carbon dioxide. Where does it come from? We have been doing that now for almost 10-years, and we are convinced that there is a major terrestrial sink on the planet, and most of the evidence suggests that it is, indeed, in North America.

The next figure shows a block diagram of how we think carbon is partitioned. This is, again, in billion-tons-of-carbon. Remember, humans put out about 8-billion-tons. On the left is the amount that the lands take up. The dark blue bars is the average between 1991 and 1997. We see that the lands have taken up about 3-billion tons, the oceans about two, and the rest remains in the atmosphere, about 3- to 4-billion-tons. But it is highly variable, and that is very important.

In 1998, the amount in the atmosphere, the red bar, jumped up to 6-million tons. The land only took up half as much as it usually did, the oceans even less. In 1999, the land picked up again and took up a lot of carbon.

We don't understand this, Mr. Chairman. We don't know why there is such high variability and such large amounts of uptake in some years. There is other evidence from surveys and models, that suggests the biosphere does not take up that much carbon. It is this uncertainty which gave rise to the U.S. Carbon Cycle Science Plan, and I think it is this plan that will help us understand these variations and pinpoint where the carbon is going.

Finally, thank you, Mr. Chairman, for your interest in this matter. I would be happy to address any questions you or your committee may have.

The CHAIRMAN. If you have a final point or some additional points, go ahead. Don't pay attention to that red light.

[Laughter.]

Dr. HOFMANN. I would like to say just a little bit more about the U.S. Carbon Cycle Science Plan.

The CHAIRMAN. We might as well turn that off. It is abetting the global warming. We don't want to do that.

[Laughter.]

Dr. HOFMANN. The U.S. Global Change Research Program several years ago produced a report entitled “A U.S. Carbon Cycle Science Plan,” and copies of this report actually were sent over here earlier, and they should be around here somewhere. It looks like this.

The CHAIRMAN. Yes, we have it up here.

Dr. HOFMANN. It is a green book with some pretty pictures on the cover. A group of 15-scientists who are leaders in carbon cycle research from all the agencies that are involved—NASA, NSF, NOAA, USDA, DOE, USGS—produced the plan which focuses on the North American carbon cycle sink. Is it a sink or isn't it?

To me, the atmosphere doesn't lie. What is in the atmosphere is sort of where the rubber meets the road because that is what is going to cause the problems. And now what we have to do is try to make the measurements on a regional scale, flux towers, inventories, make those measurements converge with the rest of the picture. It is kind of like you have an elephant and you are trying to identify it, and one group is up close and they say it is gray and wrinkly. Another one is off in an airplane and say it is a gray blob. So it is that intermediate range, getting 100 yards from it, and saying, yes, that is an elephant. That is what we need. And we know how to do it, and the Carbon Cycle Science Plan outlines it.

Thank you.

[The prepared statement of Dr. Hofmann can be found in the appendix on page 46.]

The CHAIRMAN. That would certainly lend a lot of specificity and a lot of explanation to what we are trying to get a hold of, a small gray elephant.

Mr. Johnson, welcome to the Subcommittee, Sir.

Keith, why don't you proceed?

STATEMENT OF KEITH COLLINS, CHIEF ECONOMIST, U.S. DEPARTMENT OF AGRICULTURE, WASHINGTON, DC.

Mr. COLLINS. Thank you very much, Mr. Chairman. Thank you for inviting the Department of Agriculture to participate today, and thanks, too, for holding this hearing because it brings attention to such an important subject. I am going to briefly review our activities in this area and identify some of the places where we think greater research is needed.

At USDA we believe that human-created greenhouse gas emissions present potential risks as well as opportunities for the Nation's farmers and ranchers and that over time they could have important consequences for farm production, farm prices, and farm income. Consequently, we consider carbon cycle research a top priority, a top research priority. And, in fact, in our fiscal year 2001 budget request, we have asked for more than a doubling of funding for this work.

Our program tries to understand how increasing concentrations of greenhouse gases in the atmosphere affect food, fiber, and forest production in the ecosystems that they are in and how agricultural activities can contribute to a reduction in greenhouse gases. We have a simple goal, and that is to provide credible information for farmers, ranchers, foresters, policy officials, and the public.

Our research program is conducted by scientists in several agencies: the Agricultural Research Service, the Natural Resources Conservation Service, the Forest Service. It is conducted by economists in the Economic Research Service and also conducted through grants provided to universities through the Cooperative State Research Extension and Education Service.

I want to emphasize that in many of our agencies our efforts are closely linked with the land-grant university system. And I also want to emphasize that on our program side, our delivery of conservation programs, we have long had an interest in soil organic carbon because it improves soil, water, and air quality, all co-benefits of sequestering carbon, or sequestering carbon is a co-benefit of better soil, water, and air quality.

Well, what are we doing? We are doing things like examining how plants use carbon dioxide and convert it to soil organic carbon. Some of that work looks at, for example, how higher CO_2 concentrations affect yields and how higher concentrations of CO_2, working with the water cycle, the nitrogen cycle, the phosphorus cycle, weeds, how they all interact together to affect yields.

We have research at a number of sites on how crop management practices affect carbon sequestration, and in cooperation with universities, we are taking the results of that research and trying to build a simple field-level tool, which goes by the name of CQUESTER, that producers, technicians of USDA, and consultants could all use in the field to estimate stored carbon based on a soil type, climate, land use, and crop management practice.

We are also trying to bring the benefits of soil carbon to the attention of the Nation's farmers and ranchers in various ways and communicate better with the agriculture community. For example, the recent agricultural dialogue series that we are conducting facilitated by Meridian House would be one example of that.

On the economic side, we are focusing on the economic costs and benefits of efforts to reduce emissions and sequester carbon, including looking at the impacts of alternative policies to promote increased sequestration.

In my longer testimony I also outline some of the work of the Forest Service, and I do that because I think it is very important for production agriculture. For example, they are looking at cost-efficient ways to convert wood into ethanol. We might ultimately see the use of short rotation trees perhaps grown by farmers for ethanol that could reduce emissions by both sequestering carbon and by replacing fossil fuel.

Well, despite the good things that we are doing, a lot more needs to be done, and I know on the next panel we have one of our notable researchers at USDA, John Kimble, who is going to go into some of those research challenges. We have submitted a budget request for an increase of $22 million for carbon cycle research for fiscal year 2001. Much of that effort would be focusing on measuring the effects of management practices on crop and grazing lands, establishing 20 observation sites around the country for measuring carbon flows. Our work would range from basic research on the role of soil microbes to more applied research to improve our models that estimate carbon storage under a range of conditions, locations, and practices from the field level to the regional level to the national level.

We also need improved soil databases. We would like to complete our soil survey and put online a national soils information system with soil carbon data for agricultural regions and for major crop management systems. And we also need to undertake better field validation and calibration to ground truth the modeling, the remote sensing, and the statistical carbon stock measurement approaches that are used.

This year, for example, we have a project called the terrestrial carbon management project, and what we are trying to do with that is produce credible national estimates of carbon inventories associated with agricultural land uses and management practices. And we plan to use that work to estimate how a carbon market would affect land-use change and management decisions on farms, and the effects of those on farm production, farm prices, and farm incomes.

In conclusion, I believe that USDA is working in partnership with other Federal agencies, with the university community, and we are responding to the information needs of the carbon cycle. But a lot more needs to be done. Today there is growing enthusiasm in agriculture for carbon sequestration because many producers, I believe, see an opportunity to benefit the environment, but they also see a new source of income. Well, I see that potential, too, but I believe we have to be realistic.

Today there is no effective market for carbon, and there remain considerable uncertainties regarding the levels and persistence of carbon storage associated with many agricultural activities. But what we do know is that sequestering carbon through best management practices is indispensable for soil, water, and air quality benefits. And to make those practices, those BMPs, financially rewarding for carbon storage is going to take some time and a much greater research effort.

Thank you.

[The prepared statement of Mr. Collins can be found in the appendix on page 56.]

The CHAIRMAN. Thank you, Keith.

Senator Johnson, would you like to make any comment at this point? Welcome to the Subcommittee.

STATEMENT OF HON. TIM JOHNSON, A U.S. SENATOR FROM SOUTH DAKOTA

Senator JOHNSON. Well, thank you, Mr. Chairman. I appreciate your leadership on this issue. It is one that I have some interest in. So that we can expedite the panel discussion here, which I think is the main point of all of this, I would submit my statement for the record for the Subcommittee.

The CHAIRMAN. Without objection, it will be placed in the record at this point.

Dr. Stuckey.

STATEMENT OF RICHARD E. STUCKEY, PH.D., EXECUTIVE VICE PRESIDENT, COUNCIL FOR AGRICULTURE SCIENCE AND TECHNOLOGY (CAST), AMES, IOWA

Dr. STUCKEY. Thank you, Mr. Chairman, and members of the Senate Subcommittee. I am Richard E. Stuckey, Executive Vice President of the Council for Agriculture Science and Technology (CAST), whose mission is to identify and interpret scientific research information for legislators, regulators, the media, and others involved in public policymaking. CAST is an organization that represents 38 professional scientific societies whose individual members exceed 180,000 scientists.

Because it is not possible for one person to reflect the multifaceted views of all CAST members, especially on this particular topic today, I do, however, think that my testimony represents the large majority of our membership. It has been endorsed by the Executive Committee of CAST.

CAST has addressed various aspects of agricultural and climate change on previous occasions. Many of you will recall the 1992 CAST report that was prepared for the climate change meetings held in Rio de Janeiro in 1992. In December of 1998, CAST cohosted, with the Pacific Northwest National Laboratory and Oak Ridge National Laboratory, a workshop on "Carbon Sequestration in Soils: Science, Monitoring, and Beyond." This was held at St. Michaels, Maryland. CAST subsequently produced an issue paper that summarized this large publication into about seven or eight pages on the workshop that was held. CAST has also identified a new task force that will be meeting next week to begin work on a new report that is tentatively titled "Agriculture's Response to the Climate Change Challenge."

Let me talk just a bit about the St. Michaels' workshop. This was attended by nearly 100 invited persons, mostly from the United States and from Canada. It represented people from the White House, regulators, congressional staff, plant and equipment industries, Federal agencies and laboratories, consumer groups, growers and grower organizations, and university scientists. The 3-day workshop addressed four areas of soil carbon sequestration: science, monitoring, decertification, and policy and economics. I would like to make a few comments on the first two.

The science: Findings of the St. Michaels' workshop were that organic matter contributes greatly to plant productivity and ecosystem stability. Soil organic matter plays a central role in the global carbon cycle. Agricultural practices that conserve soil and increase productivity while improving soil quality also increase the carbon content in soils, thereby removing carbon dioxide from the atmosphere.

There is excellent potential for carbon sequestration in all managed soils. Promising lines of research are evolving that could lead to an improved understanding of soil carbon dynamics and the subsequent development of superior carbon sequestration methods. Among these are understanding the mechanisms of carbon stabilization, landscape effects on carbon sequestration, biotechnology to enhance plant productivity and favor carbon sequestration, and a better understanding of the environmental effects of soil carbon sequestration on erosion, nutrient leaching, and emissions of other greenhouse gases.

A few comments about monitoring. Rapid and accurate monitoring and verification systems are a limitation at present. We do have the technology to accurate measure carbon changes in the soil. Improved and more cost-effective methods of monitoring changes in soil carbon likely will come from geographical information systems—GIS—and modeling, application of high-resolution remote sensing, and continuous direct measurements of carbon dioxide exchange between the atmosphere and terrestrial ecosystems. It will take a combination of instrumentation to effectively monitor and verify results. These would range from the in-field carbon probes to verifiable simulation model extrapolation using high-resolution remote sensing and GIS to aggregate larger regional areas with time.

On April 6th and 7th, I participated in the first of a three-part series of workshops entitled "Global Climate Change Issues for Agriculture." These series of workshops, as the former speaker Keith Collins mentioned, were sponsored by the United States Department of Agriculture, facilitated by the Meridian Institute, and the first was hosted at the American Farm Bureau Offices in Washington, DC. These workshops are comprised primarily of scientists sharing their knowledge of global climate issues with grower and farm organizations. Representatives from Federal agencies, congressional staff, the White House, and other interested parties are observers to the roundtable discussions. I do commend the USDA for sponsoring these workshops and, in particular, the many and diverse farm organizations that attend to learn, discuss, and share their views on the impacts that various actions will have on the agriculture sector.

The farm community has many legitimate concerns: Is global warming real? Does agriculture contribute and, if so, how much? Can agriculture be a solution? What are the implications of temperature and moisture shifts?

Today, agriculture through the use of best management practices contributes substantially to carbon sequestration in soils. The sequestration of carbon in soils enhances soil quality and helps offset some of the emissions produced by agriculture today, which was often described as a win-win situation by several presenters at the workshop.

As a person who interfaces with many scientists and producer groups, I want to commend the establishment of the workshops involving producer groups and scientists. I strongly believe that both groups need to collaborate with policy decisionmakers to include science-based solutions in all future policies.

In summary, Mr. Chairman and subcommittee members, I believe in agriculture there are two approaches to lessening the CO_2 and greenhouse gases, and both these are through expanded research and adoption of new technologies. Research directed toward improved sequestration of carbon in soils and plants and research directed toward new technology and improved emission efficiencies and the cropping practices that rely less on the fossil fuels are needed. Using good management techniques that include rebuilding soil organic matter, practicing less tillage rather than more, developing and using biofuels, and practicing good environmental stewardship will be important contributions by the agricultural community.

We do need to recognize the valuable service of the American farmers who provide abundant low-cost and high-quality food. We should assist the American farmer by providing research opportunities to develop new technologies. Placing the primary burden of reducing carbon dioxide and greenhouse gas emissions on agriculture without addressing other entities, both on a national and on a global scale, that contribute to the greenhouse gas emissions will be self-defeating. The greenhouse gas emissions is a global problem. With new technology yet to be discovered, agriculture will become even more benign and productive. We owe it to our society to make it so.

Lastly, I thank you very much for allowing me to present this testimony on behalf of the CAST membership.

[The prepared statement of Dr. Stuckey can be found in the appendix on page 71.]

The CHAIRMAN. We thank you, Dr. Stuckey.

We have been joined now by the distinguished Ranking Member of the Subcommittee, the distinguished Senator from Nebraska. Would you like to make a statement, Sir?

Senator KERREY. Yes.

The CHAIRMAN. Good.

STATEMENT OF HON. J. ROBERT KERREY, A U.S. SENATOR FROM NEBRASKA, RANKING MEMBER, SUBCOMMITTEE ON PRODUCTION AND PRICE COMPETITIVENESS, OF THE COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY

Senator KERREY. First, thank you very much for holding the hearing, and I think we are dealing with a subject here that—Dr. Stuckey used the phrase "win-win." There may actually be more than just two wins in this.

The CHAIRMAN. I had five in my opening statement.

[Laughter.]

The CHAIRMAN. Did you have five? Wow. Five wins.

Dr. STUCKEY. I had to keep it to 5-minutes, or I tried to.

The CHAIRMAN. That is more than he used to get in an entire year.

[Laughter.]

Yes. I am very happy you can remember over a decade ago.

[Laughter.]

Senator KERREY. I recently noted a long story on the subject of drought connected to soil and the decreased risk of soil loss as a consequence of tremendous soil conservation efforts that have occurred on private land over the last 70-years since the last time that a drought did tremendous damage to the soil of this country. I noted in this story that the heart of it was how dependent farmers are upon weather. It is still, it seems to me, one of the most important things to remind the non-agriculture community as to why we spend so much time worrying about this one business and we don't worry about other businesses nearly so much. In addition to producing a vital product, it is also producing a product and environment that is different than any other business in our economy, which is you are producing something outside. And as a consequence, you are really vulnerable to changes in the weather.

I noted in this story, in fact, that the 1988 drought produced $40 billion worth of damage versus Hurricane Andrew that produced about $28 to $33 billion and versus the 1993 Mississippi flood, which was the most destructive in terms of property damage in current dollars, of $25 billion. So not only is there a lot at stake at the micro level, there is a lot at stake at the macro level as we watch these changes in the weather and try to analyze whether or not there is a change in the climate that is occurring as a consequence of our need to produce not just food, but other things that we oftentimes both need and take for granted.

What I saw down in Argentina when we went down there for the follow-on to Kyoto was a willingness to allow something that farmers in Nebraska and Kansas and South Dakota and throughout the United States were already doing as a consequence both of a desire to save soil and the desire to reduce their energy consumption and to make their operations more efficient. So it seems to me that we have an opportunity here with our policy to not only encourage carbon sequestration, which my prediction is will be shown to be a vital part of mitigating the potential damages to the environment through climate change, but at the same time produce income to the farmer. I don't know what your other three were, but you are going to be saving soil and you are going to be making the farm more efficient. That is four. What was your fifth?

The CHAIRMAN. Well, we had clean water, clean air, saving soil, conservation, and——

Senator KERREY. We need an acronym.

[Laughter.]

We will go to work on that after this hearing.

Anyway, Mr. Chairman, I appreciate very much your calling this hearing to get this policy right. I think we could do a lot of good with one simultaneous action, and I look forward to the rest of the testimony.

The CHAIRMAN. Well, thank you. I thank the Senator for his leadership.

David, Dr. Hofmann, return with me now to the thrilling days of 1998 when the plane from New Zealand arrived with Chairman Stevens, and you all stood at parade rest before the Chairman of the Appropriations Committee at the South Pole, and we discussed climate change. I would say for my subcommittee colleagues and the audience that we were warned before we left the plane—we had several layers of clothing, to say the least—not to exert ourselves and not to drink hot coffee, and that was about, what, 9,300 feet. I think that is about right, most of it ice. And so I did precisely that. I was pretty excited, and I ran around there and went inside for some of the briefings, and the first thing I did was have a hot cup of coffee. And then I couldn't figure out why I thought we were having an earthquake in the South Pole. You get a little woozy up there with the altitude and everything else.

But the person who really got my attention was you, Dr. Hofmann, and if there is a God prince in this effort in regard to the research bill I have introduced, and in many bills that are now being considered—Senator Brownback has a bill; others have bills—I think largely you have been a real catalyst factor in that determination.

And I asked you, I just said point-blank, here we are in agriculture worried to death, where we have proposals under the Kyoto treaty that we have to go back to 1990 energy levels. We can't do that. Minus 7-percent, my Lord, we can't do that. Or at least I don't think we can do that. And then we looked at some of the proposed—I don't want to call them regulations yet, but they are proposals that are involved in the treaty. The Senate voted 95–0 in regards to saying, wait a minute, we are not too sure this is the right approach unless everybody joins the effort and unless we can prove there is no serious economic harm not only to agriculture but to the business community as well.

And I said, What do you think about that? And, of course, Dr. Hofmann was a little hesitant to get into that debate. But I said, How can we do this? And, obviously, he had all of the research in regards to the ice cores there. And so I said, you know, what is your suggestion? If we went with the Kyoto treaty, after 100-years how much carbon do we get out of the atmosphere? And I can't recall what you said, Dr. Hofmann, but it really wasn't very much. And then I said, Over 50-years, if we went through best management practices and also encouraging industry and a whole series of other things, and you indicated it would be much more salutary, or at least in terms of practical progress, it might work a lot better.

Now, I am putting a lot of words in your mouth. I hope that is your recollection of it. And I was quite interested in your research, and I thought you made one heck of a lot of sense. And the thing that I will never forget—and the staff even wrote it down for me. You said, well, you know, between 1988 and 1992, the North American continent was a carbon sink to the extent we took more out of the atmosphere than we put back in, in regards to fossil fuel emission. And that just knocked my socks off—well, not there it didn't knock my socks off, but that really impressed me. From the standpoint that a lot of people in this debate over global warming and what we do and accepting our responsibilities, I came back and I informed the entire ag community that I have contact with, hey, we can be a partner in this effort. We have just got to find out why.

We desperately need the research, and I said, well, what happened from 1992 on? Because I thought that was a startling thing that you said. Well, we really didn't have the means to go ahead and continue the monitoring. I think that is incredible, I would say to my Senate colleagues.

So after that rather long-winded dissertation, I guess, asserting to you what you said, what advice do you have for the Senate on this issue? Sort of like if the rest of the Senators ask what I asked you back in 1998.

Dr. HOFMANN. Well, first of all, I think I made 18-trips to the South Pole thus far, and while they are all rewarding, I think I remember that one in 1998 the best. We dedicated a new building there, a new atmospheric sampling building. Dr. Baker, the Administrator of NOAA, came and I knew that 6 Senators were coming shortly, and Dr. Baker left because he had to get back to Washington. But I decided I wanted to stay on and talk to these folks when they came in, which I did. And I personally found it extremely gratifying that you took the interest that you did in what we were doing down there.

One could ask why would you want to measure greenhouse gases at the South Pole. That is farthest away from the source of this pollution. And the point is that we at NOAA measure all over the world, and it is places like Barrow, Alaska, where we have an observatory, the South Pole, that kind of anchors the network. That is what holds it firm. And then all this stuff is going on in between, and by making measurements all over the globe, that is how we get the data that we can build these bar charts that I showed earlier about the sources and sinks.

So the fact that we are here today because of the interest you took in what we were doing there and what it could lead to is extremely gratifying.

Now, on the other issue, as we all know, climate change is an important issue, and I think in NOAA, as scientists, we take pride in the fact that the data that we collect, the science that we do, is done completely independently of other things that may be going on in the world. We collect data. We analyze it. We say this is our best estimate of what is happening here. And we hope that this information provides the kind of information that policymakers need in order to make the right choices when it comes to some of the choices that will have to be made.

As far as my own personal feelings, I don't think they amount to much as far as these things go, and I would like to keep the science in focus, and whenever this question comes up, I just want to say let us do the work that we need to do, and we can provide the information that you will need to make those decisions.

The CHAIRMAN. I am not going to paraphrase your remarks anymore other than that we are not going to ask you how you would vote on the Kyoto treaty, but——

Dr. HOFMANN. I don't know how to spell Kyoto.

[Laughter.]

The CHAIRMAN. It is called trouble, t-r-o-u-b-l-e.

I see that the distinguished Senator from Iowa has joined us, and I was wondering if he would want to make a statement at this point before we proceed with any questions. Would the distinguished Senator have anything to say at this point?

STATEMENT OF HON. CHARLES E. GRASSLEY, A U.S. SENATOR FROM IOWA

Senator GRASSLEY. Yes, I am going to do my statement partly. I acknowledge Dr. Stuckey being here. His leadership in this not only in the State of Iowa but through the Council on Agricultural Sciences and Technology, his leadership at the St. Michaels, Maryland, with the Department of Energy's issue of how to deal with carbon sequestration.

The conclusions that I have that I would like to discuss for two pages deal with those of us who are interested in improving the environment and promoting the well-being of the agricultural community obviously see carbon sequestration holding limitless potential. The idea of trading carbon credits between large international entities and the family farmer is very appealing. In fact, it is appealing enough now that it is appearing in the articles in all of the farm magazines that I subscribe to. And so it is out there for farmers to consider.

You are probably aware of the headline on the Wichita Eagle's website to see that this is happening as we sit here today. The headline reads: "Farmer Enlisted to Help Fight Carbon Dioxide Emissions." The stories refer to the Canadian energy companies which are willing to pay American farmers to quit plowing so that carbon is trapped in the soil.

One of my constituents from West Des Moines, Steve Griffin, of CQUEST, Ltd., states in the story that he has signed farmers up to reduce plowing by 2.5-million acres, mostly in my home State, under this Canadian offer, and right now Griffin expects to pay farmers a couple of dollars-a-year-per-acre.

The problem I see with this is that no one yet has determined the true value due to the fact that science lags in this area. And so, consequently, very important that we get these panels together to get as much information as we can and to make real advancements in this way of bettering our environment and also at the same time helping the family farmer.

I ask permission to put my entire statement in the record.

The CHAIRMAN. Without objection, it is so ordered, and I want to thank the Senator for his long-time interest and his long-time leadership in this whole subject area.

David, the ARS—there is the acronym. The Agricultural Research Service has been working to build a U.S. trace gas network at Fort Collins, and considering your office's very close proximity to the research, would NOAA be willing to work with ARS and obviously try to draw both of the agencies' expertise to perfect this research? Is there any reason why we can't do that?

Dr. HOFMANN. Mr. Chairman, no. I don't believe there are. Speaking for my laboratory and scientists that work with me, we in general welcome any collaborative arrangement that will provide more information, will further the research goals, and now we have a U.S. Carbon Cycle Science Plan which specifically talks about collaborations between people who make measurements on a very small scale to the very large scale. And also in your bill you pointed out the importance of having interagency collaboration, and that is, I think, the basis of the U.S. Carbon Cycle Science Plan.

The CHAIRMAN. Is that working a lot better now? I know when we talked about it 2-years ago, we had some concerns that the left hand didn't know what the right hand was doing, you know, the classic status. In regards to the outside entities and all the agencies involved, do you think we are doing better? You know, what is your perspective on it?

Dr. HOFMANN. I think the Carbon Cycle Science Plan clearly shows that this is what has to be done, and in terms of this particular possible collaboration with Fort Collins, it turns out that we actually are making small aircraft sampling flights in northeastern Colorado. It is one of the few sites that we can afford to make these measurements, and we would be happy to have a scientific collaboration. If somebody is working on the ground, we would like to be making measurements up above them so we can couple these together and get a lot more for the money that we are spending. And I don't see any reason why we couldn't work with the folks at Fort Collins and the Agricultural Research Service and tell them what we are doing, and perhaps we could even arrange some interactive collaboration.

The CHAIRMAN. I think it is a good suggestion. We will get in touch with Secretary Glickman.

What are you requesting in 2001 in the budget to help NOAA make some progress in carbon cycle science?

Dr. HOFMANN. NOAA has a new initiative in 2001 that is called "Climate Observations and Services." It is a new line item. We feel that in the long run this is what we are going to have to do. We are going to have to bring climate observations into a line itself.

The total bill is asking for about $28 million. In it is support for the baseline observatories that you are now familiar with. There are requests for ocean observations, for dealing with all the data that is coming in, and a lot of that would directly affect carbon cycle research. So this is an extremely important initiative. We have been working on it for a long time, and we will continue to work on it until we finally are able to make the kinds of measurements that we need to extend the range from this micro scale to the macro scale.

The CHAIRMAN. We are going to do the ag approps bill here fairly quickly. Do you think that is enough money for you, or could you stand a little plus-up? Within the budget limitations we must live with, you know, I must say that. I can't think of anything—well, I don't want to say that, but——

Dr. HOFMANN. I think stressing collaborative research between the agricultural groups and some of the things we do would be a first step.

