Approved: February 1, 2006
Date

MINUTES OF THE SENATE AGRICULTURE

The meeting was called to order by Chairman Mark Taddiken at 8:30 a.m. on January 17, 2006 in Room 423-S of the Capitol.

All members were present except:
Derek Schmidt - excused

Committee staff present:
Raney Gilliland, Kansas Legislative Research
Amy VanHouse, Kansas Legislative Research
Lisa Montgomery, Office of Revisor of Statutes
Judy Seitz, Committee Secretary

Conferees appearing before the Committee:
Charles W. Rice, Department of Agronomy, Kansas State University Research and Extension

Others attending:
See attached list.

Chairman Taddiken said there would be bill introductions at the end of the meeting.

Charles W. Rice gave a power point presentation on soil carbon sequestration in agriculture (Attachment 1). There is so much interest in carbon sequestration and climate change because of greenhouse gases (GHG). In the past 100-150 years there has been a dramatic increase in carbon dioxide, methane and nitrous oxide gases. Mr. Rice said the Arctic sea ice loss affects Kansas by the occurrence of less frequent but more intense thunderstorms. As a result there would be more droughts and greater soil erosion. He discussed methods for dealing with carbon sequestration such as land use, soil management and crop management. Mr. Rice reported that in 2003 President Bush set a goal of an 18% reduction in CHG. He also reported that the United States Department of Agriculture is working with the Department of Energy to improve volunteer GHG reduction. Several years ago there was a volunteer formation of the Kansas Coalition for Carbon Management (KCCM). Their purpose is to inform, educate and motivate land managers to apply management practices that result in reduced atmospheric carbon levels.

Mr. Rice stood for questions.

Duane Simpson Kansas Association of Ethanol Processors, requested a bill for the creation of a seven member, Governor-appointed Kansas Ethanol Council, with a three year sunset. Senator Ostmeyer moved and Senator Huelskamp seconded the motion that the bill be introduced. Motion passed.

Chairman Taddiken introduced a bill regarding water drainage districts and who is eligible to be on the board of directors. Chairman Taddiken moved and Senator Lee seconded the motion that the bill be introduced. Motion passed.

Meeting adjourned at 9:23 a.m. The next meeting is scheduled for January 18.

SENATE AGRICULTURE COMMITTEE GUEST LIST

DATE: January 17, 2006

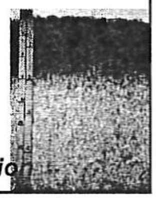
NAME	REPRESENTING
Estelle Montgomery	Hein Law Firm
John A. Donley	Kansas Lvsk. Assoc.
GINA BOWMAN-MORRILL	Coffeyville Resources, LLC
Carole Jordan	KDA
Duane Simpson	KAEP

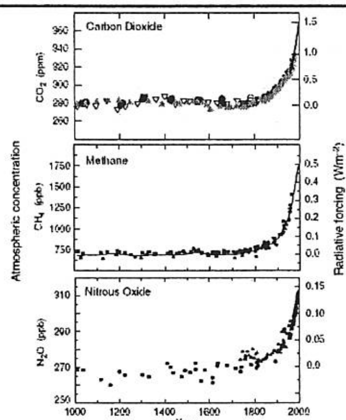
Soil Carbon Sequestration in Agriculture

Charles W. Rice
Department of Agronomy

CASMGS

K-State Research and Extension

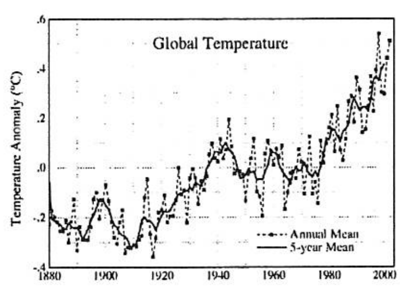




Atmospheric Concentrations of CO_2, Methane (CH_4), and Nitrous Oxide (N_2O) from 1000 A.D.