The CHAIRMAN. I would say to Senator Kerrey and Senator Grassley, we both know that when we are in the gauntlet of trying to write a new farm bill next year, this is going to be a premier item in that consideration. And the faster that we get the proper kind of research and the criteria so that we can figure out where we are on this, the faster we are able to get to a section of the farm bill to try to encourage more best management practices. And I think down the road, after a series of years, that is going to be a very significant part of the farm bill. So in terms of appropriations, what we can do to speed this up—and I know you don't want to just expedite it in terms of the time schedule. You have to do it right. You have to do it from a sound science standpoint. But I would certainly be willing to listen to anybody from NOAA and to smother our friends on the Appropriations Committee with the milk of positive, I guess, suggestions. So if you have any suggestions along that line, I would appreciate it.

Let me get to—let's see here. Keith, as we speak, the State Department is in an international conference in Montreal discussing the Intergovernmental Panel on Climate Change. That is the IPCC. That is the summary for policymakers on land use and land-use change and forestry. The summary for policymakers outlines some very critical issues for the agriculture community. Some issues include statements about North America again being a net carbon sink, the accurate definitions of reforestation, deforestation, and the role of agriculture in emission reductions.

How has the Department coordinated with the State Department to ensure that our agriculture voice is being clearly heard in this international setting? And who from the USDA is attending these meetings?

Mr. COLLINS. Mr. Chairman, that report that you just described is the summary for policymakers of a special report being done by the Intergovernmental Panel on Climate Change at the request of the UN Framework Convention on Climate Change. That report has been in construction for the past year, and the people who have drafted that report, in fact, include USDA people as well as university researchers around the country, as well as people from other Federal agencies.

That report, after it was drafted by the scientists, went through a technical review of other scientists from all around the world. And then after the technical review, it went through a governmental review, and it was at that point that USDA, besides being involved in writing it and in the technical review, also participated in the Government review.

In fact, the State Department asked USDA to coordinate the Government-wide review of that report. That was coordinated through my office, and every agency of the Federal Government participated in that, including the Department of Defense, and we prepared 200-pages of comments for the report that went back to the IPCC.

What is going on in Montreal this week is now that they have incorporated those comments in this summary of the report, which is a 95-paragraph summary, it is being gone through line by line by the countries of the world. The U.S. Government delegation is headed by the State Department. It does include—it is a very large delegation. It includes other Federal agencies.

USDA has two people on the delegation: someone from my office who is a technical expert and someone from the Forest Service who is a technical expert. And they are in contact every day with other experts at the USDA, in fact, around the country. I spoke this morning with one of our delegates who said that, since Monday—and we are now Thursday—they have gotten through about 35- of the 95-paragraphs. They are going line by line to try to reach an agreement on this report.

I want to point out on this report—and I think it will be interesting for all of us to read. It has nothing to do with policy. This is a scientific document. It is to present the state of knowledge on carbon sequestration related to land use, land-use change, and forestry. And it is being done to provide the scientific basis for the scientific body that advises the UN Framework Convention on Climate Change. That is called the Subsidiary Body on Scientific and Technological Advice. So this report goes to them. They use this report to advise the Framework Convention.

The CHAIRMAN. Well, the reason I ask that, you know, other than the obvious reason, is that last year Senator Kerrey and Senator Baucus and myself were joined by all of the major farm groups, all of the Commodity Organizations, and it was Senator Kerrey's leadership, really, that got the meeting together. And we were all concerned—and we had the Secretary there, Secretary Glickman. We were concerned that ag's voice was not being heard in the climate change debate. And then the Meridian Institute, as you recall, was asked to organize a series of workshops, and they have been ongoing.

I am basically asking, I guess, Senator Kerrey's question, so your response to this is encouraging. We will pore over with staff the 95-paragraphs and see how that can work.

Now, I think you are aware that the Department of Agriculture made a statement on its own economic analysis of the Kyoto treaty, and I am quoting here, if as a result of implementing the Protocol foreign producers face lower costs from achieving their targets relative to U.S. producers, our commodities will become less competitive, and U.S. export demand would fall. In addition, there have been quite a few analyses in regards to what would happen if the Protocol were ratified and put into effect. One, I think it is by the Farm Bureau; I am not sure about that, but there have been several. All of them around the 20- to 21-billion range.

The reason I brought that up is that I have a pamphlet here put out by the NRCS, and basically one of the conclusions is that we should go ahead with the Protocol. And I don't see the economic analysis in there, and I just think that we are putting the cart before the horse.

I don't know if you would have any comment about that, but you being the chief economist, I think that if you could put a little addendum in there or a footnote at the bottom of this, it would have been most helpful. I am not really pleased with this at all, as you can tell by my questions. I agree with the attention. I agree with all of the things up to the conclusion that says we ought to go ahead and approve this. And I would remind you there was a 95–0 vote before we could get a handle on this.

Any comment?

Mr. COLLINS. Probably plenty. First of all, on the economic analysis, we did at USDA do an economic analysis of the Kyoto Protocol. We did publish that. It is some 80-pages long. It uses the best objective economic models that we have at the Department. It did look at a price of carbon that was estimated by the Council of Economic Advisers ranging from $14 to $23 a ton under implementation of the Kyoto Protocol. We also had sensitivity analysis in that report that looked at other carbon prices as well. And we found a very, very modest impact on American agriculture with the $14 to $23 a ton price. The Farm Bureau and other studies that you mentioned simply used much, much higher prices of carbon. So it all depends on where you think the price of carbon is going to come out in this world.

Senator Grassley a moment ago talked about emissions trading. One of the things that studies have found, including the second-generation model at Stanford University, is the difference in the price of carbon between having global emissions trading and not having global emissions trading is 50-percent. You can lower the cost of meeting an emissions reduction target by 50-percent with trading compared to not having trading because you get low-cost ways of reducing carbon with trading.

So I don't know what the price of carbon is going to be, but I would say that it very much depends on the assumptions you make going into the model that you use. We thought we made a fairly reasonable set of assumptions, and we have provided some alternatives and did not come out with real large effects.

Regarding the brochure, I have read that brochure, and I don't believe it endorses the Kyoto Protocol. It mentions the Kyoto Protocol. Maybe it would have been better not to mention it in that brochure. But I think it is—I hope you would agree that the purpose of the brochure is to respond to the concerns that you, Senator Kerrey, and others had that the Department of Agriculture was not visible enough in communicating with the agriculture and rural communities about the whole issue of carbon sequestration. And so that was one attempt to do that.

I might say that we have got many other attempts, which I hope I can send you some of those as well——

The CHAIRMAN. Well, you know, let's get Bob Kerrey and I together when you have the proofs there, and we will just write the last paragraph.

Mr. COLLINS. All right. Let me mention something about that. That brochure went through several drafts, and the NRCS actually provided drafts of that brochure to all of the commodity groups and to the farm organizations and received comments from the American Farm Bureau Federation, the environmental groups and so on. They were all invited to help cosponsor it to cover the costs because we have limited resources for this kind of thing. We have a fairly small budget.

Most of them did not choose to share the cost, but they all had an opportunity to review it, and many revisions were made in response to their comments.

The CHAIRMAN. I appreciate that. I think you know where I am coming from.

Mr. COLLINS. I absolutely do.

The CHAIRMAN. And the concern that we have. Where is the one-stop location where farmers can go to find out all the information they need in regard to what is going on at the Department, other agencies, or elsewhere? In other words, sort of a clearinghouse for information, sort of a, you know, USDA global climate change office, or maybe have a leading university like Iowa State or the University of Nebraska or even Kansas State running a website with access to the clearinghouse.

Mr. COLLINS. I am empathetic to the concern behind that question.

The CHAIRMAN. Well, there are many, many producers—now, this is a hot-button item. I don't know if that is the right way to describe it, but I tell you, more and more people are understanding what carbon sequestration is. We need a better acronym and a better title, I would say to Senator Kerrey. But a lot of information out there, and we need sort of a one-stop information——

Mr. COLLINS. I couldn't agree with you more on this. I have been frustrated myself in getting information. I asked a member of my staff to give me key websites where I could get carbon sequestration information, and I got 3-pages of about 50- or 60-websites. And if you start going to those, you very quickly can get very confused.

That is one of the things that we are trying to do at USDA, is provide a better job of bringing our data, our information, our analysis online in a coherent way.

Where is the one-stop shopping? We don't have one-stop shopping in terms of a website at this point. We are trying to have one-stop shopping as a place where people can go to ask questions, and then we would try to answer those questions. We do have a global change program office. That office reports to me, and we do coordinate the activities of USDA with respect to climate change.

Now, a lot of that effort has simply been in trying to develop budgets and trying to make sure the right hand knows what the left hand is doing. But we have to go to the next step. We have to be able to organize our internal information resources and make them better available to the public.

The CHAIRMAN. I appreciate your response.

Dr. Stuckey, as I indicated last year, Senator Kerrey really got us together, and I am talking about the ag community, and we were concerned that our voice was not being heard in the debate. As a result, the Meridian Institute was asked to organize a series of workshops. And I think you just participated in the first of three. Is that not correct?

Dr. STUCKEY. Correct.

The CHAIRMAN. There are six of them?

Senator KERREY. No, April 6th.

The CHAIRMAN. Oh, April 6th. Do you want to just tell us very briefly that the recent discussion session that the institute held in conjunction with the Department, in your opinion—here is the question. Was the first working group meeting worthwhile?

Dr. STUCKEY. I definitely think it was worthwhile because it brought together a number of scientists, it brought together a diversity of farm organizations. A number are in this room that attended that session. I was able to participate and attend on the first day. It was a day-and-a-half session.

It is important that we can communicate a little better. I would constructively criticize the format that we had, in that, as scientists we often try to give the whole ball of wax, lecture too long. And so I think instead of an hour presentation followed by discussions, I personally tried to keep my comments rather brief so we could enter into some discussions. Scientists have a lot of data, a lot of information in this area, and they are eager to share that with them.

But I think it was successful from the standpoint that scientists could hear some of the grower representatives that were there in attendance, their concerns, and so for the two to get together and openly discuss those concerns and see where the science is, where it is not, I think was beneficial. And I heartily endorse the continuation of those remaining two sessions.

The CHAIRMAN. I am going to ask you the Dr. Hofmann question in terms of organization with all Federal agencies. What agency do you think is the lead agency in this regard? How well are we working together? That is the Dr. Hofmann question I asked him. I am now asking the same question of you.

Dr. STUCKEY. Well, from looking in on the outside, we see a number of agencies involved in this area, certainly NOAA; I think DOE has been a large player in this. USDA did help provide support for our original publication back in 1992. I am encouraged that they have an office of global climate change. EPA is another organization that has been involved in supporting a fair amount of research as well.

As far as the interagency cooperation among this group, I probably don't have enough, really, insight to comment. I would just say that more communication would be desirable from what I would see.

The CHAIRMAN. How does biotech fit into the carbon cycle picture? And that leads into another question. What other new technologies can agriculture utilize to help in this regard?

Dr. STUCKEY. Well, biotechnology can play a number of very important roles. One is through the structure of the plant, trying to genetically create plants that will sequester more carbon. Carbon can be sequestered in the soil as well as in the plant material in terms of the structure of the root and storing of carbon.

But from a broader perspective, biotechnology can cut down on some of the emissions through farming practices. By utilizing biotechnology, for example, it makes possible more no-till in terms of pest control. If you are able to put that resistance to weeds and insects and diseases into the plants, it requires less travel, less applications of pesticides over the soil. And so in terms of cutting down on some of the emissions that we utilize in farming today, it has a tremendous potential.

Another technology that I am very excited about that is really in its infancy is the area of nanotechnology. It is coming. It is going to be one of the next really bright spots, in particular, in cutting some of the emissions that we currently have.

The CHAIRMAN. OK. Would you just describe that very briefly?

Dr. STUCKEY. Well, perhaps for the audience maybe the easiest analogy is to look at the electronics industry, the computers. We have computers. We went to the microchips and—the chips and the microchips, and now we are going down to even a more basic level. And it is really creating some of the technologies by putting atoms and molecules and beginning at that base. That is a very elemental base.

I had the privilege in early April just prior to the Meridian Institute of attending a briefing held by some of your colleagues here in the Senate that brought in some professors and others dealing with the nanotechnology. And one of the things that they demonstrated was a 24-volt battery that wasn't more than the size of my little finger. It had all the capacity and the power of that.

And so I think in terms of what is there on the horizon through the development of some of these technologies we can really enhance the reduction in emissions and the way we farm today. We can think of tractors, other equipment and so forth, as being much more powerful, smaller, utilization of less fuels.

The CHAIRMAN. How long could agriculture soils potentially offset further increases in the atmospheric CO_2? Each year our croplands have the potential to sequester a lot of carbon every year. Is there a way you could give a projection on that?

Dr. STUCKEY. Well, I am sure some of the researchers that work in this area could give perhaps a more qualified answer. What I have learned in interacting with some of those researchers is that it is something that we shouldn't look at as a fix for the long term, but it is something that has the potential there to help mitigate substantially, for say the next 25- to 50-years, something like that time frame. And what that does is buy us a lot of time, in other words, for some of these new technologies to be evolved so we can incorporate those.

It is, in essence, a buying of time. But even though we do that, there are those other four or five win-wins that you mentioned earlier, Mr. Chairman, that have been very beneficial when we sequester carbon. So we should do it just for——

The CHAIRMAN. Right, it is good to do, anyway.

Senator Kerrey.

Senator KERREY. Dr. Hofmann, let me ask you, first of all, whether or not you see a causative relationship between these increases in CO_2 levels and climate change itself. I apologize I was not here for your verbal testimony, and I didn't get all of your testimony read. So I don't know whether you view these trend lines which, as you indicated—I did read them in your testimony. You see them varying from year to year, and there are a lot of variables that we are still trying to answer. But do you see these increases to be causative or correlative with changes in temperature?

Dr. HOFMANN. Once again climate modeling is not my field. I am a physicist. I have studied the basic phenomenon of molecules intercepting heat from the earth and re-radiating out to space. So, based on the theory of greenhouse gases, yes, they are capable of trapping heat in the atmosphere.

In fact, this planet would be a cold 5-degrees Fahrenheit if we did not have any greenhouse gases, water vapor, regular, normal carbon dioxide, in the atmosphere. So, we are very thankful for greenhouse gases.

And we can calculate how much——

Senator KERREY. So, your answer is, you do not know? Is that what this is—this is coming to a theater near you, the physicist saying he does not know?

Dr. HOFMANN. The connection between the greenhouse gases we are putting in now and climate change, again, I do not know, no.

Senator KERREY. You do not know if it is correlative or causative with increases in temperature?

Dr. HOFMANN. I only know that the theory predicts that increased greenhouse gases should warm the atmosphere. I would again say that the best that——

Senator KERREY. Are you—let me ask it differently—are you, does this change bother you? Are you alarmed—as a human being who hopes to leave the planet in better shape than what you found it, which I presume even a physicist wants to do, does it bother you? Do you think this is something we ought to be worried about? Should we be concerned about it?

Dr. HOFMANN. I think we really do need to keep track of it, to measure as much as we can and try to find out what is controlling it so that we can provide the information that you guys will need to make these decisions.

Senator KERREY. Well, I must say I think we have come a long way since both the vote that the Chairman referenced as well as Kyoto. Kyoto, and you are actually against Kyoto, in the political environment, at least in Washington, on Capitol Hill, climate change hardly ever comes up any more. If you think we ought to pay attention to it you better tell us because we are not. We are coming at this thing from a completely different direction. I see a real disconnect, frankly.

What I said earlier was a drought produced $40 billion of economic loss in 1988, a drought. Neither Hurricane Andrew nor the floods on the Mississippi River in 1993 approached that level of economic damage. So, it is true there could be, if all I do is look at it narrowly and do not accommodate the possible gains through sequestration and other activities, it is true there may be some costs attached to changing my behavior. But if the behavior that

I have is producing something bad, I should stop it, it seems to me. It seems to me the definition of insanity is to repeat something over and over and over even though I know what I am doing is producing something wrong.

Dr. HOFMANN. Yes.

Senator KERREY. We depend upon those of you who are looking at this thing in an environment where I must tell you right now people are almost afraid of climate change as they are of Social Security. We are not teeing this thing up as you can see from the well attended hearing that we have got here this afternoon.

So, I hear you are saying from your scientific evaluation of this you have not reached a conclusion as to whether or not there is either a causative or a correlative relationship with increased carbon dioxide in the atmosphere and the climate on the planet.

Dr. HOFMANN. Yes. If the models were perfect then perhaps then we could make all sorts of projections. What we know is that if you warm the planet you will put more water into the atmosphere, it will become more energetic, and, so, you can draw a lot of conclusions. Well, there might be more storms. But the models cannot yet predict those things. We are trying to get the information.

Senator KERREY. Well, only Cindy Crawford is about perfect as a model. I do not expect scientific models to be perfect.

[Laughter.]

But I do expect scientists to be able to say just as human beings, I do not need much more information other than to extend this chart out, that is a pretty reliable chart. That thing is going up to the right.

Dr. HOFMANN. That is right.

Senator KERREY. All right. So, tell me what if it hits 500 parts per million?

Dr. HOFMANN. Well, the model suggests that when it doubles about the year 2100 under business as usual, that depending on which model you are look at, there will be a temperature increase on the order of 1 to 3.5-degrees.

Senator KERREY. And what happens then?

What happens to corn farmers in Nebraska with 3-degrees of increase in temperature?

Dr. HOFMANN. That is a problem because the models cannot predict on a regional basis.

Senator KERREY. Dr. Collins, can you convert to a problem in dollars?

Mr. COLLINS. Yes, we can. In fact, I would point you to an activity that we are just completing called the National Assessment on Climate Change which has been done under the auspices of the U.S. Global Change Research Program. USDA had responsibility for two sections: the section on agriculture, and the section on forests. We will publish the section on agriculture in June. And it takes a look at all these climate change models.

It looks at the different scenarios that they are putting out and we go from that to regional yields in the United States for crops, effects on prices, effects on farm income and so on. And, so, we are going to translate that into dollars.

Senator KERREY. But your presumption is, yourself as an economist, then as somebody has evaluated this is what? What is your presumptions? Is this something that we ought to be paying attention to?

Mr. COLLINS. Oh, my presumption is that I do not have to know categorically zero or one, whether it is causative or a correlation. I am a probabilistic man. I think the evidence suggests that the probability is increasing that there is going to be temperature, precipitation changes which are going to affect humankind and agricultural. So, it is a probabilistic thing. And, as long as it is a probabilistic thing people behave based on probability.

Senator KERREY. You should write lyrics, Dr. Collins, that would be a wonderful song. I am a probabilistic man.

[Laughter.]

You have got me rocking and rolling.

The CHAIRMAN. I have a comment that I think is pertinent to your line of questioning and I do not want to interrupt you because I want to know if there are any more song titles.

Senator KERREY. Well, Mr. Chairman, the Ag Approps Committee this morning put this language in the Ag Approps bill: "The Committee does not include funds for global climate change, biomass products initiatives or the Community Federal Information Partnerships as requested in the budget. These programs do not support the current level of on-the-ground conservation technical assistance. Hereafter, no funds shall be used for the Kyoto Protocol, including such Kyoto mechanisms as carbon emission trading schemes and the clean development mechanisms that are found solely in the Kyoto Protocol and nowhere else in the laws of the United States."

I mean that is what the House Appropriations Committee did this morning at 10 o'clock. And I do not know if the Senate Ag Approps is going to do that. Let me just ask you, Dr. Hofmann, do you think that is advisable to do that?

Dr. STUCKEY. Well, he is not in charge of that, Senator. I mean we already made that point.

Senator KERREY. I am not in charge of it either, but you could ask me my opinion as to whether or not I think it is a good idea and that is what I am asking Dr. Hofmann. Do you think it is a good idea?

Dr. STUCKEY. Well, I know but you are beating up on my scientist.

[Laughter.]

And that is not fair because, you know, were you here at the opening and I do not mean to connote that you have been but I am just saying he pointed out in this graph——

Senator KERREY. Dr. Hofmann, do you feel like you are being beat up on here this afternoon?

Dr. HOFMANN. No. Not at all. No. I can respond to that. I think if I do not—this is the first I have heard about this response, and if it mentions that we should not be spending money on research in the carbon cycle, then I would be really against it.

Senator KERREY. The language is this: The Committee does not include funds for global climate change, biomass products initiatives or the Community Federal Information Partnership as requested in the budget. That is House Agriculture Approps as of this morning.

The CHAIRMAN. I have never been much of a fan of the appropriators in there.

[Laughter.]

Senator KERREY. Look, we are here to have a good time and, we are here, as well, to try to figure out what to do. My observation on climate change is that after Kyoto—and I was in the 95—I was not absent that day—I voted in the 95 because I was concerned that the Administration was heading in the direction of essentially command and control regulatory structure, imposing high energy taxes that I think would have been enormously disruptive and not likely to solve the problem. But since that time we have developed a trading regimen. Since that time we have gotten some agreement, some indication that we might be able to persuade the rest of the world to go along with trading regimens that are much more market oriented and much more likely to produce a win for production agriculture.

But Dr. Stuckey, you tell me what was the April 6th meeting like? Is there still skeptics out there?

Dr. STUCKEY. I was not there for the close of it but I suspect there is but hopefully there is better understanding. I mean I would comment back that, you know, whatever we do here in the States, this is a global problem and we can try to make some adjustments and so forth here in the States. If we target agricultural, in the whole realm of the global warming, will make very little difference if we do not have cooperation elsewhere.

Senator KERREY. Well, you can say that about nuclear weapons, and it is absolutely true, but we are the largest economy, the most powerful military, most capable democracy and the most skilled diplomats. I mean so, you know, the hand is dealt and we are leading. I do not mind that personally but that means we got to do something.

That means we do not wait for Bangladesh to tell us what to do. So, it falls to the United States of America and we are consuming a fair amount of hydrocarbons. I am not going to put the hair shirt on here. I am perfectly appreciative of the benefits that I enjoy as the consequence of a highly productive economy and we have really gotten a lot of new efficiencies just for economic reasons. And that is really what we are talking about here, looking for a way to do a program that will enable farmers to say, this makes sense for me economically. I get some income off of it, and I get soil conservation, I save energy, I reduce my costs, this makes sense. But no-till is going down, is it not, Dr. Collins?

Mr. COLLINS. Stable.

Senator KERREY. Meaning what?

Mr. COLLINS. Oh, 100-million acres or so. It is stable throughout the last couple of years.

Conservation tillage overall has——

Senator KERREY. You think it is——

Mr. COLLINS. I think it is pretty stable the last few years. It went up dramatically for a long period of time and it is no longer doing that.

Senator KERREY. So, it is stable? I mean the word I heard it was actually going down. Nationwide it is approximately the same amount of acres it was last year and the year before?

Mr. COLLINS. That is my recollection. I could be wrong but I do not think that there has been a major change.

Senator KERREY. Wow. You could be wrong.

[Laughter.]

Mr. COLLINS. I rarely submit to that but I would say about conservation tillage one of the important things with respect to climate change is that an awful lot of conservation tillage as practiced in this country involves tearing up the soil every third or fourth or fifth year and that does not sequester carbon. So, we have got a lot of work to do on conservation tillage. We are getting climate—or we are getting carbon sequestration benefits really on only about one-third of what is in conservation tillage.

Senator KERREY. Yes, but the idea for me is that whether it is the Chairmans' bill which I support or Senator Brownbeck's bill which I support or other conservation efforts, the ideal is that we begin to alter our behavior for economic reasons and we discover that it produces benefits for the environment as well, and we participate in a trading regimen, I hope, that at some point is implemented presuming that the majority of scientists who do think study this thing and have reached a conclusion that there is a causative relationship.

If there is a causative relationship here, and I survive 30-years more, I could survive to the point where somebody is going to say to me, you know, I know it was not very politically popular back in 1999 and 2000 but, my God, you looked at the chart and it was going up, why did you not do something about it? And I said, well, I did not want to ask anybody to change their behavior.

I mean it seems to me that we are going to accumulate additional research here that leads us to the conclusion that this kind of effort, done for economic and for environmental reasons by individual farmers could become a part of an overall strategy that has us saying that whether it is just for the United States or worldwide—and I fully acknowledge, you know, we got to get India, we got to get China, we got to get the rest of the world participating—that we are going to be part of a solution that produces income as well as benefits for us locally to a larger problem.

You are back for more friendly questions, Mr. Chairman.

[Laughter.]

The CHAIRMAN. No. I think you made a good point. And the point that I was trying to make before is that I went down to the South Pole in 1998 and first met Dr. Hofmann. And it was as a result of meeting with him and listening to him and seeing the evidence from the ice cores that I changed my mind. Up to that point, I had indicated my public position was, in regards to Kyoto and to agriculture, was that we, you know, it should be demonstrated that we have a very clearly defined problem. There is no question in my mind over the last several decades we have had an aberration in regards to global warming. The temperatures have increased. And there is no question in my mind that if it continues for the next decade or two that we are going to experience a lot of big-time problems in regards to the ability of our producers to produce enough food for this country and a very troubled and hungry world.

So, we have to change in terms of behavior. I think the Senator is exactly right. How we change? It seems to me we could do it a lot better with carrots than by embracing an idea—and I, you know, have taken a hard look at all the emission trading schemes and that is about the best word for it—and people who have an agenda who think it is the right to do simply because they think it is the right thing to do. It has to make sense in regards to economics.

And what Dr. Hofmann did point out to me was that over 50-years time you could either do it the regulatory process or you can do it through things like the planning that we hope to achieve to change best management practices because of the five wins that we are involved in.

And, so, I came back and I was trying to tell agriculture, hey, you cannot sit back on the sidelines any more, we can be partners in this effort and by being partners in the effort I think we can really achieve something. And that is what we are trying to do. We are trying to get all the agencies involved, the best science involved, and all the producers involved who want to do the right thing. After all it is their land, it is their wherewithal, it is their future. And I think we can get this done, but I do not think we can get it done with an agenda that simply is an agenda from the standpoint of using—I mean we all know what the design is of the treaty. You are supposed to go back to 1990 energy levels. That is not right, it is not possible. Minus 7-percent by the way.

Now, of course, that has been, you know, debated I guess back and forth but it was Dr. Hofmann who pointed out to me and I tried to put him on the griddle a little bit, you know, before, I said is this accurate on the 50-years? And at the end of 50-years, you know, where are we with the regulatory scheme? And he said, basically he does not know because we do not know.

The reason that we do not know is that we have not really committed enough funds like he did in 1990-to–1992 to say that the North American continent took more or at least as much carbon out of the atmosphere than we put in, in regards to fossil fuel emission. That has not been stated to America. When I say that before farm groups, even the ones that are interested in this, they do not realize that. I think that is an amazing fact and that we ought to find out why? And when we say why, we do not have the research or the capability to determine why.

So, if, you know, if that is a fact and it was at that particular time, we have got to find out on a regional basis why this is happening. Once you figure out why it is happening, we can address what on earth it is that we are going to do. And that was the position by Dr. Hofmann. He changed my mind on this entirely, that is why we are having the panel.

That was what I was trying to say.

Senator KERREY. Oh, I can understand that now.

The CHAIRMAN. OK.

[Laughter.]

Senator KERREY. Dr. Collins, let me ask you——

The CHAIRMAN. Here is the chart by the way if you want to look at that.

Senator KERREY. What would you, in terms of incentives, as an economist, for farmers—and one of the most important things as I have tried to figure out what to do is that we are doing this work on private land. I mean whether it is conservation work or whatever, it is private land. So, you are trying to provide, it seems to me an incentive of some kind, for best management practices. And I wonder if you have an opinion on whether or not tax credit or direct payments or other mechanisms that you have thought of we ought to be looking at to accomplish that objective?

Mr. COLLINS. Well, what you want here is a demand for carbon. Where is it going to come from? In one instance, it could come from people being altruistic or speculative like the Canadian utilities that are coming in and presumably buying carbon in Iowa. So, that is one form in which farmers are responding to undertake best management practices in response to a private sector determined incentive.

A second way of generating the demand would be for the Government to look at carbon the way it looks at erosion, you know, as a market failure. There is an externality. There is a public good aspect to going out and using taxpayer dollars to provide an incentive payment to reduce greenhouse gas emissions.

In that case, the Chairman's win to the N'th power, you would bring carbon sequestration together with the other kinds of environmental benefits that are highly connected and correlated and intertwined with carbon sequestration like water quality, air quality, soil quality and you would put that all into one program.

I mean on a very naive level you can see something like what we do with the conservation reserve program. We have an environmental benefits index. We weigh a bunch of factors. We give them a score. And then the highest score relative to the bid price on the land, we take into the program and pay $50 a month for 10- or 15-years.

You could think of adding, a carbon sequestration dimension to the environmental benefits index. I mean that is one simple thing, if that was the social value.

Other things, we do other things in our EQUIP program. We have talked here a lot about carbon sequestration. The other side of this is greenhouse gas emissions. Agriculture is not an insignificant emitter. We emit 7-percent of the total annual emissions in the U.S. They are all methane and nitrous oxide. Under the EQUIP program, for example, we have nutrient management plans. Nutrient management plans can effectively reduce nitrous oxide emissions.

So, you could conceive of putting more money into the EQUIP program in some of the activities that are funded in that that would reduce emissions or sequester carbon.

Beyond that then you are talking about different kinds of tools that we have not really looked at very much.

Senator KERREY. Can I ask you, in general, though is it more efficient to put direct payments out as opposed to using tax credits?

Mr. COLLINS. I do not know that there is a great difference.

Senator KERREY. I admit to a slight prejudice just from the standpoint of the complexity of the Tax Code. But I am thinking of situations where somebody says I am not eligible because I do not have a sufficient amount of income or my accountant did not figure it out. But from an economist's standpoint you are saying, you seem to be saying that there is no real difference between the two?

Mr. COLLINS. I do not think there is a great difference between the two. What economists look at is the cost of using tax dollars to do something and whether it is tax dollars because we are giving up less revenue to the Treasury or whether it is tax dollars because USDA's appropriation is going up, I do not know that it makes that much difference in terms of efficiency losses to our economy.

Senator KERREY. Well, it is a shame that we cannot get a bit more comprehensive approach to this, not just on the Executive Branch but often on our side. I mean I guess it was last year or the year before last we were about that close to getting the Endangered Species Act reauthorized and though it may not seem directly related, it ends up being very much related because we were trying and had at least up until the bill got pulled, language in there that would have allowed the ESA to be administered inside the context of a State conservation plan.

Oftentimes states. I know that Kansas and Nebraska and Iowa and I suspect South Dakota does as well, invest a fair amount of money, State dollars as well as local dollars, in conservation efforts and they will have a conservation plan. One of the ways that I think that you can get the skepticism out of the minds of individuals that are addressing this climate change problem is to bring the problem solving more and more back down to the local level. Some of the things you were saying in there about the CRP, especially, I hear more—and I am not sure that is what you were saying—but I hear more top-down Federal regulations and the more it can be incorporated into State conservation plans and the more people can feel like they are part of it, whether it is a local conservation district or in our State, resource districts, the more likely it is, it seems to me, that the skepticism comes out of it because then they say, you are going to let me decide what best management practices are. You tell me what the goal is, what your carbon goals are, what your water quality goals are, what your soil conservation goals are, and let me be one of the little entrepreneurs out here that figures out how best to accomplish it. It is more likely that we will have that kind of, I think, constructive flexibility as opposed to me saying flexibility means I just do not want to do it.

Mr. COLLINS. I think that is a good observation and I would say with respect to the conservation reserve program we have moved a step in that direction with our State conservation reserve enhancement programs, where the states are offering up 25-percent of the incentive payments we are making producers and we are letting the States decide what the conservation priorities are in implementing those plans. And it is not inconceivable that a State could decide that carbon sequestration is an issue that they want to deal with in a conservation reserve enhancement program.

Senator KERREY. Thank you.

The CHAIRMAN. I want to thank all the panelists. We have had a very——

Senator KERREY. Especially Dr. Hofmann.

[Laughter.]

The CHAIRMAN. Maybe we should both go down to the South Pole, it is cold down there, and see Dr. Hofmann again.

[Laughter.]

I will share a cup of coffee with you.

[Laughter.]

Senator KERREY. Do you want me to go first?

[Laughter.]

The CHAIRMAN. We would like now to welcome the second panel. I am going to make a suggestion that panel three simply come up as well. We have four chairs here. So, that is going to be Dr. Charles W. Rice, who is the Soil Microbiology Professor at Kansas State University; John M. Kimble, who is the Research Soil Scientist at the United States Department of Agriculture, in Lincoln; and William Richards, the former Chief of the Soil Conservation Service, who now resides in Circleville, Ohio; and an old-time friend of mine, John Haas, from Larned, Kansas.

Dr. Rice, will you, please, proceed and let me advise the witnesses, we have a vote at 5 o'clock but I would hope that maybe we could certainly conclude by that time.

So, if you could keep your remarks within the 5-minute time period we would appreciate it.

Please, proceed, Dr. Rice.

STATEMENT OF CHARLES W. RICE, SOIL MICROBIOLOGY PROFESSOR, KANSAS STATE UNIVERSITY, DEPARTMENT OF AGRONOMY, MANHATTAN, KANSAS

Dr. RICE. Thank you, Mr. Chairman, members of the Senate Subcommittee. I am Dr. Chuck Rice, Professor of Soil Microbiology in the Department of Agronomy at Kansas State University. I am also a member of the Soil Science Society of America and a Fellow of the American Society of Agronomy. I personally have been involved or became involved in soil organic matter and carbon research, and no-tillage research during my Ph.D. training starting in 1980.

I am pleased to be invited to testify on the role of agriculture soils in carbon cycling and mitigating greenhouse gases.

As was noted earlier, since the late 1800s, carbon dioxide has been increasing in the atmosphere at an extremely rapid rate and with much of this increase in the last 50-years or so due to the burning of fossil fuels. Ultimately we need to reduce our carbon emissions into the atmosphere, however, also, as mentioned earlier, it is going to take time to develop energy technologies and make them economically feasible. Plants and soils can buy us some of that time.

Recent models suggest that plants and soils can reduce the increase of atmospheric CO_2. How does this occur? Carbon sequestration by soils occurs primarily through the plants first. Plants convert the carbon dioxide into the plant tissue through photosynthesis, and then as those plants decompose, primarily by soil microorganisms, some of that carbon is turned into soil organic matter or humus. This humus can persist in soils on the order of hundreds to thousands of years, so, therefore, it represents a long term storage.

The estimated amount of carbon stored in the world's soils is about twice that in the plant vegetation, itself, or in the atmosphere. Hence, even a relatively small change in the soil carbon storage can represent a big impact on the carbon balance, the global carbon balance.

Agriculture has always played a key role in carbon cycling. Much of the central U.S. and Canada that is now producing our abundant food supply, as you know, was once a vast prairie. And these carbon-rich soils have their carbon levels due depleted or reduced to plowing and soil erosion. They have been reduced by about 50-percent.

However, this loss of soil carbon can be reversed and modern agriculture now represents the potential for storage of carbon in the soil. We now have and we need to develop technologies and information needed to conserve carbon that is put into the soil. I have provided a list in the written testimony of carbon conserving practices, but just some examples include conservation tillage or no-tillage, proper fertilizer management, elimination of summer fallow—that is important in the Great Plains, Colorado, Nebraska and Kansas—crop selection, including perennial crops, and vegetative buffer strips.

I would like to use no-till as one example. Research at Kansas State University and other land-grant universities have shown that no-tillage can sequester an average of a 10th to two 10ths of a ton-per-acre-per-year. What does that mean? In Kansas, if we had a million-acres converted over to no-till, that would be storing enough carbon equivalent to burning of 85-million gallons of gasoline each year.

Another example, elimination of summer fallow would have similar gains in Western Kansas and the Great Plains.

Range lands is often forgotten and it also absorbs carbon. Some of the research by Dr. Clinton Owensby and myself has shown that carbon under elevated CO_2 is increased, soil carbon is increased on the order of 2-tons-per-acre over an 8-year period.

Economic analysis suggests that soil carbon sequestration is among the most beneficial and cost-effective options available for reducing greenhouse gases, particularly over the next 30- to 50-years until we build up or develop those alternative energy sources.

At Kansas State University we have a team of research and extension faculty to conduct basic and applied research on agricultural practices to sequester soil carbon. Also as part of our mission, since we are a land grant university, our desire is to extend that information to the land managers and policy makers in Kansas.

In addition, Kansas State research and extension team has joined up with a national Consortium for Agricultural Practices to Mitigate Greenhouse Gases pronounced "casms."

This consortium includes eight land grant universities and a Department of Energy laboratory as well. This CASMGS team is made up of internationally recognized researchers and institutions in the field of carbon dynamics, soil erosion, greenhouse gases, agricultural resource economics and integrated assessments.

If you permit, the overall goal of CASMGS is to provide the tools and information needed to successfully implement the soil carbon sequestration programs so that we may lower the accumulation of greenhouse gases in the atmosphere, while providing income and incentives to producers in improving soil quality.

To achieve this goal, we need to further conduct basic and applied research, develop the models for assessment, and provide economic analysis for a better understanding in adoption of carbon sequestration practices. And then we need to take this information and provide the education and demonstrations for the producers to adopt that technology.

I also would like to remind the Committee that in addition to reducing carbon in the air, many of these practices have other benefits and I will just quickly mention four here.

One is that by increasing soil carbon restores and sustains our natural resource base which part of this country was founded upon. Second, increasing soil carbon improves the soil quality including the biodiversity of the soil, soil microorganisms, and the chemical and physical properties of the soil. Many of these practices that increase soil carbon also improve water and air quality.

Finally, agriculture soils become more productive, often with fewer inputs and, thus, increase the profitability for the producer. Thus, my four wins is for agriculture, the environment, the U.S. citizen and the producer.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Rice can be found in the appendix on page 74.]

The CHAIRMAN. Thank you.

Dr. Kimble, please proceed.

STATEMENT OF JOHN M. KIMBLE, RESEARCH SOIL SCIENTIST, U.S. DEPARTMENT OF AGRICULTURE, LINCOLN, NEBRASKA

Dr. KIMBLE. Mr. Chairman, members of the Subcommittee, I am a Research Soil Scientist at NRCS in Lincoln, Nebraska, and it is a pleasure to appear before you to discuss the issues of carbon cycle research and the role of agriculture in helping to mitigate the greenhouse gases. For the last 10-years I have worked with issues related to soil organic carbon and the role that agriculture can play in sequestration of carbon in the soil.

There is a strong linkage of the carbon cycle to the nitrogen and phosphorus cycles and all three need to be considered together. Many of the problems we have with animal wastes are related to phosphorus and nitrogen, yet, the organic matter in the waste is needed for building soil carbon. In addition, both nitrogen and phosphorus are required for photosynthesis.

We also need to consider the emissions of methane and where this fits in the overall carbon cycle. Methane is produced by ruminant livestock during feed digestion, in wetlands, rice paddies, and animal waste storage facilities.

We know that soils can sequester carbon. The average sequestration potential for cropland is about 8-percent of the total annual U.S. emissions and for grazing lands about 5-percent of annual U.S. emissions. So, it is a very large amount.

Sequestration can significantly reduce atmospheric CO_2 and at the same time improve soil quality. We have heard this many times, the win-wins. The increased carbon leads to improved soil fertility—maybe I will get more than four—reduce soil erosion, restoration of degraded lands, improve water quality and improve wildlife habitat. This is a win-win scenario——

[Laughter.]

I will lose my thought here—to agriculture as well as to society in general. I think the major benefit is society in general. So, that is one of the major winners is society.

The knowledge gaps that have been identified which require future research are the development of global data bases, information exchange, we need to understand wetland processes better, carbon sequestration in the subsoil, soil erosion and carbon dynamics—what happens to it when we erode it, do we lose it or not—plant nutrients and their interactions with soil carbon, soil structure, soil quality. We need to improve our methods for soil organic matter assessment. We need to understand tropical ecosystems, and frozen soils, what happens to them if we have warming.

Assessment of the value of carbon per ton needs to be determined and we need to look at policy options to encourage farmers and land managers to adopt recommended management practices. We know the value of conservation tillage but still need to look at the potential benefits of different types of tillage systems from simple no-till to the less more conventional strip tillage in some of these and different agro-ecological zones with different crops and different crop rotations on different soils. This research requires long-time experiments.

CRP has helped to improve highly erodible soils but the question is, have we gotten the maximum benefit from these lands? Do we need some sort of management to improve their rates of sequestration. Research is needed to determine how fertility testing information can be used to help us understand changes in soil carbon levels. We take over 2-million samples a year for this, yet, we are not using these numbers right now to relate to soil carbon changes.

Research is needed to determine why practices that are shown to work to increase carbon sequestration are not being adopted. Integrated research is needed to ascertain the value of soil carbon in terms of the effect on production and on other societal values, some of the material that Keith Collins mentioned. What is the cost-benefit of carbon sequestration?

How can we use remote sensing to observe land use changes, to improve management practices, and to enhance carbon sequestration? We need to see the effects of irrigation on carbon sequestration since irrigation is being used more and more and can affect both soil organic carbon and soil inorganic carbon.

We need to look at the effects of bioenergy on soil carbon and the crops grown and how they affect the carbon. We need research to look at crops that maintain or have increased yields but at the same time increase the amount of below-ground biomass or changing the lignin content so the carbon stays around longer.

We need to improve our ability to monitor and verify carbon stocks using direct measurements coupled with process models that will allow us to scale point data to field and whole farms and eventually to larger geographic regions.

The future understanding of the global carbon cycle depends on the development and implementation of a research program that is interdisciplinary. It must link policy makers to soil scientists, agronomists, economists, plant breeders and other scientists. We have worked alone many times, we need to work together.

We need to take the research from the laboratory and experimental fields to whole-farm operations and see how we do it on them.

Mr. Chairman, that completes my statement.

[The prepared statement of Dr. Kimble can be found in the appendix on page 83.]

The CHAIRMAN. Thank you very much, Dr. Kimble.

Mr. Richards.

STATEMENT OF WILLIAM RICHARDS, FARMER AND FORMER CHIEF OF THE SOIL CONSERVATION SERVICE, CIRCLEVILLE, OHIO

Mr. RICHARDS. Thank you, Mr. Chairman and members of the Committee for the opportunity to testify. I am going to read the short version and submit the balance for your consideration and remarks.

I will focus on how conservation tillage will sequester carbon, and may be the best solution, surely the easiest solution, to our CO_2 concerns.

I am Bill Richards, a farmer from Ohio, representing myself and our family farm. I bring the experience of 45-years of conservation farming and two-and-a-half years as Chief of the Soil Conservation Service, and the two of you will readily remember that I was on the hot seat at the height of the 1985 farm bill implementation.

Conservation tillage or no-till or what was best described as direct seeding has really been my life. We have land that has not been plowed for 40-years and we have been complete no-till for more than 20. Our soil quality is improving each year. Every spring planting gets easier and easier. We are using the same planters for the last 25-years, so, we know that it is getting easier. Direct seeding has really kept our farm competitive, expanding and profitable, all these years. It also sent me to Washington when Secretary Yeutter wanted a farmer to address the producer hostilities from the erosion requirements of the 1985 farm bill.

My background in no-till and direct seeding and with the help of the chemical and machinery industries, the farm press and other USDA agencies, we were able to sell conservation tillage as the best practice to meet the erosion requirements. And for the most part, we were successful. Erosion dropped to sustainable levels in many regions of the country and conservation tillage peaked out at roughly 40-percent of planted acres, then things changed.

The agenda switched from the real measurable problem of soil erosion to the perceived of herbicide dependence. Conservation tillage has levelled out nationally. It is gaining in cotton, wheat, and soybeans but losing in the corn belt, especially in highly erodible Iowa.

The U.S. is unlike our competitors, Canada, Argentina and Brazil, who have all passed us in the percent of cropland direct seeded. I am concerned as one of those who started this conservation tillage revolution that we have unleashed a monster because around the world millions of acres of new lands are coming into production that would be too fragile or unprofitable without conservation tillage.

I feel and hope that future conservation programs will be separate, voluntary and incentive based. I hope that we have learned our lessons on cross compliance. From my experience as a farmer and past SCS Chief, I am convinced that we get conservation on the land and behavioral change with incentives and education not requirements and regulations.

We have always known and understood the immediate fuel, labor and machine savings of conservation tillage. We also captured the management opportunity of spreading our talent over more and more acres. Then come the erosion and conservation benefits that become political after the 1985 farm bill. But only recently have we understood the long-term soil quality, water quality, and wildlife benefits accruing from continuous direct seeding.

The opportunity to increase organic matter, that is soil carbon, will first increase productivity or land value, and second, sequester carbon for a world concerned with climate change from greenhouse gases.

The Ag Research Service has found that as much as 1- to 2-percent organic matter increase in 10- to 20-years of continuous no-till. It has been said earlier. The bad news is that we have tilled away or eroded 50-percent of the organic matter from our soils in the last 100-years. But the good news is that we have the technology, the machinery and science to put it back.

Others gave a lot of statistics. I will just skip to the point that we should encourage our farmers and ranchers to do whatever is recommended to achieve these potentials. I feel that science has documented the increase in CO_2 in the atmosphere. I do not feel we know why or if man has anything to do with it, however, if the world is going to throw money at global climate change, then agriculture could, can and should earn some of that money and I might say, we will put it to good use.

I hope that in the near future we will have the opportunity to put in place a comprehensive conservation incentive program to reward producers for stewardship. We offer a solution to the global climate change, greenhouse gas problems that is a win-win for all concerned.

Whether the problems are real or perceived, public funding for increased organic matter, improve soil quality, better water quality, less erosion, all leading to higher productivity, is a good investment for our people, and the whole world.

A conservation bill would focus agriculture's importance to the environment. A conservation bill would move money to the countryside at a time when it is badly needed. But more importantly, help production agriculture address the concerns of the environmental community and avoid the temptation to regulate.

If we could get in place a freedom to conserve with a good insurance package we could avoid the temptation many have to change freedom to farm. I hope we give it time. It has our foreign competition worried and we producers enjoy the freedom to manage and compete.

Enforcement of the Clean Air Act is starting and carbon will be valuable. I am told $20 per ton is a reasonable price. The EPA and most environmentalists favor carbon trading so industry, especially utilities, will finance the carbon reduction. I think the issue for agriculture producers is whether we trade our payments, our carbon sequestering potential on the market or do we get our rewards through stewardship payments?

I am out of time and I thank you.

[The prepared statement of Mr. Richards can be found in the appendix on page 89.]

The CHAIRMAN. Bill, you made sense in 1985 and I think you made a great deal of sense then and I appreciate you coming and I appreciate your perspective from an individual producer but more especially from your experience as the head of SCS, which I still call it, by the way, SCS.

Mr. RICHARDS. Me, too.

The CHAIRMAN. John.

STATEMENT OF JOHN C. HAAS, FARMER, LARNED, KANSAS

Mr. HAAS. Mr. Chairman, Senator Kerrey, it is a pleasure to be here and appear before you this afternoon.

My name is John Haas and I live in Larned, Kansas. I am a non-irrigator farmer and I am probably a true family farmer. We farm about 4,000-acres, of which my wife and my daughter-in-law provide the combine help in the summer time. I do about 90-percent of the rest of the work.

We basically are 100-percent no-till operation. Have been for a number of years. Started into it about 1979, 1980. Some of the things that I see that have affected it—and I think there are a lot of wins, and I do not think that we can even go about numbering them all—but I will tell you what, as long as we can go 11 and 0, that is the kind of wins that we like to go with.

You know, one of the things that has happened——

The CHAIRMAN. It is a shame we did not go 12 and 0 "referring to K-State football."

[Laughter.]

Mr. HAAS. It is very difficult with Senator Kerrey there to talk about that. You know, having watched and participated in this type of thing NP. It is very interesting to me to see what has happened to the soil. Our soil today is in better shape under no-till than it has ever been since we probably broke it out.

It has a better ability to absorb moisture. We just recently have been blessed with abundant rains in my area and it was interesting to me to observe what was happening to those soil, those fields that had been no-tilled and those that had been tilled. And we see a great difference in the runoff and the percolation of the water and how that affects the soils, themselves, but in turn, it will affect the crops down the line.

With the Freedom to Farm Act in 1996, it allowed our farm to go from a wheat, milo farm, to now we grow wheat, milo, alfalfa, corn, soybeans, canola, and sunflowers. We are in an area that we get about 23-inches-of-rain. We get enough rain to raise a crop if we can hold that moisture where it falls for the times when we need it. And the only way that I can see that we can do that is under a no-till situation.

Earlier somebody talked about how do we increase the amount of organic matter on the soil to be able to not only take up that carbon but to also decrease wind erosion, water erosion, and those type of things? Well, in no-till I found the answer to it, and it is another one of those wins.

It is raising crops. As we raise more productive crops, we have more organic matter left on that soil, and that becomes one of the things that we have to deal with in planting. It is hard to plant no-till into 100 bushel-an-acre wheat stubble that has been left. But it is possible.

I think one of the biggest draw backs I see in fact of getting farmers involved in the no-till conservation type tillage, is that it takes more management. You have to be more timely. It is more difficult. You are dealing with things that you have never had to deal with, and most of them are up here in your head. Because, you know, my grandfather and my father farmed in a clean tillage type of situation, why should I change.

It is very difficult for me, having grown up under that kind of an atmosphere, to be able to go back and lay the fields in what would look like a very terrible situation, only there is nothing growing there, and to me they are beautiful. But let me assure you, your neighbors will not tell you that. And there is a psychological problem definitely in no-till circumstance.

The question that came up earlier today is how would we go about paying for this. Do we give tax credits or do we look at dollars? I would like to address that in the fact that if you want the farmers to participate I think that you look at the direct dollars not in the tax consequences. Farmers will do things for dollars.

I think this carbon sequestration is real. I think we have the ability to solve some of that and help not only our country but the world in general. I think farmers are historically the original environmentalists. They are dealing with their livelihood on that piece of ground that they farm. And no matter what people say they are dealing with what is going to happen to them, and their generations in the future. And I think, you know, as I look back and see some of the things that have happened, we have increased our wildlife habitat with no-till. Today, we have got tremendous quantities of deer, wild turkey, bobcats, quail, pheasants we did not use to have 30- or 40-years ago.

We are doing a lot of things in the country, I do not believe, that people in general really understand and see what is going on out in the country. I think that the opportunity that you have presented to me to be able to come and present some of this to you—I have varied a little bit from my written testimony but I know that that will be in the record—and it is a privilege to be here. I want to tell you that it is possible.

We do need leadership from Washington in part of it, but another way to look at how do we get the farmers to participate in this program, and I think it is very, very important, is the fact that we must involve our land grant universities and our cooperative extension services, because let us look at the GMO situation today. That came through private enterprise. Farmers bought into it and now we are starting to look at that and question that because of the adverse publicity that is out there.

The land grant system and cooperative extension has the reliability that we, as producers, will look and we like that. And, so, I just really encourage you that as this research comes about that we do not put it in different areas but that we keep it in the USDA and channel that through our land grant system and get that message out to the farmers through the extension service.

There is not another agency up here that has the ability to get to the people that the extension service does and I use them greatly.

Thank you very much for your time. I appreciate it.

[The prepared statement of Mr. Haas can be found in the appendix on page 95.]

The CHAIRMAN. OK. We thank you, John.

Dr. Rice, as you indicated while Kansas State is part of a consortium, who makes up that consortium now?

Dr. RICE. The consortium is made up of 8 land grant universities, including Colorado State, Iowa State, Kansas State, of course, Michigan State, Montana State, Ohio State, Texas A&M and University of Nebraska and the Pacific Northwest National Laboratory.

The CHAIRMAN. That is called CASMGS?

Dr. RICE. Yes, Sir.

The CHAIRMAN. CASMGS?

Dr. RICE. Hmm-hmm.

The CHAIRMAN. And the "G" is silent, obviously.

Dr. RICE. Yes.

The CHAIRMAN. Now, did the USDA provide grants or other funding to the group?

Dr. RICE. To the group, no. We have an initial appropriation from EPA that was originally for $350,000. That got cut to $332,000 for this year. Individual researchers have some competitive grants for USDA but not as a group.

The CHAIRMAN. But what funding would you need for next year and if that is forthcoming, how would it be spent?

Dr. RICE. The proposal that the group has put together is around $10 million a year, and that will be used for continuing the applied research, to develop the inventories for greenhouse gases, the economic analysis to help both the producers and inform the policy makers.

The CHAIRMAN. John just indicated that it would be absolutely essential to work with through the extension service and our land grant universities. What is Kansas State doing to assist producers?

Dr. RICE. Mr. Chairman, we are fortunate at Kansas State that we have a good research extension team. We have just produced a no-till handbook as an example. And 7,500 copies were produced and I think we are running out. So, we are looking at a second version or even maybe putting it on the Web. We have an extensive network of field sites that provide opportunities for field days. County agent training, I have helped train county agents that, of course, outreach then to the individual producer.

Even my time Committment has been increased in the last several months here communicating to government agencies, nongovernmental agencies around the State.

The CHAIRMAN. Dr. Kimble, you have got a book out that you helped edit, "The Potential of U.S. Cropland to Sequester Carbon and to Mitigate the Greenhouse Effect" and you made the point that bio-fuels could help sequester anywhere from 35- to 63-million-metric-tons-of-carbon per year. Explain to me how bio-fuels relate to carbon sequestration.