From IPCC (2001)

Global Annual Surface Temperature

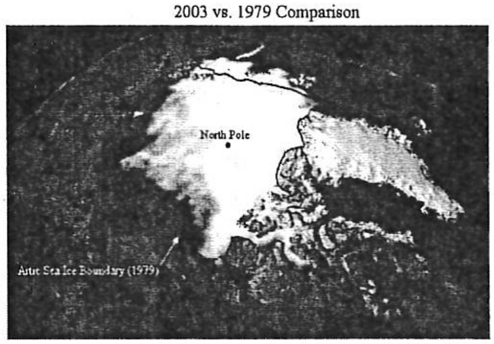


Trend of global annual surface temperature relative to 1951-1980 mean.
http://www.giss.nasa.gov/research/observe/surftemp/

Senate Agriculture Committee
1-17-06
Attachment 1

Arctic Sea Ice Loss: Greater than Land Area of Texas, California, and Maryland Combined

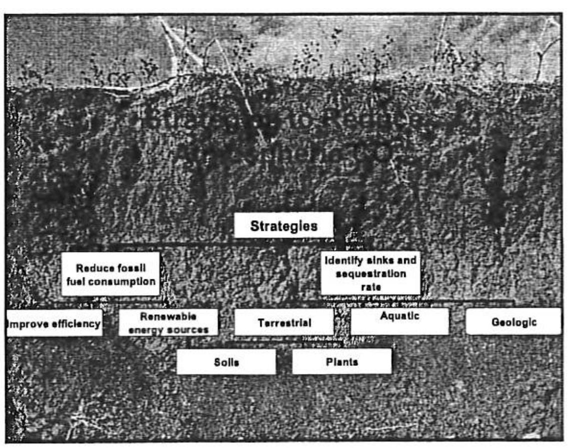
2003 vs. 1979 Comparison



What does it mean for KS?

If precipitation is the same but more variable
- i.e. less frequent but more intense thunderstorms

Then:
- More droughts
  - Shift crops (corn to sorghum)
- Greater erosion



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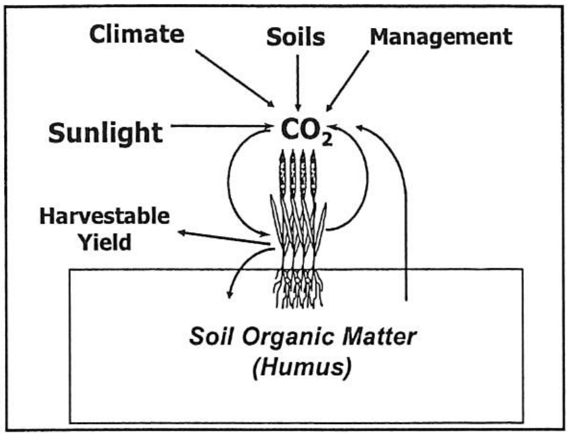
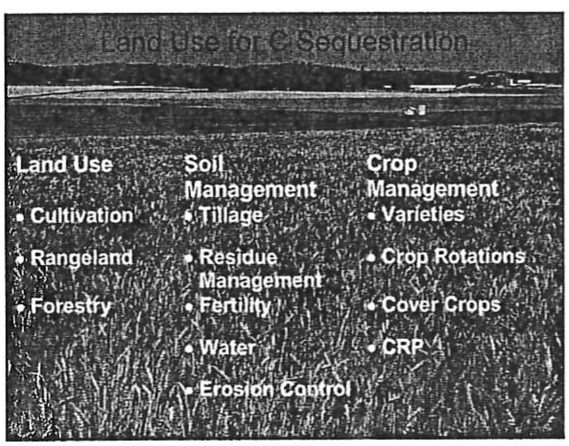


Consortium for Agricultural Soil Mitigation of Greenhouse Gases

- *To provide the tools and information to successfully implement soil carbon sequestration so that*
  - *the accumulation of greenhouse gases is lowered in the atmosphere,*
  - *while providing income and incentives to farmers and improving the soil.*

Kansas State University	Colorado State University
Iowa State University	Michigan State University
Montana State University	University of Nebraska
Ohio State University	Purdue University
Texas A&M University	Pacific Northwest National Labs