Dr. KIMBLE. You get two benefits from the bio-fuels. One is you are offsetting the use of nonrenewable resources by doing this but bio-fuels, switch grass, rapidly growing willow trees or whatever, also have an extensive root system. You are taking nonproductive land, maybe highly eroded land, and putting it into productive use. So, your putting a lot more carbon into the ground by using, growing these crops.

So, you are getting the benefit of, you know, replacing nonrenewable resources and you are also getting the benefit of increasing the soil carbon by increasing the amount of carbon input into the ground. It is not just removing the bio-fuels where they make them into ethanol or other fuels but it is also the carbon into the ground.

The CHAIRMAN. You have got some testimony about remote sensing and that really got my attention. We have a group of researchers at the University of Kansas and that is the remote sensing center for the region in regards to NASA.

Last year, let me point out, that these researchers developed a remote sensing model that was 95-percent accurate in predicting the Iowa corn harvest—I am sorry that Senator Bradley had to leave—by 2-months in advance of the actual harvest. The USDA did not get their final numbers until after harvest, obviously. So, my question to you is how important us remote sensing to your research and do you foresee remote sensing being a bigger part of yours and others in regard to soil science?

Dr. KIMBLE. Yes. Remote sensing is a very important tool. We can look at land use change and we can see how much areas are going into no-till, are we having an increase or decrease in conservation tillage. We use it in NRCS—which you call, SCS, which I do, too, but I am not supposed to; I work for them so I have more restraints, I guess—but we use it in our mapping to develop the data bases.

The CHAIRMAN. You should hear what farmers call them. Go ahead.

[Laughter.]

Dr. KIMBLE. Remote sensing is, you know, it is how we gather a lot of our data to go into the data bases we need. It is a very important tool. It can help us look at drought. You know, predict when we may have droughts, looking at, you know, they are developing sensors with NASA to look at moisture in the ground so we can get earlier predictions of what is going on. It is, to me, it is part of the future.

If I go onto a farm I can look at a small area but with remote sensing I can integrate over a whole watershed which we have to do. So, to me, it is a really powerful tool that we need to keep using and increasing its use of.

The CHAIRMAN. Bill, tell me, you made the comment that farm land values increase as the level of organic materials like carbon in the soil increases and that crop yields increase. Do you have any tangible numbers there or, you know, just a guess?

Mr. RICHARDS. Just by looking at farm sales and looking at values around me, when that organic matter goes up, in other words, between a Brookston soil, which is our best, and a Crosby, there is about a 2-percent difference. Now, there are other things there, but that is a good $500 or more.

You can also come at it the other way that 2-percent organic matter would probably add about 20-bushels-an-acre to that corn yield, at $2 a bushel, 8-percent, that comes back to that $500. So, it is for real.

The CHAIRMAN. It is significant.

How would you compare information transmitted from the Department of Agriculture versus the Conservation Technology Information Center and Extension, etc., and here is the obvious question: Would a more consolidated approach to information transmission be useful to you as a producer?

Mr. RICHARDS. Well, as a producer, I did not realize there was a problem NRCS and USDA does the measuring, CTIC merely reports those figures. I should say I am on the CTIC Board but, you know, to me it is a good example of public/private partnership. And we hope it is working.

The CHAIRMAN. John, you have been a good friend to Kansas State, obviously, down through the years and a key member of something called the Council for Agricultural Research Extension and Teaching—that is CARET—over the years. And you have also been a participant in the University's test plots for canola for that research and then through your own personal experience the question is, should the University and other land grant institutions be involved in this research? Why should producers take a proactive role in assisting this research?

This is a softball question to you, but go ahead.

Mr. HAAS. Oh, yeah. That has an easy answer to it. I really enjoy having demonstration plots and test plots on our farm because when those plots are there then I can see what they are doing under my conditions. Right now, we have the canola breeder at Kansas State, Charlie Rife who has an experimental plot there on the farm. Last year, we had a little over 10-percent of the State's canola growing on our farm.

Unfortunately, it was destroyed in a hail storm just prior to harvest. But I think what it shows is possible as people go by——

The CHAIRMAN. Well, you will benefit a lot more once we pass the Kerrey-Roberts crop protection amendment.

Mr. HAAS. I am looking forward to it.

[Laughter.]

Mr. HAAS. But, you know, there is nothing better to draw farmer's attention than to see some, farmer out there doing something different that nobody else not doing, and then they start watching that. And you just hope that if it is good that it is on the popular road and if it is bad, it is on the back 40.

But the University really puts its best foot forward when they come out and evaluate. Next month or at the end of this month, I guess the 24th of May, Charlie is going to come out and we are going to have a field day at that canola plot. We are going to talk about the different variety that he has planted. What he sees in the future for canola. I am sure that we will have a great participation from the area.

There is a lot of trust in the land grant system in production agriculture. We look to the extension service for information. That is nonbiased information. A lot of times if we get it out of private industry, there is a reason for what we are getting. But the University works very hard at having nonbiased information and we appreciate that and it is very valuable to us.

The CHAIRMAN. Now, just quickly for a final comment. Would you go down your cropping pattern changes again and this is just for the benefit of Senator Kerrey and others, in that Kansas used to be known as sort of a mono-agriculture State, more especially in the old big first district, now 66-counties. Very similar to the district represented by Bill Barrett. And that has changed absolutely dramatically.

And you went down a list on your farm. You want to do that again?

Mr. HAAS. Sure, I would be very happy to. We historically were a wheat farm. And in the 1950s milo was brought in to it and then when we saw the hybrids come, we were split somewhat between 50-percent wheat, 50-percent milo. Well, really, a third wheat, a third milo, third fallow.

Today, because of the ability that we have to pick those crops that we see have the best economic return and through no-till having the moisture available to grow some of these crops, today wheat has become a minor crop for us. We grow alfalfa, corn, soybeans, sunflowers, and canola. And if there was something else, I would try it, too.

But I will tell you what, our economic stability has become very solid in the adaptation to the different crops versus one or two. I do not worry about one particular market. I do not worry about one particular hail storm.

You know, last year we lost 50-percent of our wheat to a hail storm but, yet, we had a very good year. Now, that is adding into the government payments and so forth that came from Washington. And let me assure you that economically in production agriculture if those payments were not there, it would have been a disastrous year across-the-board in agriculture.

The CHAIRMAN. You can move a little south and a little bit east and there are about 35,000-acres-of-cotton production in Kansas. The most efficient cotton that is now produced in the United States because it is so cold it kills the bugs.

Mr. HAAS. Absolutely.

The CHAIRMAN. We would have never thought that when Stephen Foster wrote the song, “Those Old Cotton Fields Back Home” he was talking about Kansas.

Mr. HAAS. You know, another thing to interject in that, Mr. Chairman, is the fact that with the biotechnology that we see available to us in crops, we are reducing our uses, particularly insecticides. If we can grow a bt corn and save from spraying that corn with an insecticide that kills everything, all the insects around it, it is better.

We have got a lot of things going for production agriculture today and I think the carbon sequestration that we are looking at is just another positive and I think it has a place to play in the role.

The CHAIRMAN. I apologize for Senator Kerrey who had to leave and I guess we got to visiting too much, John, in regards to our mutual prejudice which, you know, obviously, makes us both very smart.

[Laughter.]

But I want to thank all of the witnesses and the previous witnesses. This has been the first hearing of this subcommittee in quite a bit of time. I think we focused on the right topic and I want to thank the witnesses.

We are going to see if we cannot work with the appropriators to see if we can have a greater investment in regards to carbon sequestration. We are going to be working with the Department to make sure that they maintain a very strong voice and that we try to do a better job of consolidating and having that clearinghouse that our producers really want and should have.

I think this is a very exciting topic. As I have said, again, I think that this is part of the answer, a big answer to global warming, and it is a positive answer aside from all the debate we are having as to whether that is the proper—whether the Kyoto Treaty would be the proper role or not.

So, I thank the witnesses and the Subcommittee is adjourned.

[Whereupon, at 4:10 p.m., the Subcommittee was adjourned.]

APPENDIX

MAY 4, 2000

OPENING STATEMENT OF SENATOR PAT ROBERTS

SUBCOMMITTEE ON PRODUCTION AND PRICE COMPETITIVENESS

HEARING ON CARBON CYCLE RESEARCH AND AGRICULTURE'S ROLE IN REDUCING CLIMATE CHANGE

MAY 4, 2000

Good afternoon and welcome to today's hearing.

Given scientific uncertainties about the magnitude, timing, rate, and regional consequences of climate change, what are the appropriate responses to the problem for world decision makers? The Administration has decided that the Kyoto Protocol, which mandates the United States to cut its energy usage seven percent below 1990 levels with no developing nation participation, is the appropriate method.

I am not going to open up a debate about climate change, but I am interested in finding a solution. One component of a solution is croplands, soils, and forests that soak up carbon dioxide. We will hear today from the leader of the NOAA agency that reported that crops, soils, and forests have the ability to absorb most if not all of the carbon dioxide emitted through fossil fuel emissions.

Is there a sensible solution to climate change that has benefits for agriculture rather than pursuing a diplomatic strategy that may impose harsh unforseen consequences on the United States?

I have introduced legislation that will promote agricultural research in the area of climate change while giving producers and policymakers a better understanding of the link between the carbon cycle and agricultural best management practices.

My bill, S.1066, the Carbon Cycle and Agricultural Best Practices Research Act, authorizes the USDA to conduct needed research on the mechanics of storing carbon in soil and to preform research that will better define agriculture's ability to solve climate change. Why? Agriculture may have the ability to store 200 million tons of carbon annually or the equivalent of 307 million tons of coal. For a regional perspective, a large utility in Kansas uses 10 to 11 million tons of coal annually.

The research focuses on best management practices such as conservation tillage, efficient fertilizer application, intensive crop rotations, and increased cover crops. These practices reduce soil erosion, reduce fuel costs, improve soil fertility, improve water quality, and increase production. For this reason, the promotion of conservation practices in agriculture remains a win win opportunity for everyone.

With that in mind, I am pleased to welcome the panels here today and look forward to hearing about agriculture's role in mitigating greenhouse gases. Today's panelists include representatives from government agencies, leading carbon cycle researchers, and agriculture producers who have embraced best management practices. Unfortunately, because we are in the middle of planting season, one of the producers invited to testify, Mr. Clark Woodworth from Sterling, Kansas, could not make the trip to Washington, and I would like to submit his testimony for the record.

I would like to remind the panelists that your entire testimony will be submitted for the record and ask that you limit your statements to no more than five minutes so that everyone has ample time to be heard.

Written Testimony of
David J. Hofmann, Director
NOAA Climate Monitoring and Diagnostics Laboratory
Before the
Senate Agriculture, Nutrition and Forestry Committee
Subcommittee on Production and Price Competitiveness

Atmospheric Carbon Dioxide – Current Understanding and Plans for Future Research
May 4, 2000

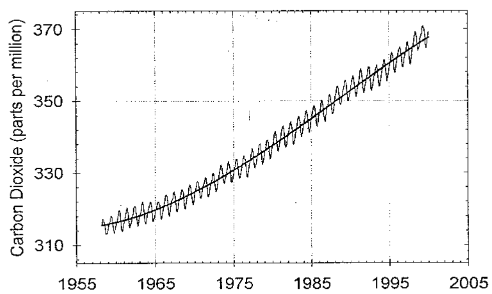
Introduction

Good afternoon. I am Dr. David Hofmann, the Director of NOAA's Climate Monitoring and Diagnostics Laboratory (CMDL) in Boulder, Colorado. Thank you, Chairman Roberts, for inviting me to provide testimony on carbon cycle research and the importance of the terrestrial biosphere (soils, trees, plants, etc.) in taking up excess carbon dioxide. I am honored to be here today. I will briefly review what we know about carbon dioxide uptake by the terrestrial biosphere, which may be important for agricultural management practices, and how carbon cycle research can be improved. The scientific community understands the mechanics of the carbon cycle better now than just 10 years ago. However, there is a great need to better understand the natural variability in carbon dioxide uptake by the terrestrial biosphere.

Carbon cycle research is focused on understanding the science of one element of forced climate change: greenhouse gases. Understanding the sources and sinks (uptake mechanisms) of carbon dioxide and methane, two of the most important greenhouse gases known to be increasing in our atmosphere, is the primary research goal in carbon cycle research.

Greenhouse Gasses

The beginning of the industrial age, a time when the burning of fossil fuels (wood, coal, oil and gas) and conversion of forested land for agricultural use began to increase, initiated an increase in the concentration of carbon dioxide in the atmosphere. One of the most famous environmental data sets showing this trend over the past 42 years is the atmospheric carbon dioxide record that has been measured at Mauna Loa, the CMDL Baseline Observatory in Hawaii (see figure below).



The dramatic increase in atmospheric carbon dioxide concentrations measured at NOAA's Mauna Loa Observatory since 1958. Data prior to 1974 is from the Scripps Institute of Oceanography. Carbon dioxide is taken up through photosynthesis in the summer producing the observed annual oscillations in concentration.

Records such as this provide incontrovertible evidence that greenhouse gases are increasing in the atmosphere. However, the processes which affect the concentration of greenhouse gases in the atmosphere are complicated and a better understanding is required to properly represent them in climate models.

We depend on natural greenhouse gases to make Earth habitable. Without them the planet would have an average temperature of about 5 degrees Fahrenheit, well below freezing. But future increases in greenhouse gases of the magnitude expected during the 21st century must be considered seriously as these increases could affect the future economy and well-being of the nation. For this reason, enhanced study of the global carbon cycle deserves our highest attention and vigilance.

The Carbon Cycle and the Primary Carbon Reservoirs

The carbon cycle is the process by which the Earth exchanges huge amounts of carbon between three major reservoirs, the land, the oceans and the atmosphere. On land, carbon dioxide is taken up by trees and other plants during photosynthesis, and is sequestered in soils when plants die and undergo incomplete decay. Carbon dioxide is given off during respiration of biological systems. Oceans exchange carbon dioxide with air at the surface, although some of the dissolved carbon dioxide in the ocean water is not returned to the atmosphere. The amount of carbon dioxide that remains in the atmosphere is the difference between these huge carbon dioxide inputs and outputs of the land and oceans. We can now measure the atmospheric content of carbon dioxide on a global average quite accurately. We also know the magnitude of fossil fuel emissions. Deforestation in the tropics is less well known but can be estimated. Putting these numbers together tells us how large the global uptake or "sink" for carbon dioxide must be.

While the net amount of carbon dioxide from natural emissions and uptakes is only a few percent of the total amount of carbon dioxide exchanged each year, it nevertheless represents a large amount of carbon, measured in units of billions of metric tons per year. One metric ton equals 1000 kilograms or 2200 pounds. Each year, the world emits almost 7 billion metric tons of carbon in the form of carbon dioxide from fossil fuel emissions. An additional one to two billion metric tons is added through deforestation in the tropics. Of the roughly 8 billion metric tons total involved, the terrestrial biosphere takes up, on average, about 3 billion metric tons per year, and the oceans about 2 billion metric tons per year, leaving on average about 3 billion metric tons per year in the atmosphere. From year to year, the terrestrial uptake and the amount remaining in the atmosphere vary by more than 1 billion metric tons per year.

The increase in carbon dioxide in the atmosphere appears to generally follow the increase in carbon dioxide from fossil fuel emissions. The proportion of carbon dioxide absorbed in the ocean and land has, since measurements began, been about half of the amount emitted through human activity, on average, indicating that as carbon dioxide increases in the atmosphere, the uptake processes become more efficient. However, the fact that about one half of the new carbon dioxide which enters the atmosphere is not absorbed means that as fossil fuel emissions continue to increase, the atmospheric concentration of carbon dioxide will also continue to increase.

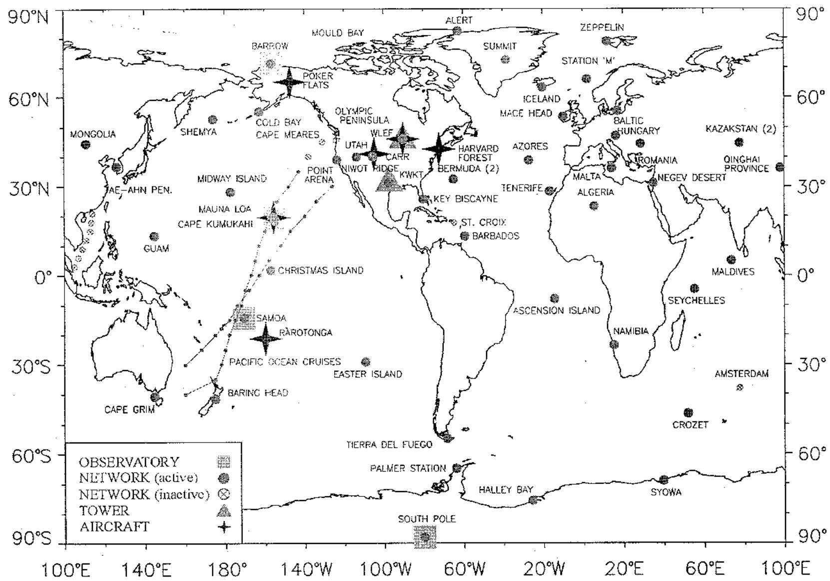
The rate of increase in fossil fuel emissions has been very steady, although the increase each year of atmospheric carbon dioxide is not. In some years the planet is able to take up almost all of the human-related carbon dioxide, in others almost none. This indicates that the carbon sinks must be highly variable. Recent measurements suggest that high surface temperatures may enhance emissions of methane from wetlands and may possibly increase carbon dioxide emissions as well. Ocean upwelling, which brings carbon dioxide-rich waters to the surface, changes during ocean warmings associated with the familiar "El Niño." This changes the amount of carbon dioxide taken up by the oceans. Thus, the ability of the planet to take up excess carbon dioxide is intimately related to climate and cannot be considered in isolation.

Measurements of carbon dioxide sinks are being made in an attempt to characterize the sinks so they can be incorporated into predictive climate models. Most of the measurements have been made on land because it is more accessible for measurement than the ocean and it appears to be more variable than the ocean sink, suggesting a more complicated system which will probably require more study to reach an acceptable understanding.

What is Known About the Terrestrial Carbon Sink?

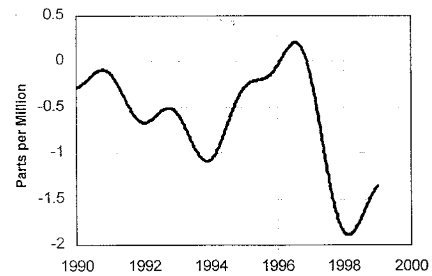
Until recently, estimates of terrestrial carbon sinks have been derived from land use surveys and global mass balance calculations. These techniques have given estimates of the terrestrial carbon sink in the 1-2 billion metric tons of carbon per year range. However, in the past decade, atmospheric measurements of carbon dioxide on a global scale have matured to the point where estimates of the terrestrial carbon dioxide sink can be made independent of these inventories and mass balance calculations. These measurements suggest that the terrestrial biosphere is considerably more important in carbon dioxide uptake than previously believed.

Atmospheric measurements of carbon dioxide cover wide-ranging distance scales. For example, the amount of carbon dioxide coming out of or going in to a local region can be measured to characterize different ecosystems (forest, tundra, cropland, etc.). On a larger scale, carbon dioxide can be measured on coastlines in clean maritime air that has not been altered by terrestrial sources. NOAA operates four Baseline Observatories (Barrow, Alaska; Mauna Loa, Hawaii; American Samoa; and the South Pole) where all the greenhouse gases have been monitored on a continuous basis for up to 42 years. In addition, NOAA operates a cooperative air sampling network consisting of about 45 global sites plus measurements from ships at sea (see map). The air samples are sent to CMDL for analysis. This network has recently been augmented with tall (1300-2000 feet) communications towers and automatic air samplers on small aircraft.



Global carbon dioxide sampling sites of the National Oceanic and Atmospheric Administration. These include continuous measurements from Baseline Observatories at Barrow, Alaska; Mauna Loa, Hawaii; American Samoa; the South Pole, and from tall communication towers in Wisconsin and Texas, and whole air samples from a global cooperative network, including aircraft measurements.

Comparing the amount of carbon dioxide coming on shore in the western U.S. with that leaving the eastern U.S. under the prevailing westerly winds (see graph below) clearly shows that since 1990, the averaged concentration of carbon dioxide from sites in the northern Atlantic are less than those from the northern Pacific. If we assume there is no escape of air enriched with CO2 from the continental U.S. into Canada, the Caribbean or Mexico, nor entry of low-CO2 air from these regions into the U.S., then this suggests that the North American continent has, for at least the past ten years, been on average absorbing carbon dioxide as air passes across it.



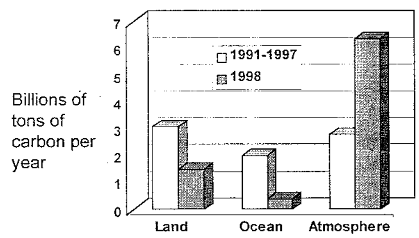
The difference of the average atmospheric carbon dioxide concentrations in the north Atlantic and the north Pacific oceans (north Atlantic minus north Pacific) since 1990. This difference is almost always negative indicating that carbon dioxide levels are almost always smaller downwind of the U.S. than upwind. The data are from NOAA's global carbon dioxide sampling network.

While this analysis is over-simplified and the data are still too sparse to quantify the process adequately, these and other data have been used in conjunction with atmospheric transport models to show that for the 1988-1992 period the global terrestrial biosphere took up about 2.2 billion metric tons of carbon per year with the great majority (1.6 billion metric tons of carbon per year, with an uncertainty of 0.5 billion metric tons of carbon per year) taken up by the North American continent (Fan et al., *Science*, October 16, 1998). This is a very important result as it indicates that the North American continent is a much larger carbon dioxide sink than previously believed. Yet, prior and subsequent direct measurements of carbon content of the land and recent modeling of land surface carbon exchange do not indicate a large North American carbon sink. This illustrates the need for continued investment in research designed to resolve the scientific uncertainties surrounding terrestrial carbon sinks.

There is additional, independent evidence that the entire terrestrial sink, most of which is in the Northern Hemisphere, is large. Carbon dioxide molecules are not all the same. About one in a hundred molecules will have a heavy carbon isotope (^{13}C). It is known that the terrestrial process of photosynthesis preferably takes up regular carbon dioxide thus enriching the amount of heavy carbon dioxide in air that has been in terrestrial biological systems. In contrast, the ocean carbon dioxide exchange process does not discriminate against heavy carbon dioxide.

Since 1990, measurements of the concentration of both regular and "heavy" carbon dioxide and a global transport model have been used by CMDL to "fingerprint" the history of the measured carbon dioxide. (see graph below). These measurements now suggest that from 1991-

1997, the terrestrial biosphere was the dominant global sink of carbon dioxide with an average value of 3.1 billion metric tons per year with an uncertainty of about 1.2 billion metric tons per year. The oceans were estimated to have taken up about 2.0 billion metric tons of carbon per year with an uncertainty of 0.4 billion metric tons. The average increase in atmospheric carbon dioxide over this period was 2.8 billion metric tons per year. However, the numbers vary from year to year. For example, in 1998 atmospheric carbon dioxide increased by 6.4 billion metric tons, the largest increase in any year since global measurements began about 1980. The analysis showed that the terrestrial biosphere took up about half of the normal amount, about 1.5 billion metric tons, while the oceans took up only about 1/5 of the normal amount, about 0.4 billion metric tons, possibly a result of the major El Niño in 1998. Thus, there appears to be substantial year-to-year variability in the major carbon dioxide sinks.



Carbon dioxide uptake by the world's land and oceans and the portion remaining in the atmosphere for the 1991-1997 period, and during 1998 when the atmospheric carbon dioxide growth rate was the highest on record. The analysis is derived from data of the National Oceanic and Atmospheric Administration's global carbon dioxide sampling network. See the text for uncertainty estimates.

Another promising independent technique for identifying carbon dioxide sources and sinks is related to measurement of the amount of oxygen in the atmosphere. Recently it has become possible to measure the oxygen to nitrogen ratio with enough accuracy to detect the global decrease in oxygen related to fossil fuel combustion. By comparing the rate of oxygen loss with the rate of carbon dioxide gain in the atmosphere, one can determine the influence of the terrestrial biosphere since oxygen is produced during photosynthesis. Initial results indicate the magnitude of the terrestrial biosphere and ocean sinks to be in general agreement with the "heavy" carbon dioxide work.

All the evidence from atmospheric measurements indicates that there is substantial variability in terrestrial carbon dioxide uptake, which is not well understood. Temperature changes can affect soil respiration, for example. Estimates indicate that about two-thirds of the global terrestrial carbon is in soils and accurate inventories and variability of this component are not available. Future effects of climate change on carbon sequestration must be considered. If we are to have any hope of prudent management with the goal of influencing terrestrial carbon dioxide uptake, we must understand the cause of the variability in carbon dioxide uptake.

The U.S. Carbon Cycle Science Plan

Because of the importance of understanding the global carbon cycle, in 1999, the U.S. Global Change Research Program (USGCRP), at the request of its sponsoring agencies (USDA, DOE, USGS, NASA, NOAA and NSF), and with the help of a consortium of U.S. scientists who are leaders in carbon cycle science, produced a report entitled "A U.S. Carbon Cycle Science Plan." It presents a strategy for a research program to deliver credible predictions of future atmospheric carbon dioxide levels, given realistic emission and climate scenarios. The research program will address two very easily stated scientific questions:

- What has happened to carbon dioxide already emitted by human activities?

- What will be the future atmospheric carbon dioxide concentration from past and future emissions?

If we had the answers to these two questions, climate models would be able to make more accurate predictions.

The basic strategy of the plan is twofold:

- To develop a small number of new feasible, cost-effective, and compelling research initiatives to improve understanding of the three carbon reservoirs: land, ocean and atmosphere, and their mutual interactions.

- To strengthen the relevant research agendas of the agencies involved in the research through better cooperation, focus, conceptual and strategic framework, and articulation of goals.

The scientific goals of the plan include the following:

- Determine the magnitude and variability of Northern Hemisphere terrestrial carbon dioxide uptake.

- Determine the spatial distribution, variability and sensitivity to climate change of oceanic carbon dioxide uptake.

- Determine the impact of historical and current land use change in the Northern Hemisphere and in the tropics.
- Evaluate potential management strategies for enhancing carbon sequestration.
- Incorporate appropriate carbon cycle – climate feedbacks into global climate models.

Some of the specific measurement enhancements deemed necessary include:

- An expanded carbon dioxide exchange (flux) measurement network to characterize uptake for various biomes;
- An expanded airborne carbon dioxide monitoring network utilizing general aviation aircraft at 50 distributed North American sites to characterize uptake on a regional (multi-state) scale;
- An expanded global carbon dioxide surface monitoring network which would increase the present number of stations by a factor of three;
- An expanded terrestrial carbon land use inventory, including vegetation cover, above-and-below ground carbon and rates of change, including satellite observations and analysis of current soil carbon inventories and new measurements of eroded carbon and other effects of land use on soil carbon;
- Regional observational experiments including coordinated airborne, ship, terrestrial and satellite measurements with model development and testing;
- Long-term vegetation, soil, and carbon dioxide and methane flux measurements for major biomes to evaluate natural disturbance and management effects on carbon fluxes; and
- Global ocean measurements of ocean-atmospheric carbon dioxide exchange and atmosphere-ocean-biology interactions.

In addition, ocean process studies and the development and application of models for analysis of data, synthesis, prediction and policy would be enhanced. This would include Earth System models that predict carbon dioxide and climate interactively.

Conclusion

Progress on the understanding of the global carbon cycle and how it has responded to human presence on the planet has been remarkable in the past 10 years. We now believe that the North American continent presents a major sink for carbon dioxide emissions. We also know that this sink is highly variable but we do not know why. The U.S. now has a plan that includes the study of this important sink, and in particular, its regional nature. We also have a community of scientists who are ready to execute that plan.

Thank you, Mr. Chairman, for your interest in this matter. I would be happy to address any questions you and your Committee may have.

STATEMENT OF KEITH COLLINS, CHIEF ECONOMIST
U.S. DEPARTMENT OF AGRICULTURE
BEFORE THE U.S. SENATE SUBCOMMITTEE ON
PRODUCTION AND PRICE COMPETITIVENESS OF
THE COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY
May 4, 2000

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to discuss the Department of Agriculture's (USDA's) program of research on the carbon cycle, best management practices and production agriculture. I will outline why we think research on the carbon cycle and best management practices is and should continue to be a top priority at USDA. I also will briefly review our program of work and identify the areas where we think greater research efforts are needed.

The holding of this hearing makes an important statement about how Federal and State agricultural research resources can best help American farmers and ultimately American food consumers. The farm economy is now in its third consecutive year of low prices and weak markets, and we need to maintain a sound program of research and financial assistance that will help producers deal with economic downturns. However, as this hearing will emphasize, we must also conduct research that will help production agriculture avoid future problems and create new economic opportunities. Research on the carbon cycle and best management practices addresses both of those goals.

Regardless of what one believes is the probability that human-created greenhouse gas emissions will change the climate, there is no doubt that such emissions present both potential risks and opportunities for production agriculture that, over time, could have significant consequences for farm production, prices and incomes. If we fail to undertake adequate research, we will not fully understand how crops, livestock, trees, pests, and other facets of ecosystems will respond to higher levels of greenhouse gasses in the atmosphere. We will fail to understand cost-effective ways to make agriculture and forests more adaptable to any changes in climate and weather, should they occur. We will fail to understand the details of the carbon cycle and the possibilities for farmers and foresters to sequester carbon. And, we will fail to have the measurement, verification and monitoring mechanisms in place that would facilitate greenhouse gas emitters purchasing carbon-sequestering activities from farmers and foresters. In order to help avoid potential future problems and to realize emerging opportunities for agriculture, USDA conducts a core program of research on global change, and the President's FY 2001 budget requests that Congress significantly expand the program.

AGRICULTURE IN THE CARBON CYCLE

Carbon in the environment is at the center of numerous issues that affect agriculture, ranging from its role in agricultural productivity of crops and soils to possible impacts on the global climate due to rising concentrations in the atmosphere. Accounting for all the world's carbon–the carbon stock–and the quantities that flow through the various pools–the carbon flux–is a complex task, but here is a rough picture. The global stock of carbon, estimated at just a little under 50,000 billion metric tons, is stored in four pools: oceans; fossil fuel reserves, such as coal and oil; terrestrial systems, such as trees and soils; and the atmosphere. By far the largest pool of carbon is contained in oceans, which hold more than 80 percent of the global stock of carbon. Fossil fuel reserves and the terrestrial ecosystem store about 10 and 4 percent of the total, respectively. Less than 2 percent of the total stock of carbon is stored in the atmosphere. However, this 2 percent of the total carbon stock that is stored in the atmosphere is the reason we are here today. Since pre-industrial times, the atmospheric concentration of carbon dioxide has increased by 30 percent, with most of this increase caused by human activities.

For example, during the 1990's, human induced carbon emissions averaged 8.3 billion metric tons per year, with fossil fuel combustion accounting for 6.3 billion metric tons and land use changes, such as deforestation, accounting for the remaining 2.0 billion metric tons. Over the same time period, oceans and terrestrial systems sequestered about 2.3 and 2.7 billion metric tons of the carbon emissions per year, respectively. As a result, human induced carbon emissions increased atmospheric carbon by about 3.3 billion tons of carbon per year.

This comparison of sources of emissions and sequestration into sinks highlights three essential ways to reduce the amount of carbon stored in the atmosphere. First, emissions from fossil fuel combustion can be reduced by improving energy efficiency and/or reducing fossil fuel use. Second, the amount of carbon stored in oceans can be increased, an active area of research in other parts of the government. Or, third, the emissions from land use changes can be reduced and/or the amount of carbon that can be stored in terrestrial systems can be increased through improved agricultural and forestry practices.

Agriculture is both a carbon source and sink. Clearing of native vegetation in forests, prairies, and wetlands released carbon dioxide because the plants removed were decomposed by microorganisms. Turning the soil by plowing changed the soil structure and aeration, and soil microbes were stimulated to decompose organic matter in the soil, releasing carbon dioxide. Under such practices, the estimated carbon content of soil in the central U.S. corn belt dropped by 47 percent during the first half of the 20th century.

Beginning in the 1960s, with the adaptation of reduced tillage, reversion of marginally productive agricultural lands to native vegetation, and other land management practices, the picture began to change. By 1990, carbon in the corn belt soils had increased to 61 percent of turn-of-the-century levels. Coupled with these new management strategies was an improved understanding of the importance of soil carbon. Soil organic carbon helps the soil resist erosion by "gluing" soil mineral particles into stable aggregates, which contribute to a beneficial soil condition known as tilth. This tilth also contributes to water infiltration, air and water holding capacity, and good seed germination and plant root growth. Soil organic carbon helps keep nutrients and pesticides from washing into water bodies; it helps soil resist the effect of drought; and it reduces flooding. Simply put, practices that enhance soil carbon content have broad benefits to soil, water and air quality, on and off the farm.

USDA RESEARCH ON THE CARBON CYCLE

Across the Federal government, about $1.7 billion is being spent this year in scientific research and on surface and space-based observations under the U.S. Global Change Research Program (USGCRP) to better understand global environmental change. A key component of this program is the study of the global carbon cycle undertaken cooperatively by the following agencies: USDA, Department of Energy, U.S. Geological Survey, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration and the National Science Foundation. The goal is to answer the questions: what has happened to the carbon emitted by human activities, and what will be the future atmospheric concentration of carbon dioxide resulting from past and future emissions? The Carbon and Climate Working Group of the USGCRP recently produced a long-term research plan entitled: A U.S. Carbon Cycle Science Plan, which details how all the cooperating agencies contribute to a coherent, effective research program.

USDA's program of work on the carbon cycle is an important part of this overall Federal effort. USDA's Global Change Program is funded at $52.5 million for FY 2000. Reflecting the enormous number of important issues needing greater research, USDA has requested funding of

$108.6 million for FY 2001, an increase of $56.1 million. I would like to discuss a few of our current activities and then what we see as the research needs that are behind our budget request.

USDA's Current Activities

USDA scientists have demonstrated that rising concentrations of greenhouse gases in the atmosphere affect crop production in complex ways. Research has demonstrated increased carbon dioxide can stimulate plant growth and crop yield, and the Agricultural Research Service (ARS) National Water Conservation Laboratory at Phoenix, Arizona, has been a leader in this research. However, extensive work there and at other USDA locations has shown that many other effects of carbon dioxide on cropping systems, along with temperature and water availability, must be considered before the risks, benefits, and appropriate management strategies can be identified for crops and soils.

Work done at Beltsville, Maryland has determined that carbon dioxide affects the branching pattern of some soybean varieties, which affects flowering, which in turn affects yield. This helps explain why some varieties are stimulated more than others by carbon dioxide. This same research unit is also showing how weeds are affected. Some weed species may be stimulated more than crops, and some may be more resistant to commonly used herbicides. More work on invasive species and possible links to increased carbon dioxide and climate change is being conducted by USDA scientists at Tucson, Arizona, and Temple, Texas.

Research at Auburn, Alabama, is focused on how crop management and tillage practices affect root development. Plant roots stay in the soil after the crop is harvested, so this is a major way atmospheric carbon is moved into the soil. New work at Auburn will determine the extent of sequestration of greenhouse gases in cropland soils associated with conventional and conservation tillage systems, with and without cover crops. This work, along with research on the microbes involved with carbon transformations in soil, will help identify important connections between management practices and carbon storage.

Plants are not exposed to just one atmospheric gas at a time, which complicates projections of how much plant growth and carbon sequestration may be stimulated by increased carbon dioxide. Scientists at Raleigh, North Carolina, are working on how ground-level ozone, weakens the boost crops may get from increased carbon dioxide. Increases in temperature may also lessen the expected crop stimulation by carbon dioxide, according to recent work at Gainesville, Florida. Thus, our research indicates that the fertilization effect, viewed as a benefit by some, may be counteracted by increased temperatures, pollutants or other factors not anticipated, such as increased pests or changes in nutrient content. This is an important area of needed research, one to be conducted in collaboration with universities.

Work at Fort Collins, Colorado is focusing on estimating carbon sequestration in soil and the effects of various management practices. This group is a major source of information for Federal agencies on the size of carbon pools and potential sequestration in agricultural soils. One important project building on this work is a field planning tool known as CQUESTER being developed collaboratively by ARS, NRCS and universities. This tool could be used by producers, technicians and consultants to estimate soil carbon based on soil type, climate, land use and land management practices. Tools like this are essential to development of a carbon market.

Rangelands and pastures represent nearly a third of the land area of the contiguous 48 States, so understanding their carbon dioxide effects is essential to projecting total carbon storage in soils. Scientists at Ft. Collins and in Cheyenne, Wyoming are studying the response of native shortgrass species in the Colorado steppe to rising carbon dioxide. Increased carbon dioxide increases plant growth and increases soil water, but changes in the nutritional value of the plants may affect how grazing lands must be managed. New work is getting underway at Mandan, North Dakota, for estimating carbon storage in grazing lands under different forage management and livestock systems. The special questions surrounding carbon sequestration in cold, wet soils are being addressed in new work at Morris, Minnesota.

Methane is another important gas in the global carbon picture, and researchers in Watkinsville, Georgia, have been studying ways to improve the day-to-day estimates of methane and ammonia emissions from Southeast swine facilities. Anaerobic lagoons are considered to be sources of methane and nitrogen gases and aerosols. These studies improve our estimates of greenhouse gas emissions and assist producers, regulatory agencies, and designers in minimizing the impact of high-density animal production.

USDA economists in the Economic Research Service (ERS) this past year continued to assess the economic implications of how the agricultural economy is affected by climate change and examine the costs and benefits associated with efforts to reduce greenhouse gas emissions and sequester carbon. Key research objectives include assessing the farm sector impacts of using a national system of carbon permits to reduce greenhouse gas emissions and evaluating alternative policies for promoting carbon sequestration activities on agricultural lands such as converting pasture and cropland to forests and expanding the use of conservation tillage systems.

Forest Service (FS) researchers have been assessing global change effects on forest health and productivity. Factors such as drought, ozone, fire, site fertility, insects and diseases affect the health and productivity of California conifer forests. FS research documented significant changes in the growth and development of ponderosa and Jeffrey pine in response to ozone exposure and nitrogen deposition. Root biomass decreases with exposure to air pollution raising important questions about predisposing trees to drought induced mortality and related insect attacks. Air pollution can alter pine phenology such that, at the most extreme, an evergreen tree becomes functionally deciduous. The interaction of ozone and nitrogen pollution has serious implications for the storage of carbon in both soils and above ground in ecosystems subject to air pollution.

FS researchers have also been assessing predicting forest fires through improved ecosystem models. Dynamic simulations indicate that fire frequency could increase over much of the West and under the hotter scenarios, over many of the Eastern U.S. forests.

FS researchers have also looked at the potential for reducing greenhouse gas emissions from wood and wood processing. An analytical system was developed to evaluate the types and amounts of emissions generated during the processing and use of wood composites, allowing lumber and composites processing conditions to be optimized to reduce and control emissions currently being discharged.

Similarly, FS research has been assessing the role of recycling to reduce greenhouse gases. With 350 million tons of wood consumed in the United States annually, recycling of paper and wood has been shown through life cycle assessment to contribute greatly to reducing the amount of greenhouse gasses in the atmosphere. One major barriers to recycling paper is removing pressure sensitive adhesives from labels and envelopes, a problem affecting a significant portion of recycled paper. FS research is developing easily removable adhesives in recycling screening operations to solve this problem.

Lastly, FS researchers have also been exploring how to create biofuels from wood. Biofuels producing liquid fuels such as ethanol from wood could replace the fossil fuels that contribute to greenhouse gasses. Research is developing the fundamental knowledge required to economically and efficiently convert wood to ethanol. New recombinant strains of yeast were developed that can more rapidly ferment the two major sugar types in wood hydrolzates to ethanol at greater yield. This is extremely important because fermentation of these 2 types of sugars is essential to attaining maximum conversion rates and yields.

USDA's Research Objectives for FY 2001

USDA's planned program of work is divided into two areas: (1) the Global Change Research Program, which includes research on the carbon cycle, ecosystems, atmospheric chemistry, and the global water cycle; and (2) the proposed Climate Change Technology Initiative (CCTI).

Carbon Cycle Research. USDA currently spends $15.4 million on carbon cycle research and has proposed a $22 million increase in FY 2001. The goal is to improve the scientific understanding of how carbon is sequestered in agricultural soils, how soil carbon is measured and tracked over time, and how farm production decisions and government policy might help facilitate carbon sequestration in agricultural soils.

Carbon cycle science. The types of research that additional funding would support include the ARS collaborating with other Federal agencies to expand data and research on the role of agriculture in the carbon balance and define ways which farmers and ranchers can store carbon in agricultural soils. Special emphasis would be given to measuring the effects of management and conservation practices on carbon storage in cropland and grazing lands, particularly the long-term impacts of tillage and residue management systems on accumulation of organic carbon. Some of the major interests are: improving mathematical models for estimating current carbon stocks in agricultural soils, and the potential to store more, at scales ranging from the continental down to the single field; determining the impact of various soil, plant, and animal management strategies on carbon storage in soils; developing improved, economical techniques for measuring soil carbon; quantifying storage of atmospheric carbon in clay soils, and in carbonates and other inorganic forms; determining the carbon flows into and out of a range of soil types in a network of 20 observation sites to be established across the country; identifying which soil microbes are most important in cycling carbon in soil, and how to manage them for best practices; developing and applying new technologies for monitoring methane emissions from agricultural activities; and determining relationships among the cycling of carbon and nitrogen in agricultural systems.

Measurement and evaluation in agricultural soils and forest lands. Measuring soil carbon data across soil types, climate regimes, and management systems is essential to establish a scientific basis for a terrestrial carbon inventory, to conduct environmental and economic policy analysis, and for a market in carbon to develop. The Natural Resources Conservation Service (NRCS) cooperative soil survey data bases are building blocks needed to better understand and measure terrestrial carbon sinks. An enormous amount of work in inventorying the nation's soils has already been done over a long period of time. Proposed enhancements to these data bases, along with associated models and inventory and assessment products, are needed to analyze policies directed at carbon sequestration and provide scientifically grounded tools for potential carbon crediting or trading. NRCS would accelerate digitizing the county level soil surveys and update state level soil maps, which are the primary geospatial data layers linked to the national soils database. NRCS would complete the system by achieving on-line access and adding soil carbon data for major agricultural regions on major crops in common production systems. Carbon on rangelands and woodland would also be quantified. NRCS also would conduct evaluations, such as field validation and calibration, of modeling, remote sensing, and statistical inventory approaches to field level, regional and national scale carbon stock assessments that are sensitive to the land management practices and agronomic systems that affect soil carbon levels.

The FS would identify and quantify carbon sources, sinks and fluxes for all U.S. forest land, including marginal agricultural land and other potential conversion land use types. FS would expand the carbon accounting model and develop forestry carbon budget accounts based on expected land-use and product changes. FS would build on existing research and collaboration with industry, landowners, universities and other agencies to develop verifiable measure of carbon stock and fluxes.

Economics of carbon sequestration. ERS would assess the economic feasibility of U.S. climate change mitigation strategies focusing on the economic potential for U.S. carbon sequestration and emissions reductions in agriculture; the use of economic incentives to encourage sequestration on agricultural lands; and the potential to target existing USDA conservation programs towards greenhouse gas mitigation activities in the farm sector.

Climate Change Technology Initiative. USDA is requesting funding of $24 million to support efforts in three important areas: biomass, carbon sequestration, and agricultural practices aimed at reducing agriculture's vulnerability to climate change.

Biomass. An increase of $14 million would support USDA research on converting biomass to energy. FS would conduct research on small diameter and short-rotation trees, ways to improve feedstocks and feedstock production systems for biobased products and bioenergy, and conduct research to improve wood utilization and promote forest health. ARS would focus on biomass conversion technologies, develop more productive varieties and improved practices for perennial grasses and legumes in sustainable bioenergy/bioproduct crop production systems, and evaluate the associated environmental benefits.

Carbon Sequestration. The budget also proposes $6.0 million more for carbon sequestration activities by FS and the NRCS. NRCS would develop and conduct demonstration and pilot projects that focus on both carbon sequestering management production systems and on greenhouse gas abatement systems. Incentives, planning tools, and technical assistance for conservation systems that enhance soil carbon sequestration and reduce greenhouse gas emission, while also achieving water quality, wildlife, and other environmental benefits would be field tested and evaluated. FS would develop and demonstrate management options for improving direct sequestration of carbon in forest soils. FS would also identify and test methods of using forest soils for the direct storage of carbon, including burial, incorporation of organics, and other innovation concepts, in addition to the capture of carbon dioxide in biotic processes.

Agricultural Practices. Lastly, the budget proposes $4 million more to undertake research aimed at reducing agriculture's vulnerability to climate change. For example, ARS would develop simulation models and data bases suitable for predicting the effects of global change on agricultural ecosystems and develop new technologies to improve crop tolerance to extreme environmental conditions.

BEST MANAGEMENT PRACTICES

Carbon sequestration, and to some extent emissions reductions, are ancillary benefits of traditional conservation practices that are supported by USDA conservation programs, such as the Conservation Technical Assistance program that address the nation's working lands.

Erosion control practices that increase vegetative soil cover, such as residue management, cover crops, crop rotations, etc., increase soil carbon. Conservation tillage, especially continuous no-till, reduces soil carbon oxidation and emission of CO_2 from the soil. Well-managed application of manure and other organic amendments also contributes to soil organic carbon while providing direct water quality benefits. The establishment, on cultivated cropland, of perennially vegetated buffers such as grassed waterways, grassed terraces, riparian buffers, field borders, contour buffers, cross wind trap strips, and filter strips also contribute to enhanced soil organic carbon while performing their designed erosion control, water quality, or wildlife habitat function. Restoring wetlands, grasslands, and forestlands to their natural state contributes to carbon sequestration, as each of these land cover types generally sequester more soil organic carbon than cultivated cropland. Protecting wetlands and grasslands from conversion to cropland also ensures that they continue to sequester carbon at higher rates than when cultivated. Improving grazing land management contributes to a larger soil carbon pool. Improving livestock production efficiency decreases methane emission. Protecting farmland from conversion to urban development potentially contributes to soil carbon sequestration as any built-on soil is permanently removed from the potential soil carbon pool.

The greenhouse gas mitigation benefits of best management practices can be significant. One of today's witnesses, USDA scientist John Kimble and others, have estimated that the overall potential to sequester carbon is 69 to 175 million metric tons per year, 4 to 11 percent of total annual U.S. emissions of greenhouse gasses. Grazing lands also have the potential to sequester significant amounts. The activities that can move toward these potentials are in many cases the best management practices just described, which USDA conservationists have advocated for many years because they improve soil, water and air quality. While the theoretical potential is great, the barriers to large increases in carbon sequestration and the development of a carbon market that would provide meaningful financial returns to producers include the uncertainties related to carbon measurement and verification and the current low market value of carbon.

TERRESTRIAL CARBON MEASUREMENT (TCM) PROJECT

I have mentioned the work USDA is doing to measure soil carbon at specific sites using soil testing and the larger scale estimation using models, such as CQUESTER. To develop more accurate and more recent national estimates of current carbon sequestration, USDA and university cooperators this year are estimating carbon sources and sinks in forests and agricultural soils under our TCM project.

The Forest Carbon Management (FCM) aspect of the project will expand on the existing FS carbon measurement infrastructure, which includes multiple data sets, such as the 1997 Forest Inventory and Analysis Program, and physical and economic models. The FS carbon stock estimate is a comprehensive estimate taking into consideration all carbon pools on all forested lands. Identifying individual management practices or projects and measuring their associated carbon is much more difficult in that most land managers implement a suite of practices simultaneously. One analytical task is to identify the area of land in the United States affected by various activities (e.g., fire, pests, harvesting, etc.) and partition the comprehensive U.S. carbon budget into these categories. A second task includes an evaluation of ongoing and proposed policies and programs as they relate to carbon sequestration.

The Agricultural Carbon Management (ACM) aspect of the project will provide scientifically credible estimates of agriculture soil carbon associated with human induced activities in agricultural land use change categories (i.e., cropland, conservation set-aside, pasture/range, wetlands, degraded) and land management intensities (i.e., tillage type, crop residue management, use of cover crops, crop rotations, fertilizer management). Carbon measurement will depend on detailed data from the 1997 National Resources Inventory. In addition, the ACM project will provide scientifically credible estimates of how a carbon market (through domestic and international policies) would affect land use and land management decisions and their associated impacts on agricultural soil carbon.

Mr Chairman, the Department very much appreciates your leadership on carbon sequestration and the increase in research intensity that you advocate. We generally support the objectives of your bill, S. 1066, which coincide with many of our current activities and plans. While we have some specific concerns, we would be pleased to work with you on strengthening your proposed legislation. That completes my comments and I would be happy to respond to questions.

Statement Presented to the Senate Subcommittee on Production and Price Competitiveness of the Committee on Agriculture, Nutrition, and Forestry

May 4, 2000

Presented by

Richard E. Stuckey, Ph.D.
CAST Executive Vice President

On behalf of

The Council for Agricultural Science and Technology
Ames, Iowa

Thank you Mr. Chairman and Members of the Senate Subcommittee on Production and Price Competitiveness of the Committee on Agriculture, Nutrition, and Forestry. I am Richard E. Stuckey, Executive Vice President of the Council for Agricultural Science and Technology (CAST). CAST's mission is to identify and interpret scientific research information for legislators, regulators, the media and others involved in policy making. CAST is an organization that represents 38 professional scientific societies whose individual members exceed 180,000 scientists.

I am pleased to be invited to testify on behalf of CAST on agriculture's role in carbon cycling and mitigating greenhouse gases. Because it is not possible for any one person to reflect the multifaceted views of all CAST members on this particular topic, I do, however, believe I speak for a large majority of our membership. The CAST Executive Committee endorses my testimony.

CAST has addressed various aspects of agricultural and climatic change on previous occasions. Many of you will recall the 1992 CAST report entitled *Preparing U.S. Agriculture for Climate Change* that was prepared for the United Nations Framework Convention on Climate Change held in Rio de Janeiro in 1992. In December 1998, CAST cohosted, with Pacific Northwest National Laboratory and Oak Ridge National Laboratory, a workshop on *Carbon Sequestration in Soils: Science, Monitoring, and Beyond* at St. Michaels, MD. CAST subsequently produced an issue paper summarizing the workshop discussion of the St. Michaels' meeting, and it is attached to my submitted written testimony. CAST has identified a new task force that will be meeting next week to begin work on a new report, tentatively titled "Agriculture's Response to the Climate Change Challenge."

The St. Michaels' workshop was attended by nearly 100 invited persons, mostly from the United States and Canada, representing the White House, regulators, congressional staff, plant and equipment industries, federal agencies and laboratories, consumer groups, growers and grower associations, university scientists, national and international organizations. The 3-day workshop addressed four areas: (1) science needs and new technology for soil carbon sequestration; (2) monitoring and verifying soil organic carbon sequestration; (3) desertification control to sequester carbon (C) and mitigate the greenhouse effect; and (4) soil carbon: policy and economics.

Findings of the St. Michaels' workshop that were reported in the CAST issue paper include the acknowledgment that organic matter contributes greatly to plant productivity and ecosystem stability. Soil organic matter plays a central role in the global carbon cycle. Soils can act as a sink or as a source of carbon. Land management is a critical component of whether the net change in the soil C is a gain or a loss. Agricultural practices that conserve soil and increase productivity while improving soil quality also increase the C content in soils, thereby removing CO_2 from the atmosphere. There is excellent potential for C sequestration in all managed soils, and in some cases, the sequestration may be able to restore more than two-thirds of the C lost from conversion to agriculture and perhaps exceed original C contents in some soils and regions. This restoration of C needs to involve a search for ways to cause greater, more rapid, and longer-lasting sequestration. Promising lines of research are evolving that could lead to an improved understanding of soil C dynamics and the subsequent development of superior C sequestration methods. Among these are understanding the mechanisms of C stabilization, landscape effects on C sequestration, biotechnology to enhance plant productivity and favor C sequestration, and a better understanding of the environmental effects of soil C sequestration on erosion, nutrient leaching, and emissions of other greenhouse gases.

Rapid and accurate monitoring and verification systems are a limitation at present. However, we do have the technology to accurately measure carbon changes in soil. Improved and more cost-effective methods of monitoring changes in soil C likely will come from geographical information systems (GIS) and modeling, application of high-resolution remote sensing, and continuous direct measurements of CO_2 exchange between the atmosphere and terrestrial ecosystems. It will take a combination of instrumentation to effectively monitor and verify results, ranging from direct in-field carbon-probes to verifiable simulation model extrapolation using high resolution remote sensing and GIS to aggregate larger regional areas with time.