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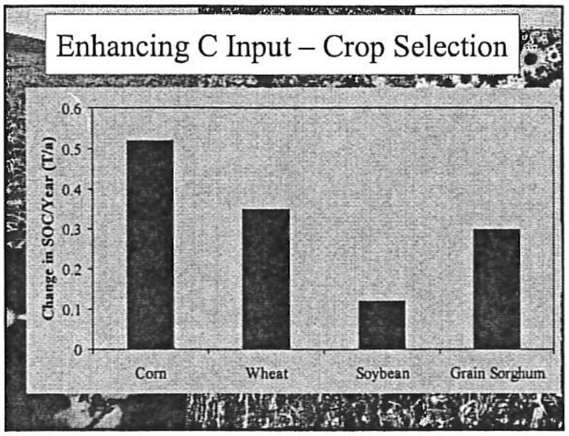
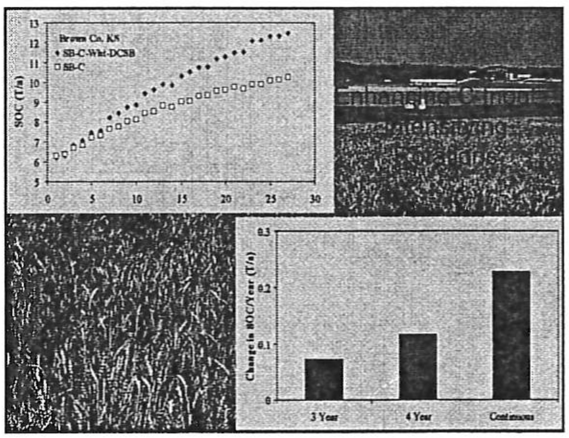
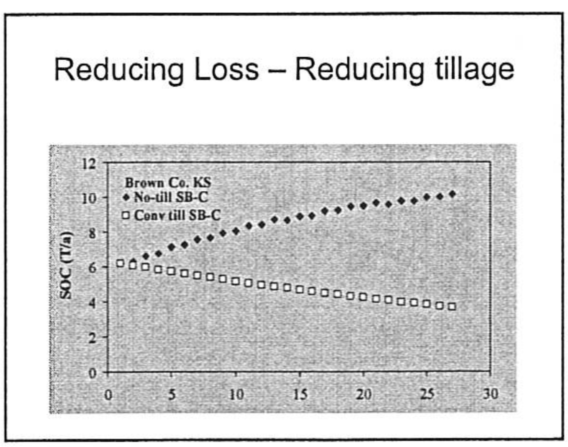

Enhancing C Input – Crop Selection
Change in SOC/Year (T/a)
0.6
0.5
0.4
0.3
0.2
0.1
0
Corn
Wheat
Soybean
Grain Sorghum


Brown Co. KS
SB-C-Wht-DCSB
SB-C
SOC (T/a)
Change in SOC/Year (T/a)
3 Year
4 Year


Reducing Loss – Reducing tillage
Brown Co. KS
No-till SB-C
Conv till SB-C
SOC (T/a)
12
10
8
6
4
2
0
0
5
10
15
20
25
30

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Treatment	Scenario	Rate (Mg C/ha/y)	Duration (yrs)	State
Eliminate summer fallow	3-year system 4-year system Continuous cropping	0.073 0.117 0.229	12	Eastern Colorado
Integrated Nutrient Management (corn)	NT 150 N manure NT 150 N Fert CT 150 N manure	1.19 1.05 1.01	10	NE Kansas
Rotations	CT - NT wheat CT - NT sorghum CTsorg/NTwheat to NT sorg/wheat	0.764 0.605 0.624	10	SC KS
CRP		0.80	12	NE

No-Tillage

- Restores soil carbon
- Saves labor
- Controls weed
- Reduces erosion
- Conserves moisture
- Planting on the best date
- Saves fuel
- Lowers machinery costs

Corn production relative to conventional tillage in NE KS (10 years)