On April 6 and 7, I participated in the first of a three-part series of workshops entitled "Global Climate Change Issues for Agriculture." These series of workshops are sponsored by the United States Department of Agriculture, facilitated by the Meridian Institute, and the first was hosted at the American Farm Bureau Offices in Washington, DC. These workshops are comprised primarily of scientists sharing their knowledge of global climate issues with grower and farm organizations. Representatives from federal agencies, congressional staff, The White House, and other interested parties are observers to the roundtable discussions. I commend the USDA for sponsoring these workshops and, in particular, the many and diverse farm organizations that attend to learn, discuss, and share their views on the impacts that various actions will have on the agriculture sector. The farm community has many legitimate concerns: Is global warming real? Does agriculture contribute and, if so, how much? Can agriculture be a solution? How will this affect agriculture's business? What are the implications of temperature and moisture shifts? Mr. Chairman, agriculture does contribute to the problem of greenhouse gas emissions. The public too often perceives agriculture only as a problem, not as a solution to mitigating greenhouse gases. Today, agriculture, through the use of best management practices contributes substantially to C sequestration in soil. The sequestration of carbon in soils enhances soil quality and helps offset some of the emissions produced by agriculture today; a win-win situation as described by several presenters at the April 6-7 workshop.

As a person who interfaces with many scientists and producer groups as well as having an active interest in a farming operation in my native Ohio, I want to commend the establishment of the workshops involving producer groups and scientists. I strongly believe that both groups need to collaborate with policy decision makers to include science-based solutions in all future policies.

In summary, Mr. Chairman and members of this subcommittee, I believe in agriculture there are two approaches to lessening the CO_2 and greenhouse gases, and both of those approaches are through expanded research and adoption of new technologies. The approaches are research directed toward improved sequestration of C in soils and plants, and research directed toward new technology and improved emission efficiencies and the cropping practices that rely less on the fossil fuels. Using good management techniques that include rebuilding soil organic matter, practicing less tillage rather than more, developing and using biofuels, and practicing good environmental stewardship will be an important contribution by the agricultural community. We do need to recognize the valuable service of the American farmers who provide abundant low cost, and high quality food. I believe American farmers share a goal of minimizing impacts on the environment. We should assist the American farmer by providing research opportunities to develop new technologies. Placing the primary burden of reducing CO_2 and greenhouse gas emissions on agriculture without addressing other entities, both on a national and on a global scale, that contribute to greenhouse gas emissions will be self-defeating. The greenhouse gas emissions is a global problem. I am convinced American farmers are willing to do their part. With new technology yet to be discovered, agriculture will become even more benign and productive. We owe it to our society to make it so. Lastly, I thank you very much for allowing me to present this testimony on behalf of the CAST membership.

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SUBCOMMITTEE ON PRODUCTION AND PRICE COMPETITIVENESS HEARING ON CARBON CYCLE RESEARCH AND AGRICULTURE'S ROLE IN REDUCING CLIMATE CHANGE

Testimony of Charles W. Rice, Professor of Soil Microbiology
Department of Agronomy, Kansas State University

Thank you Mr. Chairman and members of the Senate Subcommittee on Production and Price Competitiveness of the Committee on Agriculture, Nutrition, and Forestry. I am Dr. Charles W. Rice, Professor of Soil Microbiology in the Department of Agronomy at Kansas State University. I am a member of the Soil Science Society of America and a Fellow of the American Society of Agronomy. I hold membership in several other professional organizations including Ecological Society of America and American Association for the Advancement of the Sciences. I personally have been involved in soil organic matter and no-tillage research during my Ph.D. training starting in 1980.

I am please to be invited to testify on the role agricultural soils in carbon cycling and mitigating greenhouse gases.

INTRODUCTION

Since the late 1800's fossil fuel use, expansion of cultivated agriculture, and forest clearing have led to an increase in atmospheric CO_2 from 260 ppm to current levels >370 ppm (IPPC, 1995) (Fig. 1). This increase in atmospheric CO_2 potentially impacts climate, as it is a greenhouse gas.

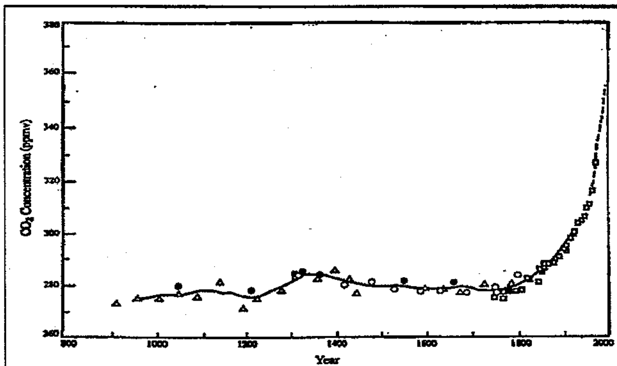


Figure 1. Temporal changes in atmospheric concentration of CO_2 (IPCC, 1995).

Most of the recent increase in CO_2 has been attributed to combustion of fossil fuels for energy and transportation, but changes in land use also contribute to atmospheric CO_2. Land use contributes to CO_2 by 1) combustion of biomass (forest clearing), and 2) release of soil organic carbon (C) following cultivation.

Recent models of land use suggest terrestrial systems can mitigate the increase of atmospheric CO_2 by sequestering C into vegetation and soils. The estimated amount of C stored in world soils is about 1100 to 1600 Pg, more than twice the C in living vegetation (560 Pg) or in the atmosphere (750 Pg) (Sundquist, 1993). Hence, even relatively small changes in soil C storage per unit area could have a significant impact on the global C balance. Approximately 50% of the soil organic carbon (soil organic matter) has been lost from the soil over a period of 50 to 100 years of cultivation. However, this loss of soil carbon also represents the potential for storage of C in agricultural soils. Carbon sequestration by soils occurs primarily through plants (Fig. 2). Plants convert CO_2 into tissue through photosynthesis. Upon their death, plant tissues decompose, primarily by soil microorganisms, and the carbon in the plant material is eventually released back into the atmosphere as CO_2. However some of the C in plant material forms soil organic matter sometimes referred to as "humus." Some of this carbon in the soil can persist in soils for hundreds and even thousands of years.

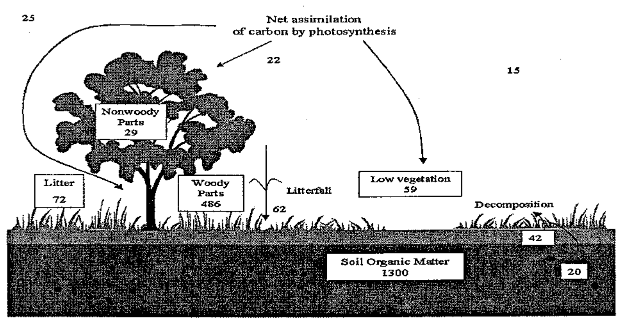


Figure 2. Terrestrial carbon cycle. Values in boxes represent Gt C and those assicated with arrows represent Gt/yr.

Agriculture's Role

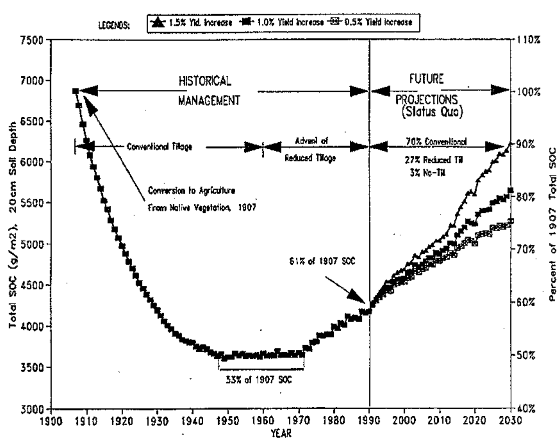
The amount of carbon soils can sequester is dependent on several factors. Inherent factors include climate variables (temperature and rainfall) and clay content. Much of the

Table 1. Land Use for C Sequestration (Lal et al., 1998)		
Management Strategies		
Land Use	Soil Management	Crop Management
• Cultivation • Forestry • Rangeland	• Tillage • Residue Management • Fertility • Water Management • Erosion Control	• Varieties • Crop Rotations • Cover Crops • CRP

(Table 1)

central United States and Canada, which was once prairie, is now in cultivated agriculture. The grasses of prairies store much of their C belowground, which is eventually converted to soil organic carbon. Previous cultivated agricultural practices have decreased soil C, but advancement in crop and soil management practices have the potential to increase soil C. Table 1 lists several practices affecting the soil's ability to sequester C (Lal et al., 1998).

The impact of soil and crop management is illustrated in Fig. 3. As noted earlier, agriculture in the 1800 and early 1900's relied upon the plowing the soil with low crop yields and crop residues were often removed. This combination of agricultural practices resulted in reducing the replenishment of organic



material (carbon) to the soil. As a result soil C content decreased by as much as 50% over a 50 to 70 year period. In recent decades, higher yields, return of crop residues, and development of conservation tillage practices have begun to increase soil carbon. Simulated soil C levels are projected to increase due to improved crop yields. A projected 1.5% annual increase in yields (the current annual rate is 1.8% per year) will result in 1.8 Gt of soil C over a 40 y period in the central U.S. (Flach et al., 1997). Flach et al. (1997) suggested if a 1% annual increase in productivity were achieved globally, then 15% of the C emissions could be sequestered in soil due to increased crop productivity.

Additional gains in soil C in agricultural soils could be achieved by a reduction in tillage and better management of residues Table 2.

Table 2. Estimates of C sequestration potential through improved management of U.S. cropland (Lal et al., 1999)

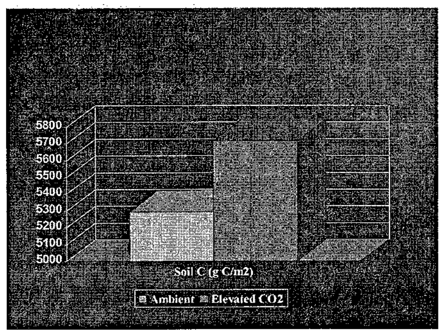
Agricultural practice	(MTC/ha/y)
Conservation Reserve Program	0.3 – 0.7
Conservation tillage	0.24 – 0.40
Fertilizer management	0.5 – 0.15
Rotation with winter cover crops	0.1 – 0.3
Summer fallow elimination	0.1 – 0.3

Comparisons of no-tillage with spring plow have projected 20 to 80% higher soil C with no-tillage after 40 years (Donnigian et al., 1994). Others have reported field studies with approximately 30% increases in soil C due to no-tillage when compared with conventional tillage (Kern and Johnson, 1993). At Kansas State University, we have shown an increase in soil C of approximately 0.2 MT C/ha/y. This is equivalent to an increase of 1 ton C/acre over a 10-year period. The amount of carbon sequestered is on the lower end of the range given by Lal et al. (1998). Cropping sequences can also affect soil C. In Kansas, intensifying cropping systems by conversion from wheat-fallow rotation to wheat-grain sorghum-fallow rotation in western Kansas increased soil C levels (Havlin et al., 1990). Combinations of high intensity cropping with no-tillage gave maximum benefits modeled for several locations in the North American prairies (Paustian et al., 1998) (Table 3).

Table 3. Change in soil C due to cropping intensity and tillage (g C m^{-2}) (Adapted from Paustain et al., 1998)

	Cropping intensity/tillage			
	-----High----		-------Low------	
Site	CT	NT	CT	NT
Wisconsin	1300	1400	-30	260
Kansas	2000	2300	980	1100
Canada	290	450	-90	100
Nebraska	1170	1320	140	230
Colorado	810	970	-80	30

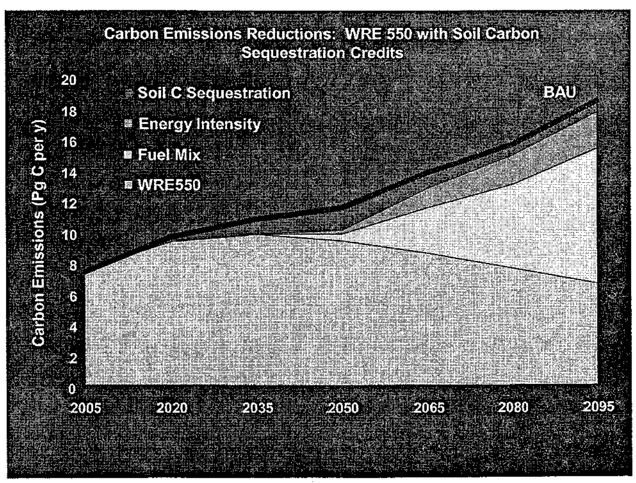
Grassland systems also can contribute to C sequestration when properly managed. Research at Kansas State University has shown that under elevated atmospheric CO_2 the soil contained 6% more C to a depth of 15 cm compared with ambient conditions (Rice et al., 1999). The increased in soil C was due to increased plant production followed by incorporation into the soil. The amount of C sequestered over the 8-year experimental period was equivalent to 2 tons C/acre. Proper fire management also increases soil C. We have reported a 5 % increase with annual burning compared to unburned tallgrass prairie (Rice et al., 1999).



While much of the discussion of carbon sequestration has been directed to forests, global estimates for C sequestration for different ecosystems indicate the agricultural lands are 45 to 90 % of forests (Metting et al., 1999) (Table 3). If grasslands and rangelands are considered, then managed lands contributions to carbon sequestration are greater than forests. Thus all ecosystems must be considered in any plan to increase C sequestration.

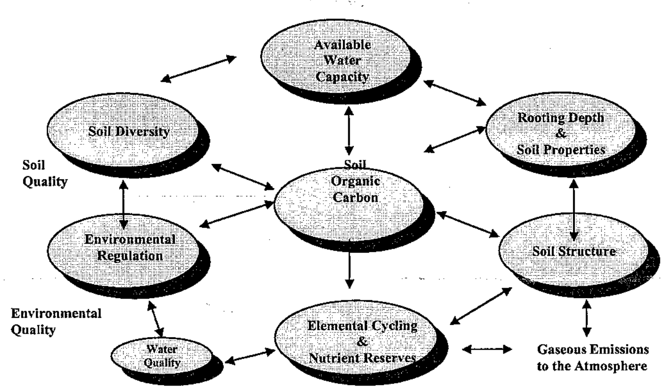
Table 3. Global terrestrial C sequestration potential (adapted from Metting et al., 1999)	
Ecosystems	Potential (Gt C/y)[2]
Agricultural lands	0.85 – 0.90
Biomass crops for biofuel	0.5 – 0.8
Grasslands	0.5
Rangelands	1.2
Forests	1 – 2

Economic analysis suggest that soil carbon sequestration is among the most beneficial and cost effective options available for reducing greenhouse gases, particularly over the next 30 years until alternative energy sources are developed and become economic feasible. Recent estimates of the potential for U.S. agriculture, using existing technologies, are on the order of 75-200 MMT C per year (Lal et al., 1998; Bruce et al., 1998). The figure below illustrates a scenario in which carbon sequestration is allowed. Under this scenario, soils achieve the necessary net carbon emissions until 2050. After 2050 reductions in carbon emissions must come from changes in energy technologies.



Additional benefits

Managing agricultural soils for sequestering C will result in additional benefits.



Increasing soil organic C include increased crop productivity and enhanced soil, water, and air quality. In addition, management practices that increase soil C also tend to reduce soil erosion, reduce anthropogenic energy inputs into the soil, and improve soil resources.

Research Consortium (CASMGS)

The Consortium for Agricultural Soil Mitigation of Greenhouse Gases (CASMGS- pronounced like chasms) will provide the information and technology necessary to develop, analyze, and implement carbon sequestration strategies. CASMGS is a multi-year, collaborative effort to improve the scientific basis of using land management practices to increase soil carbon sequestration and to provide the tools needed for policy assessment, quantification, and verification. The CASMGS team is made of internationally recognized researchers and institutions in the fields of soil carbon dynamics, soil-derived greenhouse gases, soil erosion, water quality and computer modeling, land resource data analysis, agricultural resource economics and integrated assessments. The scientists are from major land-grant universities and a national laboratory. Participant institutions are: Colorado State University, Iowa State University, Kansas State University, Michigan State University, Montana State University, Texas A & M University, the University of Nebraska, and the Pacific Northwest National Laboratory.

The overall goal of CASMGS is ***to provide the tools and information needed to successfully implement soil carbon sequestration programs so that we may lower the accumulation of greenhouse gases in the atmosphere, while providing income and incentives to producers and improving soil quality. Such benefits include an increased and stable agricultural production and an overall reduction of soil erosion and pollutions by agricultural chemicals and fertilizers.***

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Testimony of John M. Kimble
Research Soil Scientist, USDA-NRCS
Before the Senate Subcommittee on Production
and Price Competitiveness on Agriculture, Nutrition and Forestry
May 4, 2000

Mr. Chairman, members of the Subcommittee, I am a research soil scientist with the USDA Natural Resources Conservation Service (NRCS) in Lincoln, NE, and it is a pleasure to appear before you to discuss the issue of carbon cycle research and the role of agriculture in helping to mitigate greenhouse gasses. I am presenting this testimony, but it comes from cooperative work of Dr. Ronald Follett, of the Agriculture Research Service, Dr. Rattan Lal, of the Ohio State University, and me, and I would be remiss in not pointing this out. The success we have had is a result of the close cooperation of NRCS, ARS, and The Ohio State University as well as with many other scientists. I strongly feel such cooperation is needed in any future research work.

I have been working with colleagues for the last 10 years dealing with issues related to soil organic carbon and the role that agriculture can play in the sequestration of carbon in the soil both as soil organic carbon (SOC) and soil inorganic carbon (SIC). We have produced several books related to the issue of soils, greenhouse gasses, and carbon sequestration. Two of these books, *The Potential of U.S. Cropland to Sequester Carbon and Mitigate the Greenhouse Effect* by Lal, R., J.M. Kimble, R.F. Follett, and C.V. Cole and *The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect* edited by R. F. Follett, J. M. Kimble, and R. Lal, were written to answer questions related to the role of agriculture in carbon sequestration. The complete list of books that have come from a series of meetings we have organized is attached for reference.

These books highlight what is currently known about soils and the carbon cycle. They also list areas where we need to expand our knowledge base so that we can develop recommended management practices to increase the sequestration of carbon in soils. It should be noted that there is a strong linkage of the carbon cycle to the nitrogen and phosphorus cycles and that all three need to be considered together. Many of the problems we have with animal wastes are related to phosphorus and nitrogen, yet the organic matter in the wastes is needed for building soil carbon. In addition, both nitrogen and phosphorus are required for the photosynthesis process. Photosynthesis fixes atmospheric carbon dioxide in living plants. As plants decompose some of the plant material is converted into soil organic matter. Therefore, an understanding of the three cycles and their interactions is required. We also need to consider the emissions of methane and where this fits in the overall carbon cycle in agriculture. Methane is produced by ruminant livestock during feed digestion, and in wetlands, rice paddies, and animal waste storage facilities. Landfills are the largest single manmade source of methane emissions in the U.S.

We know that soils can sequester carbon. USDA estimates that the potential sequestration range of cropland is in the range of 69.4 to 195 million metric tons of carbon (MMTC)/yr with an average of 132 MMTC/yr, which is about 8 percent of the total U.S. annual emissions of all Green House Gases (GHG's). Grazing lands have the potential to sequester 30 to 110.0 MMTC/yr with an average of 70 MMTC/yr, or about 5 percent of the total annual emissions of all GHG's. Thus, the combined total for cropland and grazing lands is about 13 percent. Sequestration can significantly reduce atmospheric CO_2, and, at the same time, improves soil quality by increasing the carbon in the soil. The increased carbon leads to improved soil fertility, an increased water-holding capacity, reduced soil erosion, restoration of degraded lands, improved water quality, and improved wildlife habitat at the same time that it mitigates the greenhouse effect. This is a win-win scenario with many benefits to agriculture, as well as to society in general.

As outlined in both of the books, we know a great deal about the processes and what is needed to sequester carbon in soils, the overall carbon cycle, and the linkage of the nitrogen and phosphorus cycles, yet there are still many areas that require more research. As stated above, there is an interaction of the carbon and nitrogen cycles. We need to have nitrogen and phosphorus for plant growth, but we need to develop mechanisms to add nitrogen in organic forms, through fixation by plants, or in slow-release forms that mineralize to ammonium while minimizing the amounts present in the nitrate form. Research is needed in the efficiency of fertilizer use. When commercial fertilizers are used, we must consider the amount of CO_2 released in their production and we need to do a full accounting of all inputs. Fertilization will not be done as a means to increase carbon sequestration but to increase agriculture production, but that still means we need to do a full accounting.

There are many other knowledge gaps that have been identified in our meetings and it is these gaps which point future research needs. In 1996, we identified some areas where these gaps exist. They include (1) tropical ecosystems; (2) frozen soils; (3) wetlands, Histosols, Andisols, and Aridisols soil types; (4) C sequestration in the Subsoil; (5) soil erosion and C dynamics; (6) plant nutrients and their interactions with soil C; (7) soil structure and soil quality indices; (8) methods of soil organic assessment; (9) global database and information exchange; (10) interdisciplinary collaboration; (11) assessment of the value of carbon/ton; and (12) policy options to encourage farmers and land managers to adopt recommended management practices. Questions arising from these knowledge gaps have been answered in part over the last few years, but many still require further research.

We know the value of conservation tillage but still need to look at the potential benefits of different types of tillage systems in different agro-ecological zones, with different crops and crop rotations, and on different soils. This research requires long-term experiments. Research also needs to be conducted on a whole-farm basis. At meetings I have heard farmers say "that these practices work on your small scale experimental station plots, but will they work on my farm on a larger scale?" Researchers need to work with the farmers to look at actual fields, which may have a great deal of soil variability and to see if we can measure changes there.

Conservation Reserve Program (CRP) and other programs have helped to improve and protect highly erodible lands, and they have a high potential for sequestering carbon, but the question is have we gotten the maximum benefit from these lands? Do they need additional management to improve the rates of carbon sequestration? Should limited grazing be allowed to more closely mimic a natural ecosystem in which grazing of grasslands occurs?

Research is needed to determine how fertility testing information can be used to help us understand changes in soil carbon levels. Over 2 million samples are analyzed each year for this purpose. Soil organic matter is one of the things measured during fertility testing. How can we use these measurements to look at changes in the soil carbon levels over time? We need to look at changes over time on farms using no-till or other conservation tillage systems and on farms using conventional tillage. We need to compare different practices on similar soils. We need to look at carbon changes deeper in the profile. Some studies suggest that there may be gains in the topsoil with no-till but a loss of deeper soil carbon. A major research effort is needed to address this question.

Research is needed to determine why practices that work or are shown to increase the amount of carbon sequestration are not being adopted. Why is the amount of land where no-till has been used being reduced? Is it that farmers do not trust the research, or are they finding yield reductions or some other perceived problem? Again, this question relates to the need for on-farm research with inputs from farmers and land managers to facilitate and answer questions that producers have.

Integrated research is needed to ascertain the value of soil carbon in terms of its effect on production and on other societal values. What is the cost/benefit of carbon sequestration?

How can we use remote sensing to observe land use changes to improve management practices, and to enhance carbon sequestration? Remote sensing allows us to look at the changes at both the farm and at the watershed levels. New remote sensing technology may need to be developed in cooperation with USDA, NASA, and university groups. Projects need to cover broad geographical boundaries that may not fit within one state. Federal agencies (ARS and NRCS) need the funding proposal in the President's proposal for the U.S. Global Change Research Program and the Climate Change Technology Initiative.

We need to see what the effects of irrigation are on carbon sequestration since irrigation can affect both SOC and SIC. Changes in one may be offset by changes in the other. Irrigation is a major land use change, but its long-term effects on carbon are not clearly understood.

We need to look at the effects of bio-energy crops (i.e., switchgrass or even corn) on soil carbon. Production of these crops can help to reduce the dependency on nonrenewable resources. Many grow rapidly and are high yielding, but are they also increasing carbon storage below ground?

Until now, individual research scientists have accomplished a great deal in carbon research. Now is the time for an interdisciplinary approach linking policy makers to soil scientists, agronomists, economists, and plant breeders to develop a systematic research program that can address knowledge gaps and priorities. Research at the farm level requires the input of farmers and ranch managers, and must be geared to the realities of production agriculture.

Research in crop breeding has looked at yield increases, pest control, and water use efficiency. We now need to look at crops that will maintain or increase yields but at the same time increase the amount of biomass below ground or change the overall biomass so that its effectiveness in carbon sequestration is increased (i.e., for example a changing the lignin content of plants).

We need research to develop a process from which to estimate and verify changes in carbon stocks. This will require a research agenda that links many different scientists, working toward a common goal. The future understanding of the global carbon cycle depends on the implementation of a program, which is interdisciplinary in nature drawing on the expertise of these scientists. We need to work at the watershed level or within broad ecological regions, and we need to look at the problems without disciplinary boundaries. We need to take the research from the laboratory and experimental fields to whole-farm operations.

So as you can see, many unanswered questions exist regarding carbon sequestration and finding answers to these questions could provide significant benefits to American agriculture. For this reason, in the FY 2001 Budget, the Administration proposed for USDA $84 million for the U.S. Global Climate Change Research Program Activities, including $12 million for NRCS soil carbon inventories, and $24 million for the Global Climate Change Technology Initiative (an increase of $11 million), including $3 million for NRCS pilot projects on crop residue and animal waste management. Providing the requested funding for these activities would be an important step toward improving our understanding of agriculture's role in carbon sequestration.

Mr. Chairman, that completes my statement. I would be happy to answer any questions.

Testimony of William Richards

Farmer and former Chief of the Soil Conservation Service

Before the Senate Subcommittee on Production and Price Competitiveness

Hearing on Carbon Cycle Research
and Agriculture's Role in Reducing Climate Change

May 4, 2000

Mr. Chairman and members of the Senate:

Thank you for the opportunity to testify before this committee. I represent myself and our family farming operation. I bring the experience of forty years of conservation tillage and two and one-half years as Chief of the Soil Conservation Service. It was two and one-half years of very rewarding service as we were able to help producers meet the environmental requirements of the 85 and 90 farm programs.

Now it's the millennium, the beginning of a new century, America is awash in prosperity, the best fed, best housed and best entertained people the world has known, yet billions over the world are hungry and we food producers are not sharing these good times. Add to this the public concerns for green space, recreation, wildlife, food safety, and the environment, all luxuries only the well fed and the properous can afford and you have the stage set for the farm and environmental debate of our new century.

Freedom to Farm (the last or phase-out farm support program) matures in 2002 and only with massive supplemental and disaster assistance have we supported the agricultural economy thru 1999 and will probably continue thru 2000 or as long as the United States enjoys a booming economy and budget surplus.

However, federal funds for conservation and environment assistance directed toward agriculture have steadily declined over the past eight years. This is ironic because conservation was used as the "excuse" to funnel money to an improvished countryside back in the beginning of farm programs in the 1930's. This funding and these early programs started the federal and state conservation movement. The resulting reductions in water and wind erosion and the instilling of a conservation ethic has became a model for the world. Conservation cost share and free technical assistance became a standard part of federal farm legislation.

This changed in 1985 when erosion control and wetland preservation were made requirements for participation in commodity support and other USDA programs. It was called cross compliance. This U-turn in the politics of conservation from totally "voluntary" to "required" sent shock waves through production agriculture; the resulting producer's hostility helped send me to Washington as the SCS chief. With my background in no-til or direct seeding and with the help of the chemical and the machinery industries, The Farm Press and the other USDA agencies we were able to sell conservation tillage as the best practice to meet erosion requirements, and for the most part we were successful. Erosion dropped to sustainable levels in many regions of the country and conservation tillage peaked out at roughly 40% of planted acres.

Then politics changed. The signal from Washington was conservation tillage was no longer politically correct. The agenda switched from the real measurable problem of soil erosion to the preceived problem of herbicide dependance. Conservation tillage (30% or more surface residue) has levelled out nationally It's gaining in cotton, wheat and soybeans but loosing in the corn belt, especially in highly erodible Iowa where we lost

1,433,000 acres or ten percent in 1998 by Conservation Technology Information Center measurements.

The United States is unlike our competitors, Canada, Argentina and Brazil who have all passed us in the percent of cropland direct seeded. Competition will be the ultimate factor that dictates adoption. I'm concerned as one of those who started the conservation tillage revolution that we've "unleased a monster". Around the world millions of acres of new lands are coming into production that would be too fragile or unprofitable without conservation tillage.

Why is conservation tillage in the U. S. loosing ground? We know of some yield problems both real and preceived. We need encouragement from conservation leaders, especially those from NRCS. We need more research and equipment design, especially in the northern cornbelt but I submit the big factor is politics. Many believe USDA has slacked off on compliance and Congress has reacted to the farmer backlash of "required" conservation.

I feel and hope future conservation programs will be separate, voluntary, and incentive based. We have learned our lessons on cross compliance. From experience as a farmer and past SCS chief, I'm convinced we get conservation on the land and behavorial change with incentives and education, not requirements and regulations.

We must realize the environmental political focus is changing. No longer is soil erosion the only issue. We must now address water quality,air quality, wildlife habitat, and etc. and again conservation tillage will be in the forefront. We have always known and understood the immediate fuel, labor and machine savings of conservation tillage. We also captured the management opportunity of spreading our talent over more acres with reduced tillage. Then came the erosion and conservation benefits that became political after the '85 farm bill. Only recently have we understood the long term soil quality, water quality and wildlife benefits accuring from continuous direct seeding. No-til or direct seeding will become universal because of the long term soil quality improvements and raw world competition.

The opportunity to increase organic matter (soil carbon) will first, increase productivity or land value and second, sequester carbon for a world concerned with climate change from greenhouse gasses.

"The Agricultural Research Service has found as much as one to two percent organic manner increase in 10 to 20 years of continuous no till. The bad news is that we have tilled away or eroded 50 percent of organic matter from our soils over the last 100 years. Scientists estimate that we have lost 5 to 6 billion tons of carbon from our nation's farmland. By converting from plow till to no till and including cover crops in the rotation cycle, we can resequester soil carbon at the rate of 300 to 500 pounds per acre per year. So the good news, we have the technology, machinery, and science to put it back. What's this worth in land value? In our country on lighter soils, probably five hundred dollars per acre at current price levels. Something landowners cannot ignore.

What it's worth to the public depends on how we address the clean air and greenhouse gas problems. President Clinton has announced tougher emission controls for new automobiles and S. U. V's which adds two hundred plus dollars to the cost of each vehicle. Many feel agriculture has the potential to sequester the carbon for 50 percent of our auto emissions. Scientists at Ohio State and NRCS/ARS have estimated that adoption of recommended agriculture practices on U.S. cropland has a potential to sequester 70 to 200 milllion tons of carbon per year. In addition, grazing lands have a potential to sequester 30 to 110 millions tons of C per year. We should encourage our farmers and ranchers to do whatever is recommended to achieve these potentials. When the public (and Congress) understand this, carbon sequestration will be the action in the next round of farm and conservation legislation. I feel the public, if given the chance, would quickly choose their big autos over payments to producers for sequestration. Science has documented the increase in CO2 in the atmosphere. I don't feel we know why, or if man has anything to do with it, however, the world is going to throw money and/or regulations at global climate change and agriculture can and should earn some of this money.

I serve as an advisor on the USDA Climate Change Assessment Team and this year's federal budget contains four billion dollars for global climate work of which agriculture will receive fifty seven million. I was in Costa Rica three years ago and visited land owners who were buying cheap land banking on the United States and European Union funding to keep it in trees. Ohio power companies are already investing in South America. Environmentalist over the world are preparing for a harvest of public money! The competition will be keen. It will be trees, grass, wildlife habitat, verses cropland, grazing, and wood production. The pressure to take land out of agriculture production will increase as many in the environmental community believe the solution to over production and low commodity prices is simply public control of land or long term CRP which only exports our production and environmental problems to other countries. I hear it frequently, "We've bought that land three times in the last fifty years, next time we should keep it." We in agriculture must get our environmental solutions into the public arena and into legislation.

I hope in the near future we will have the opportunity to put in place a comprehensive conservation incentive program to reward producers for stewardship. We offer a solution to the global climate change - greenhouse gas problems that's a win-win for all concerned. Whether the problems are real or perceived, public funding for increase organic matter, improved soil quality, better water quality, and less erosion, all leading to "higher productivity" is a good investment for our people and the whole world and it can be sold under the banner of carbon sequestration.

We need a program similiar to the concept introduced in the Senate earlier this year. It would establish a voluntary program that will reward producers for good environmental stewardship with the basic practice conservation tillage. Grain and livestock producers would contract for five years to follow a total resource management plan that calls for a menu of practices that pertain to their operations. Producers could earn up to forty percent of their county rental rate and livestock producers ten percent of sales per year with practices such as conservation tillage, comprehensive soil and nutrient management, prescision nutrient application, odor reduction, lagoon management, managed rotational grazing, windbreaks, buffers, stream improvements, and etc. all practices that are profitable for the producer, good for the land, and good for the public.

Such legislation should be voluntary, in addition to and separate from the Farm Bill due in 2002. A separate Conservation Bill would bring into focus agriculture's importance to the environment. A Conservation Bill at this time would move money to the countryside at a time it is badly needed, but more importantly help production agriculture address the concerns of the environmental community and avoid the temptation or desire to regulate. USDA and a scaled back NRCS would have problems delivering such a comprehensive program and may have to look to state and local conservation agencies and private industry for help to service us producers. NRCS does not have the experienced staff and talent we had to administer the '85 and '90 Farm Programs.

If we could get in place a "Freedom to Conserve" coupled with a good crop insurance package let's call "Freedom to Survive" we could avoid the temptation many have to change "Freedom to Farm". Let's give it time - it has our foreign competition worried and we producers enjoy the freedom to manage and compete. A Freedom to Conserve could cost up to six billion per year in the out years. Expensive but the taxpayer will be getting direct benefits from soil, water, and air quality and economic stability in the countryside. Conservation stewardship payments are also permitted under the Nafta, Gatt, and WTO rules.

I challenge Congress to consider a Conservation Bill that would encourage producers to sequester corbon. The time is now. Enforcement of the Clean Air Act is starting and carbon will be valuable. I'm told twenty dollars per ton is a reasonable price The EPA and most environmentalists favor carbon trading so industry, especially utilities will finance the carbon reduction. The issue for agricultural producers is whether we trade our carbon sequestering potential on the market or do we get our rewards thru stewardship payments from the public. However, we producers should be careful - remember the market says those who pollute (emit carbon) will pay those who conserve (sequester); that could be some of us! Of course, over time the market will prevail - that's our system. The public may even decide greenhouse gasses, global warming, etc.are not worth the price.

However, a comprehensive, reward based, stewardship conservation program is good investment for producers, consumers, and the environment and it will sequester carbon. Increase in carbon reserves of the nation's farmland through adoption of conservation tillage provides numerous ancillary benefits to society and the world community. Reduction in water runoff and soil erosion decreases risks of non-point source pollution, reduces siltation of waterways and reservoirs, decreases the risks of flooding, and reduces emission of greenhouse gases. Society owes it to farmers for taking personal risks while benefitting humanity. My hope is we start with a stewardship program and give our scientists time to research the long term solutions to the public's real and perceived global concerns.

Thank you again for the opportunity to submit this testimony.

William J. Richards
Farmer and former Chief of the Soil Conservation Service in the Bush Administration

United States Senate

Committee on
Agriculture, Nutrition and Forestry

Testimony

John C. Haas

May 4, 2000

My name is John Haas and I am a farmer in southwest Kansas. I live in Larned, Kansas and am the third generation farming the Haas family farm. I am a member of the Kansas and the National Grain Sorghum Producers Association. I also represent Kansas State University on the Council for Agricultural Research, Extension and Teaching. (CARET)

I have been actively farming for more than 40 years and have seen numerous changes take place over that time. The change I would like to address today is commonly referred to as conservation farming, mulch till farming, no-till or reduced tillage farming. I first started experimenting with the no-till type farming in 1980 but after about 3 years I abandoned it because at that time we didn't have the planting equipment available to deal with the great amounts of residue that were left on the surface of the ground. Also the herbicides that were available were either too expensive of just didn't work to the degree that was needed.

I again returned to the reduced tillage ways in the early 1990's and found that we had a lot better equipment and herbicides available and there had been a lot of work done by our land grant university's and experimental stations. With guidance available from the Extension Service and my past experience, I found the going much more to my liking. Today I am almost completely no-till on all 4000 acres that I farm.

You might ask why would a person change completely their style of farming if what they were doing was working. That is what I would like to discuss next. By reducing greatly or completely doing away with tilling the land several things happen. First and probably most important is we no longer lose all that moisture when working the ground with an implement. We know that every time the ground is worked we lose the moisture as deep as we work the soil therefore each rain must first replenish that surface moisture before we can build up any sub-surface moisture. We only get about 23" of rain per year and sometimes we can get 1/4 of that at one time. That is plenty of rain to raise a crop if only we can catch and hold it where and when it falls.

With the previous crops residue on the surface of the soil there is a shading effect much as when you mulch your garden with straw. As the winds blow across the fields the standing residue reduces the ability of the wind to contact the soil directly, thereby reducing the evaporation loss. The sun also cannot strike the soil directly and therefore the soil stays a little cooler and there is less loss of precious moisture. As the rains fall the drops of rain will strike the residue first and break up that droplet there by making it easier for the soil to absorb.

As the soil absorbs more of the falling rain, that means there is less run-off. By reducing the run-off we greatly reduce water erosion. By reducing the erosion we don't let the top soil wash away and pollute the streams. This means that everyone wins as we greatly reduce point source pollution. The farmer keeps his top soil and the surface water stays cleaner. I have observed the actual healing of gullies over time by the use of no-till style of farming.

When the soil is left undisturbed it will start a renewal process. The structure or building blocks of the soil will improve. This makes for better water storage capacity, a better environment for plant root development, a better environment for the soil microbial activity, more earth worm activity and a soil that will support heavy loads without causing compaction.

Many soils have a restrictive layer at about 5" deep that is caused by continually working at this depth or working when the soil is too wet. I have found that after about 3 years of no-till this restrictive layer starts to disappear. I believe that mother nature prepares the best seed bed by the freezing and thawing during the winter. It takes man with big tractors and implements to disturb this process.

The pay off for me by using the no-till or reduced tillage system has been the raising of much better crops. Not only do I raise better crops but a greater variety of crops which have a higher value in the market place.

By now you probably are probably asking if it is so great why don't all farmers use this method? There is one large draw back. It is called change. Changing from a way that has been the practice for generations to an entirely different new concept. The changing of turning the residue under to leaving it all on top of the soil. It also requires much greater management on the part of the operator. Timeliness is probably the key. Timeliness on when to use the proper herbicides, when to plant and when to fertilize. Great patience is also needed because when you have to deal with the large amounts of residue, planting can be very difficult. Faith is another trait required of a no-till operator. To know what you are doing will really work when all your neighbors are still doing the conventional tillage that your father and grandfather use to do. There is also the planting equipment that is needed. You need the best, most modern of equipment and it must be kept in top mechanical shape because planting no-till is very hard on the equipment. This equipment can cost upward of $2,000.00 per foot. Plus, there is the out of the pocket costs. Many farmers don't feel that it costs much to use the tractor and implements that they already own. The purchase of herbicides are an immediate cost. I find that I need less implements and smaller tractors than if I was conventional tilling my farm. This adds up to less fuel burned, lower repair bills and less dollars in capital investments. It also allows for more time to be spent on other jobs around the farm.

Is this the answer for the future of agriculture in the United States? I really don't know but I do know this is working for me at the present time and has increased by income and allowed me to produce new and different crops.

I want to thank you for this opportunity to testify before this committee.

DOCUMENTS SUBMITTED FOR THE RECORD

MAY 4, 2000

9509 N. Langdon Rd.
Sterling, Kansas 67579
May 2, 2000

Senate Agriculture Committee
328A.Russell Bld.
Washington, DC. 20510

Dear Sirs:

Thank you for the opportunity to state my point of view on this revolution in farming.

We farm 2600 acres in central Kansas 100% no- till with 4 months of hired labor. I am a graduate of Cornell University with a degree *in* Agriculture Economics. I came from a western New York State family farm background and have been actively farming in Kansas since 1982. 1 originally became interested in no-till farming for economic reasons. I have since found out, there are a multitude of reasons to make this new system of farming work.

One of the big benefits of no-till is soil conservation. The wind blown soil conservation in this part of the windy plains has huge value. Stubble attached to the soil has almost a zero windspeed at ground level. Water infiltration rates after heavy rains have increased. Our wet mudholes have dis-appeared, because of the burrowing holes of the earthworms. The earthworm population has exploded. There is no soil washing into the ditched because of the stubble. On the negative side the colder and wetter soils have reduced the early growth rates of the plants, but the water savings show up later in the season, with higher yields, when we get into our dry season in August and September. An amazing fact is the organic matter levels in our soils has gone from .4% to 1.2% in 4 years time.

Insects and diseases are no more of a problem than in a tillage system.

We have found that the monoculture of a single crop doesn't work in no-till situations. We have got to have a quick rotation of atleast a minimum of 3 crops, preferably 4-5 crops. to make this no-till system work. The 1996 Freedom To Farm bill has allowed us to make these changes. The moisture savings has allowed us to grow more water intensive crops in this area. The quick rotation has allowed me to reduce my herbicide bill from $48000 annually, 3 to 4 years ago, to $29000 in 1999. One surprising benefit is the reduction of weeds and weed seeds because of the quick rotation. This quick rotation does not allow a natural resistance to herbicides to be built up as it would occur in a monoculture. I have not made a post-emergent spry in my grain sorghum crop since I became a no-tiller. Before, this was an annual expense.

Soil fertility management is no more or less of a problem than in conventional tillage. Long term stratification of nutrients in the upper surface of the soil may be a problem we will have to address long term.

Another benefit is the reduction of equipment needed to operate these farm. Over the last 20 years, the cost of new equipment has risen at a faster rate than other costs. Twenty years ago a mid-size combine would cost 22,000 bushels of corn now costs 100,000 bushels of corn. No-till has allowed me to eliminate all of my tillage expense, fixed and variable. The use of herbicides are a substitution for expensive tillage trips across the field. Most tillage trips were accomplished at a rate of 15 acres an hour where spraying trips can be maintained at 80-100 acres an hour.

There is very little operational expense to a sprayer compared to the operational costs and repair expenses of tillage equipment. Another huge benefit, is that I have reduced my operational costs $28 per acre over conventional tillage. This is extremely important in an era of falling prices. On the negative side, the farm innovators are so far ahead of the equipment industry, that we are mostly designing our own equipment through trial and error.

The nature of no-till forces farmers to become better managers. This system forces a higher level of management than a tillage system that can cover up its sins with a plow. Even though this adds time, on my part, it is a non-cash cost since I do not hire a crop consultant. The time savings of no-till has allowed me to do my own crop scouting at a savings of $3.50 an acre. Also we can farm an acre of ground with approximately 35-40% less time invested, than a tillage system.

There is a social cost to this increased level of efficency. I no longer need to hire a full time employee. I have reduced my demand for a portion of my farm equipment because T no longer have a need for them. This next statement is an extremely important concept. If most farmers sell their crops at their variable cost of production, the movement towards no-till farming, with its increased level of efficiency and lower production costs, will probably cause an even greater loss in our value of our production. In the past, it has cost about $3,45 to produce a bushel of wheat. I can now produce it for around $1.80-$2.00 a bushel depending on yield.

I can not see far enough into the future to understand where and how to be more efficient than I am today-This concerns me because I need to stay ahead of my neighbors and competition in other countries. In the short turn, I am becoming extremely competitive because I am 3 to 5 years ahead of my competition in adopting this new technology. In the long term I am not sure what I can do to maintain my competitive advantage. I can not survive in a long term environment as an <u>average</u> producer.

I would like to thank Senator Roberts and this committee for the passage of the Freedom To Farm bill. It has bought me time as an innovator to maintain a healthy business.

Respectfully Submitted,

Clark Woodworth

base to support continued economic development, recreation, and the environment.

CONSERVATION OPERATIONS

2000 appropriation	$660,812,000
2001 budget estimate	747,243,000
Provided in the bill	676,812,000
Comparison:	
2000 appropriation	+16,000,000
2001 budget estimate	−70,431,000

The purpose of conservation operations is to sustain agricultural productivity and protect and enhance the natural resource base. This is done through providing America's private land conservation to land users, communities, units of state and local government, and other Federal agencies in planning and implementing natural resources solutions to reduce erosion, improve soil and water quantity and quality, improve and conserve wetlands, enhance fish and wildlife habitat, improve air quality, improve pasture and range conditions, reduce upstream flooding, and improve woodlands. Assistance is also provided to implement highly erodible land (HEL), wetlands (swampbuster), wetlands reserve program (WRP), and conservation reserve program (CRP) provisions of the 1985 Food Security Act, as amended by the Food, Agriculture, Conservation, and Trade Act of 1990, the 1993 Omnibus Reconciliation Act, and the Federal Agriculture Improvement and Reform Act of 1996.

COMMITTEE PROVISIONS

For Conservation Operations, the Committee provides an appropriation of $676,812,000, an increase of $16,000,000 above the amount available for fiscal year 2000 and a decrease of $70,431,000 below the budget request.

The Committee does not include funds for global climate change, biomass products initiative, or the Community Federal Information Partnerships as requested in the budget. These programs do not support the current level of on-the-ground conservation technical assistance.

The Committee does not concur with the request to transfer $36,000,000 from NRCS for Common Computing Environment (CCE)/Service Center Modernization (SCM), but rather encourages the Chief to work with the Secretary to determine a fair and equitable amount to support CCE/SCM efforts.

The Committee includes legislative language prohibiting the use of funds to carry out the urban resources partnership (URP) program and the American heritage rivers initiative (AHRI). The Committee notes that an evaluation report conducted by the Office of Inspector General found: (1) that the Under Secretary chose not to follow the normal legislative process to initiate the URP program, and (2) good management practices were not followed in implementing an URP program and $20.3 million in program expenditures were made without proper statutory authority and funding authorities. The Committee directs that the $2,204,000, and the associated staff years included in the explanatory notes for URP program and AHRI be used to fund conversation technical assistance.

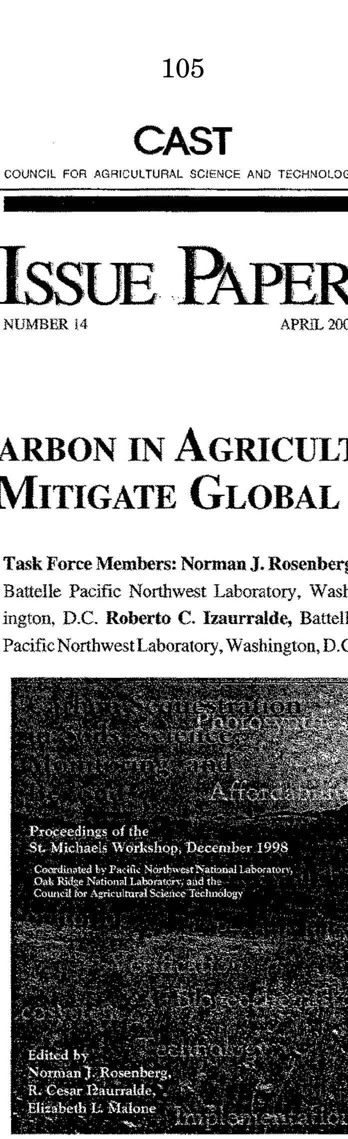
CAST
COUNCIL FOR AGRICULTURAL SCIENCE AND TECHNOLOGY

ISSUE PAPER

NUMBER 14 APRIL 2000

STORING CARBON IN AGRICULTURAL SOILS TO HELP MITIGATE GLOBAL WARMING

Task Force Members: Norman J. Rosenberg, Battelle Pacific Northwest Laboratory, Washington, D.C. **Roberto C. Izaurralde,** Battelle Pacific Northwest Laboratory, Washington, D.C.



Norman J. Rosenberg, R. Cesar Izaurralde, Elizabeth L. Malone (Eds.). 1999. ***Carbon Sequestration in Soils: Science, Monitoring, and Beyond. Proceedings of the St. Michaels Workshop, December 1998.*** **Available with CAST discount from Battelle Press, Columbus, Ohio at (800) 451-3543 or www.battelle.org/bookstore.**

Summary

As an important constituent of soils, organic matter contributes greatly to plant productivity and ecosystem stability. Soil organic matter is also an important repository of carbon (C) and plays a central role in the global C-cycle. Soils may act either as a source, releasing C to the atmosphere, or as a sink into which C from the atmosphere is deposited, depending on season, time of day, vegetative cover, weather conditions, and land management. But land management is the critical determinant of whether the net change in soil C is a gain or a loss. Since the beginning of the industrial revolution, land use changes, such as conversion of temperate forests and prairies to agricultural fields, have contributed significantly to the recorded increase in concentration of atmospheric CO_2. And current deforestation in the tropics continues to add CO_2 to the atmosphere. Because of justified concern that emissions of CO_2 and other greenhouse gases in the atmosphere are causing global warming, national policies and programs are emerging to slow, offset, or eliminate emissions. Agricultural practices that conserve soil and increase productivity while improving soil quality also increase the C content in soils, thereby removing CO_2 from the atmosphere. Integrated assessments of energy and economic options needed to stabilize atmospheric CO_2 during this century indicate that soil C-sequestration can provide an important opportunity for limiting the increase of atmospheric CO_2, especially if action is taken worldwide during the next three decades.

But a stronger knowledge base that now exists is required before this can be accomplished. In December of 1998, a workshop was convened at St. Michaels, Maryland by the Department of Energy's Pacific Northwest and Oak Ridge National Laboratories, in conjunction

with CAST, to address the questions of (1) how best to improve the scientific understanding of the biophysical processes that regulate C-sequestration in currently farmed lands and lands requiring protection and/or reclamation from desertification; (2) how best to monitor natural and management-driven change in soil C-content; and (3) how best to implement soil C-sequestration programs. The 100 scientists, practitioners, and policy makers who attended the workshop emphasized the need for research leading to an in-depth understanding of the mechanisms responsible for C stabilization and turnover in soil aggregates, of landscape effects on C sequestration, and of ways to use C sequestration to combat desertification. High priority was assigned to research on the environmental impacts of soil C-sequestration and on the applications of genetic engineering to enhance plant productivity and to increase C sequestration. The workshop also recognized the urgent need for a rapid, economical, reliable method to verify and to monitor soil C-sequestration. A more comprehensive understanding of the social, economic, and environmental implications of incentives potentially leading to widespread adoption of soil C-sequestration programs was also deemed essential.

Introduction

Addition of organic matter to soil increases water-holding capacity, imparts fertility, increases soil aggregation, and improves tilth. Depending on the type — humus, manure, stubble, or litter — organic matter is between 40 and 60% carbon (C). In the form of carbon dioxide (CO_2), C is accumulating in the atmosphere as the result of fossil fuel combustion, land use change, and tropical deforestation (Table 1). The atmospheric concentration of CO_2 has increased by about 32% from about 280 parts per million by volume (ppmv) at the beginning of the industrial revolution (ca. 1850) to about 370 ppmv today.

There is strong consensus among atmospheric scientists that continued increase in the concentration of atmospheric CO_2 and other greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) will enhance the earth's natural greenhouse effect and lead to global warming (Intergovernmental Panel on Climate Change, 1996). Some scientists argue from the fact that 1997 was the warmest and 1998 the second warmest years on record that the global climate change "footprint" already is detectable.

Carbon dioxide, the greenhouse gas of primary concern with regard to climate change, is also essential to photosynthesis. Elevated CO_2 concentration stimulates photosynthesis and growth in plants with C-3 metabolism (legumes, small grains, most trees) and decreases transpiration, or water use, in plants with C-3 and C-4 (tropical grasses such as maize, sorghum, and sugar cane) metabolism. Together, these phenomena are termed the *CO_2-fertilization effect.*

Table 1. Global carbon (C) flux budget

Carbon Flows	Pg[a] C
Annual atmospheric increase of carbon dioxide (CO_2)	3.4
Sources	
Fossil fuels	6.4
Land use change	1.1
Tropical deforestation	1.6
Sinks	
Terrestrial in temperate regions	2.0
Oceans	2.0
"Missing"	1.7
Potential sinks in croplands alone (50 to 100y[b])	40 to 80 Pg C

[a]1 Pg = 1 billion tonnes or 10^{15} grams.
[b]Intergovernmental Panel on Climate Change, 1996.

Table 1 provides current estimates of global C *sources* and *sinks*. Fossil fuel combustion, land use change, and tropical deforestation are global C *sources* adding about 9.1 Pg C/year (yr) (1 Pg is equal to 1 billion metric tonnes, or 10^{15} grams [g]) to the atmosphere. Of this, only about 3.4 Pg C/yr accumulates in the atmosphere. The remainder is absorbed by global C sinks such as the oceans (about 2.0 Pg C/yr) and by the regrowth of forests in temperate regions (also about 2.0 Pg C/yr). About 1.7 Pg C/yr is not accounted for. Most of this "missing C" is probably going into the terrestrial biosphere in the Northern Hemisphere. Likely, the CO_2-fertilization effect is contributing to the increased capture of C in terrestrial ecosystems.

The Intergovernmental Panel on Climate Change (1996) estimated in its Second Assessment Report that it may be possible during the next 50 to 100 years to sequester 40 to 80 Pg of C in cropland soils (Cole et al., 1996; Paustian et al., 1998; Rosenberg et al., 1998). Table 1 shows that, if these estimates are accurate, agricultural soils alone could capture enough C to offset further increases in the atmospheric inventory for 12 to 24 years. These calculations are crude, but they do suggest a potential to offset significant amounts of CO_2 emissions by sequestering C in the soils of lands now in agricultural production. Of course, there is additional C sequestration potential in the soils of managed forests and grassland, a potential not addressed here. And, as will be discussed below, there is a great potential for C storage in the soils of degraded and desertified lands. But unless alternatives to fossil fuels are found, the energy demands created by growing populations and rising standards of living could greatly increase CO_2 emissions over this century and the capacity of agricultural soils to sequester C could be exhausted, to little long-term effect.

The decade of the 1990s marked the beginnings of a political recognition of the threats that greenhouse gas emissions — at increasing or even at steady rates — may pose to stability of the global climate. In response to this threat, the United Nations adopted the Framework Convention on Climate Change (UNFCCC) in Rio de Janeiro in 1992 (United Nations, 1992). The convention aims at the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." In December 1997, the parties to the UNFCCC met in Kyoto, Japan and drafted a protocol to place binding limits on and to begin the process of stabilizing atmospheric concentrations of greenhouse gas emissions (United Nations, 1997). The protocol recognizes that its objectives can be met by either *decreasing the rate at which greenhouse gases are emitted to the atmosphere or increasing the rate at which they are removed from it.* It was well recognized in the Kyoto negotiations that photosynthesis, by fixing C in standing and below-ground portions of trees and other plants, provides a powerful means of removing CO_2 from the atmosphere and sequestering it in the terrestrial biosphere. The Kyoto Protocol establishes the concept of credits for C sinks (Article 3.3) but allows credits for a limited list of activities including afforestation and reforestation (Article 3.4). The protocol allows no credits for soil-C sequestration except, perhaps, (and this is not yet clear) for C accumulating in the soils of afforested or reforested lands. The Kyoto Protocol does not currently permit sequestration in agricultural soils to produce C sequestration credits, although the capacity for allowing such credits clearly exists. Ostensibly because of the difficulty and costliness of verifying that C is actually being sequestered and maintained in soils, this mitigation option was set aside in the Kyoto negotiations; it is, however, mentioned specifically in Article 3.4 for possible inclusion at a later time.

Another way of looking at the potential role of soil C-sequestration appears in Figure 1, which

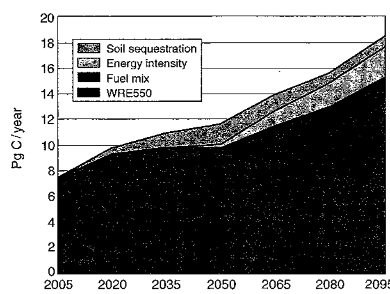


Figure 1. Global carbon emissions trajectories (Pg = 10^{15} g) of carbon (C) during this century according to the MiniCAM's business as usual scenario (top line) and the Wigley-Richels-Edmonds scenario (bottom line) required to limit atmospheric carbon dioxide concentration to 550 parts per million per volume (Wigley et al., 1996). The figure shows a hypothetical path to C emission reductions under a scenario in which credit for soil C sequestration is allowed. Soil C sequestration alone achieves the necessary net C emission reduction in the early part of the century. From the middle of the century on, further emission reductions must come from energy system changes (such as fuel switching and decreased total energy consumption).

was produced with the integrated assessment model MiniCAM 98.3 (Edmonds et al., 1996a, b; Rosenberg et al., 1999). The top line in the figure represents the anticipated increase in C emissions to the atmosphere in the twenty-first century, using a so-called "business-as-usual" scenario produced by the Intergovernmental Panel on Climate Change (1990). The figure also shows the Wigley-Richels-Edmonds CO_2 stabilization trajectory whereby C emissions are allowed to increase to a maximum by 2035 but reduced steadily to about 6–7 Pg C/yr by 2100. Bringing the upper emissions line down to the desired level will require substantive changes in current energy systems. The caption of Figure 1 identifies technologies that will promote the needed change in the next century. Increased efficiency in the uses of fossil fuels; development of non-C-emitting fuels; improvements in power generation; a greater role for biomass fuels (which recycle C but do not increase its concentration in the atmosphere), solar, wind, and nuclear energy; and other technological advances ultimately will be needed to mitigate climate change. Figure 1 shows that soil C-sequestration can play a strategic role but, in and of itself, cannot offset all of the excess C emissions. Soil C-sequestration, however, could alone make up the difference between the expected and desired emissions trajectories in the first three to four decades of the twenty-first century, thus buying time for development of the technological advances just identified. The calculations shown in Figure 1 are based on the assumption that in the twenty-first century, agricultural soils will sequester C at global annual rates ranging from 0.4 to 0.8 Pg/yr, with rates twice as great in the initial years and half as great in the later years. It is further assumed that the potential of soil C-sequestration is realized without additional net cost to the economy — not unreasonable in view of the known benefits of organic matter in soils. Additionally, by allowing time for new technologies to be developed and for existing facilities to live out their design lifetimes, the costs of an avoided tonne of C emissions during the next century can be cut approximately in half.

How realistic are the potential soil C-sequestration estimates on which the IPCC economic modeling is based? The panel's estimates for cropland assume the restoration of up to two-thirds of soil C released by the conversion of grasslands, wetlands, and forests to agriculture since the mid-nineteenth century. The experimental record confirms that C *can* be returned to soils in such quantities. For example, C has been accumulating at rates exceeding 1 Mg/ha/yr (1 Mg = 10^6 g = 1 metric tonne) in former U.S. croplands planted to perennial grasses through the Conservation Reserve Program (CRP) (Gebhart et al., 1994). Soil C increases ranging from 1.3 to 2.5 Mg/ha/yr have been estimated in experiments on formerly cultivated land planted to switchgrass (*Panicum virgatum*), a biomass crop (preliminary data, Oak Ridge National Laboratory). Further, there have been a substantial number of experiments in the last two or three decades with low-till and no-till management of farm fields that demonstrate these practices lead to increases in soil C content (Janzen et al., 1998; Lal et al., 1998; Nyborg et al., 1995).

Despite the indications that needed quantities of C can be sequestered in agricultural soils, there remain four important questions regarding such a possibility.

1. Can methods be developed to increase the quantities of C accumulating in soils and, perhaps more important, can the length of time during which C resides in soils be extended?
2. Can opportunities for C sequestration be extended beyond the currently farmed lands to the vast areas of degraded and desertified lands worldwide?
3. Can we develop quick, inexpensive, reliable methods to monitor and to verify that C is actually being sequestered and maintained in soils?
4. What are the political and economic problems associated with implementation of soil C- sequestration programs worldwide?

In December 1998, a workshop exploring these questions was organized by the Pacific Northwest National Laboratory, the Oak Ridge National Laboratory, and the Council for Agricultural Science and Technology and held in St. Michaels, Maryland. The workshop was attended by nearly 100 Canadian and U.S. scientists, practitioners, and policy makers representing agricultural commodity groups and industries, Congress, governmental agencies, national laboratories, universities, and the World Bank. Support for the workshop was provided by the U.S. Environmental Protection Agency, the U.S. Department of Agriculture, the U.S. Department of Energy, the Monsanto Company, and the National Aeronautics and Space Administration. Position papers addressing the four key questions were prepared for presentation and discussion. The papers, revised to take account of workshop critiques, discussions, and recommendations, are reported in Rosenberg et al. (1999).

Key Findings of the St. Michaels Workshop

New Science

The potential for C sequestration in all managed soils is great, and progress can be made using proven crop, range, and forest management practices. The potential might be even greater if ways could be found to restore more than the two-thirds of the C lost from conversion to agriculture and perhaps even to exceed original C contents in some soils and regions. Carbon restoration would involve a search for ways to effect greater, more rapid, and longer-lasting sequestration. Promising lines of research are evolving that could lead to an improved understanding of soil C dynamics and the subsequent development of superior C sequestration methods. The studies have the following goals:

- to improve the understanding of the mechanisms of C stabilization and turnover in soil aggregates;
- to improve the description of the various C pools and the transfer among them to allow more realistic modeling of the dynamics of soil organic matter;
- to improve understanding of landscape effects on C sequestration and how it might be controlled through precision farming;
- to apply genetic engineering to enhance plant productivity and to favor C sequestration; and
- to improve understanding of the environmental effects of soil C-sequestration on erosion, nutrient leaching, and emissions of other greenhouse gases.

Soil Carbon Sequestration/Desertification Linkage

There are estimated to be some 2 billion hectares of desertified and degraded lands worldwide, 75% of them in the tropics, with degradation most severe in the dry tropics. The potential for C sequestration on these lands probably is even greater than on currently farmed lands. Improvements in rangeland management, dryland farming, and irrigation can add C to soils in these regions and provide the impetus for changes in land management practices that will begin the essential process of stabilizing soil against further erosion and degradation while improving fertility and productivity. Erosion control, forest establishment in dry regions, and biomass cultivation seem to offer the greatest potential for increased C sequestration on degraded lands. Soil C-sequestration offers a special opportunity to address objectives of two United Nations Conventions simultaneously — the UNFCCC and the Convention to Combat Desertification.

Monitoring and Verification

There is opposition to the use of soil C-sequestration to offset C emissions in the calculations of a nation's adherence to its Kyoto Protocol commitments. One reason for this opposition is the perception that it will be difficult if not impossible to verify claims that C is actually being sequestered in the soils of fields that may eventually number in the millions. It is currently possible to monitor changes in soil C content, but methods are time consuming and expensive and not sensitive enough to distinguish year-to- year change. If there are to be international agreements allowing soil sequestration to figure into a nation's C balance, agreed-upon means of verification will be necessary. Improved methods for monitoring changes in soil organic C might involve spatial integration based on process modeling and geographical information systems (GIS), application of high-resolution remote sensing, and continuous direct measurements of CO_2 exchange between the atmosphere and terrestrial ecosystems. In addition, new instruments are needed that can serve as direct in-field "carbon-probes." All of these verification and monitoring methods will have to be developed or tailored to operate at different scales, e.g., field or region. Verification of changes in soil C in individual fields will rely on laboratory analyses of soil samples or, perhaps a few years from now, on C probes. Estimates of regional soil C changes will be made with the aid of simulation models. High-resolution remote sensing and GIS will be used to extrapolate C-sequestration data from field observations and modeling results, to aggregate them to still broader regions, and to track trends in C sequestration with time.

Implementation Issues and Environmental Consequences

The possibility, suggested by the IPCC findings and the Kyoto Protocol, that C may become a tradable commodity has not gone unnoticed in the agriculture and forestry communities. Beneficial land-management practices might be encouraged if credit toward national emissions targets could be gained by increasing C stores on agricultural lands. But uncertainty about costs, benefits, and risks of new technologies to increase C sequestration could impede adoption. To address farmers' reluctance to adopt C sequestration practices, financial incentives could be used to encourage practices such as conservation tillage. Government payments, tax credits, and/or emissions trading within the private sector also could be employed.

Despite uncertainty on many levels, soil C sequestration projects are beginning. Some utilities and other emitters of greenhouse gases, anticipating a future in which reductions in CO_2 emissions may become mandatory, already are searching for cost-effective ways to offset or otherwise meet imposed limits. And transactions already are being made: In October 1999, the Trans Alta Corporation, a member of the Greenhouse Emissions Management Consortium (GEMCo, an association of energy utilities in Western Canada), announced an agreement to purchase up to 2.8 million tonnes of C emission reduction credits (CERCs) from farms in the United States. The IGF insurance company will solicit the CERCs from eligible farmers or landowners, initially from Iowa and ultimately from the entire nation. We do not yet fully understand the social, economic, and environmental implications of incentives leading to widespread adoption of soil C-sequestration programs. Most foreseeable outcomes seem benign - for example, an increased commitment to minimum-till practices. Another likely outcome is increased effort to restore degraded lands and to retire less productive agricultural lands into permanent grass or forest cover. Sustained efforts to continue and/or expand Conservation Reserve Programs will contribute to C sequestration not only through reduction of erosion in marginal land but also through restoration of lost soil C. All these actions have the potential to decrease soil erosion and its negative consequences on water quality and sedimentation and to improve soil quality. Additionally, because increases in soil organic matter content increase water-holding capacity, irrigation requirements could be decreased. Conversion of agricultural lands to grasslands or to forest could expand to provide wildlife habitat. Decreased soil disturbance and, possibly, diminished use of fertilizer could alter volume and chemical content of runoff from agricultural lands. This in turn could decrease water pollution; enhance water quality for use by nonagricultural water consumers; and improve the ecology of streams, rivers, lakes, and aquifers in these regions.

Negative social, economic, and ecological effects also are possible. Programs designed to move agricultural lands into forestry could negatively affect the traditional forest sector, leading either to deforestation of traditional parcels or to decreased levels of management and lessened C sequestration. Such actions might offset much of the benefit of sequestering C in agricultural soils as lands so employed could compete with food and fiber production. The results might be decreased production; increased consumer prices for crops, meat, and fiber; and decreased export earnings.

Decreased tillage intensity often leaves more plant material on the soil surface. Conservation tillage frequently requires additional pesticides to control weeds, diseases, and insects. Increased use of pesticides may have detrimental effects on ecological systems and water quality. Conversion of croplands to grasslands tends to decrease emissions of nitrous oxide (N_2O), a gas that, molecule for molecule, has a much stronger greenhouse effect than does CO_2. Such land use changes may also lead to a restoration of the soil's capacity to function as a site for destruction of CH_4 molecules.

Conclusion

Such seemingly benign activity as soil C-sequestration is not without cost. The production, transport, and application of chemical fertilizers, manures, and pesticides and the pumping and delivery of irrigation water needed to increase plant growth and to encourage C sequestration all require expenditures of energy — in this instance, the release of CO_2 from fossil fuels. It is necessary to determine to what extent the energy costs (C emissions) of the practices used to increase C sequestration in soils might actually diminish its net benefits. Of course, it is unlikely that soils ever will be managed for the primary purpose of C sequestration. Rather, fertilizers, manures, chemicals, and irrigation water will continue to be used primarily for the production of food, fiber, and — increasingly in the new century — biomass as a substitute for fossil fuel. As fossil fuels are replaced with bio-products, carbon sequestration will become an important fringe benefit and an integral part of a strategy to control global warming.

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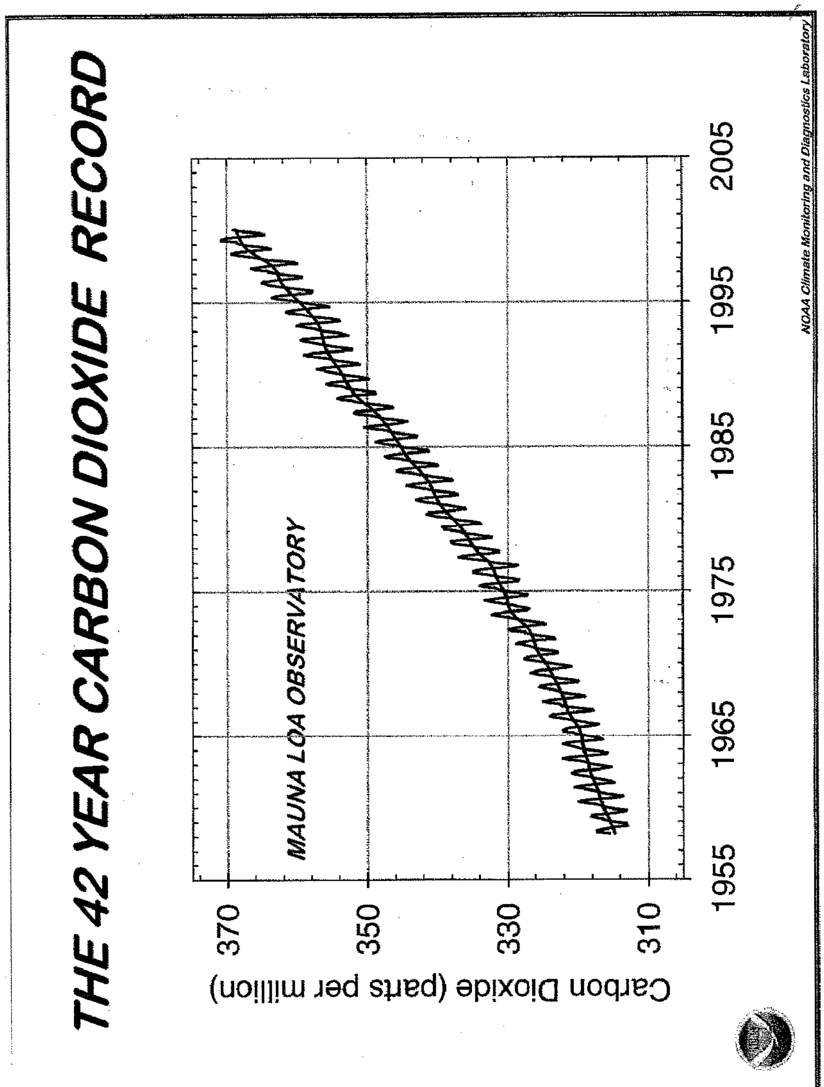
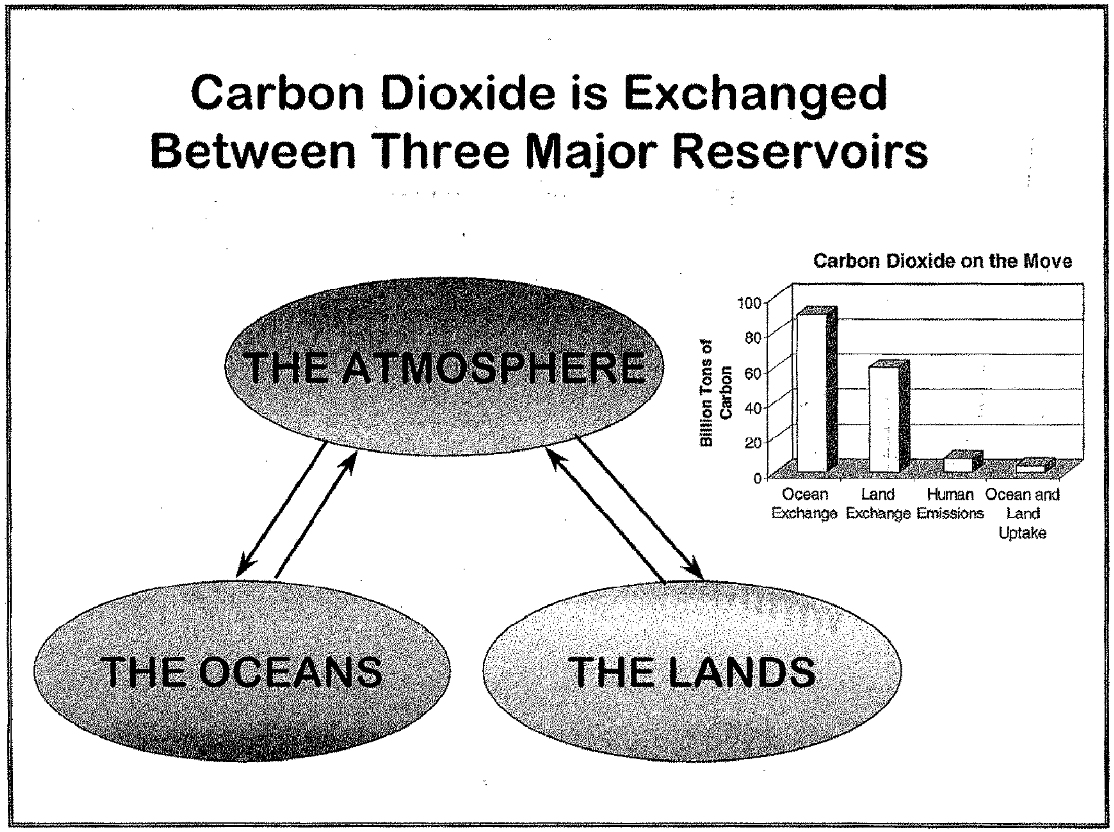
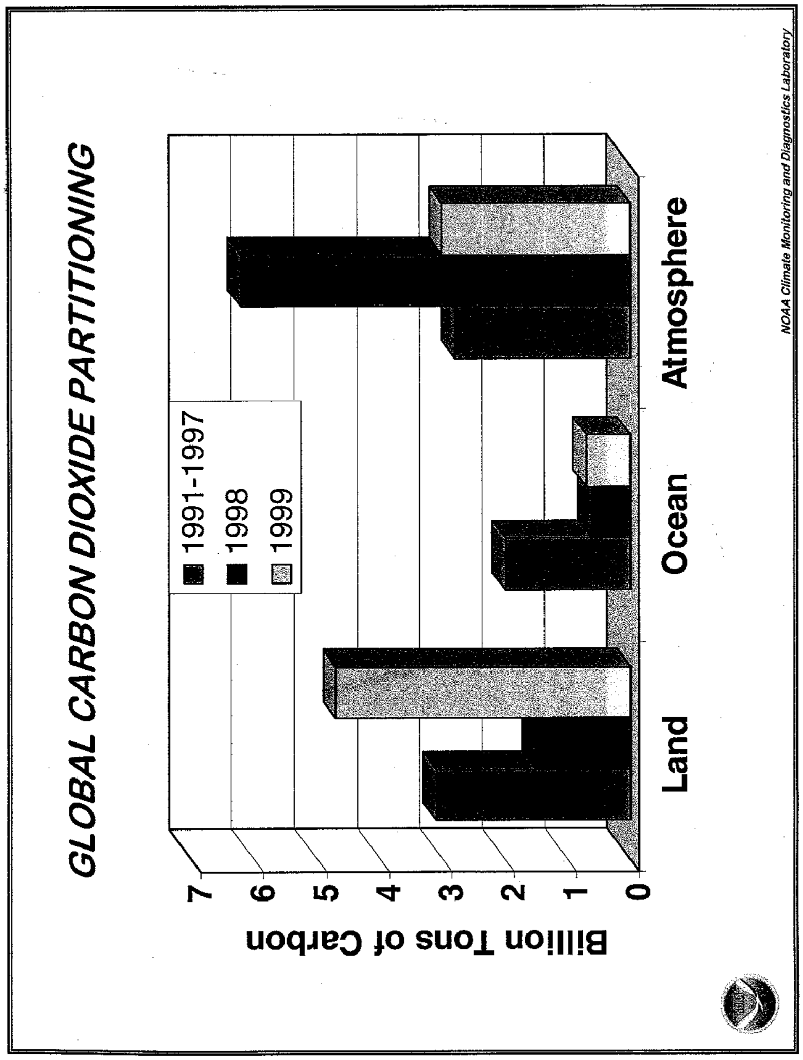

THE 42 YEAR CARBON DIOXIDE RECORD
MAUNA LOA OBSERVATORY
Carbon Dioxide (parts per million)
370
350
330
310
1955
1965
1975
1985
1995
2005
NOAA Climate Monitoring and Diagnostics Laboratory


Carbon Dioxide is Exchanged
Between Three Major Reservoirs
THE ATMOSPHERE
THE OCEANS
THE LANDS
Carbon Dioxide on the Move
Billion Tons of Carbon
100
80
60
40
20
0
Ocean Exchange
Land Exchange
Human Emissions
Ocean and Land Uptake


GLOBAL CARBON DIOXIDE PARTITIONING
Billion Tons of Carbon
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Land
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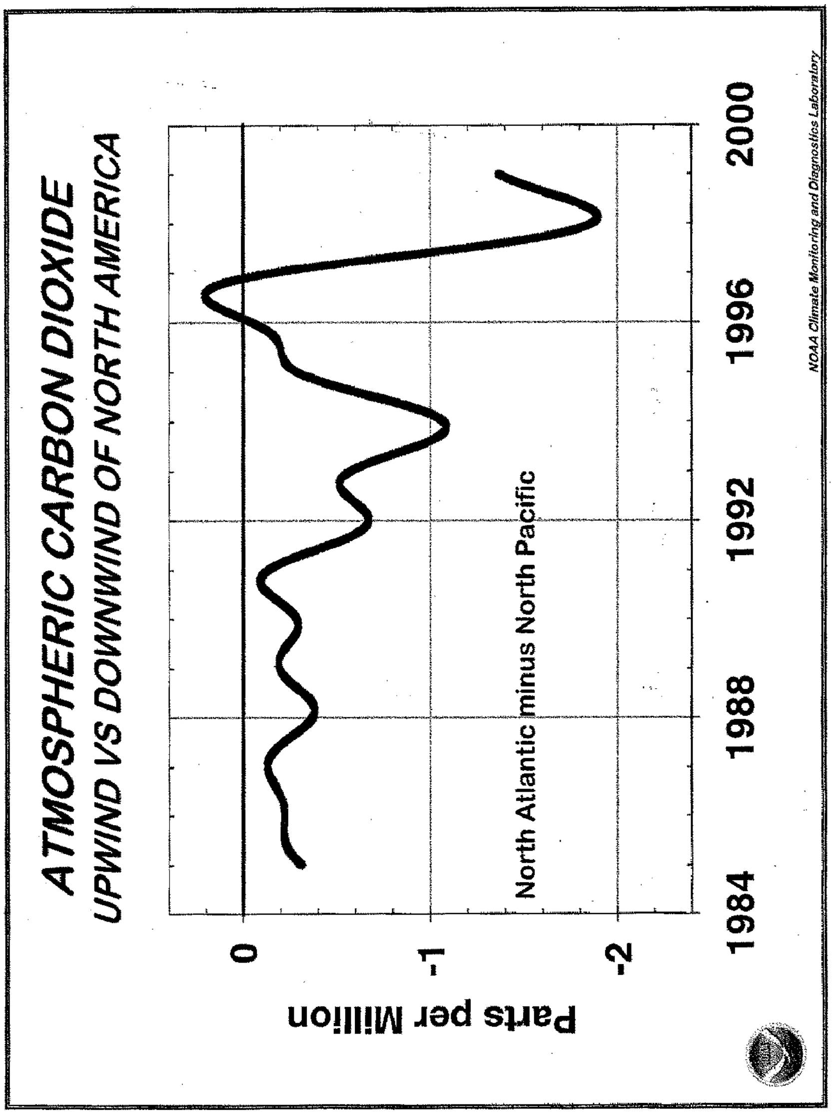
NOAA Climate Monitoring and Diagnostics Laboratory


ATMOSPHERIC CARBON DIOXIDE
UPWIND VS DOWNWIND OF NORTH AMERICA
Parts per Million
0
-1
-2
1984
1988
1992
1996
2000
North Atlantic minus North Pacific
NOAA Climate Monitoring and Diagnostics Laboratory