	CT-168-M	NT-84 F	NT-168 F	NT-84M	NT-168M
Mean Yield (Bu/a) (85.8)	77.9	75.7	**87.6**	69.2	74.3
Net Return ($/a) (39.19)	22.86	63.48	**73.28**	51.43	44.04
Soil C (MT C/ha/y)	1.01	0.13	**1.05**	0.22	1.19
Emissions from Inputs (MT C/ha/y)	-0.053	-0.060	-0.016	-0.087	-0.070
Net C (MT C/ha/y)	1.08	0.02	**1.08**	0.29	1.25

Pendell et al. 2004

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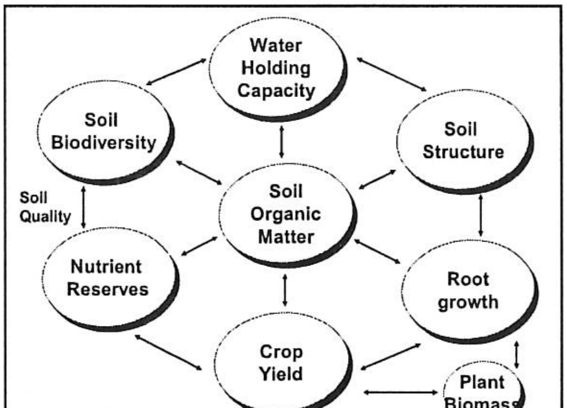
Sorghum and wheat production in SC KS (10 years)

	CT-WW	CT-SS	CTS-NTW	NT-SS	NTS-NTW
Net Return ($/ha)	20.24	**63.51**	**54.26**	**58.29**	45.62
Soil C (MT C/ha/y)	1.34	0.27	0.83	0.88	**1.48**
Emissions from Inputs (MT C/ha/y)	0.11	0.12	0.11	0.18	0.12
Net C (MT C/ha/y)	1.23	0.15	**0.73**	**0.76**	**1.35**

Williams et al. 2004



Lal, Kimble, and Follett 1997

Value of Soil Organic Carbon

- Value of N, P, K, and H_2O in kg of humus about = $0.20
- This converts to about $1100 per acre when you have 1% soil organic matter (0.6% carbon)
- So an increase by 0.1% would be $110 per acre.

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United States efforts in Agriculture

- Federal government established a goal of 18% improvement in GHG efficiency (Roughly a reduction of 100 Mt carbon)
- USDA is utilizing conservation programs to encourage carbon sequestration and GHG reductions
  - GHG offsets are factors in setting priorities under:
    - The Environmental Quality Incentives Program
    - The Conservation Reserve Program
    - The Forest Land Enhancement Program
- Federal government challenged the private sector to take action
  - USDA is working with the Department of Energy to improve the voluntary GHG reduction registry
  - USDA is negotiating voluntary agreements with businesses and sectors
  - Several corporations are undertaking projects in partnership with farmers and land owners
- Science and technology
  - Development and demonstration of biomass energy, bio-based products, bio-fuels and bio-power.

Carbon Credits/Trading

- Carbon reduction
  - C reduction at point of emissions
  - C reduction by sequestration
- Is it cheaper to buy a credit than control emissions?

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Examples of feasibility and pilot projects on soil carbon sequestration

Region	Land Use	Land management change
Saskatchewan, Canada	Cropland	Direct seeding / cropping intensification
Pacific Northwest, USA	Cropland	Direct seeding / cropping intensification
Midwest Iowa, Kansas	**Cropland Grass planting**	**No-till New grass plantings**
Oaxaca, Mexico	Crop / natural fallow secondary forest	Fruit tree intercrops with annual crops / Conservation tillage
Pampas, Argentina	Cropland	Direct seeding
Kazakhstan	Cropland	Agriculture to grassland

Izaurralde (2004), Rice

What is needed

- Sellers of C credits: Land managers
- Aggregator
- Buyers
- Monitoring/Verification

Kansas Coalition for Carbon Management

- **Mission**
  - **To inform, educate and motivate land managers to apply management practices that result in reduced atmospheric carbon levels**
    - Website
      - www.oznet.ksu.edu/kccm

KCCM
Kansas Coalition for Carbon Management

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Kansas Coalition for Carbon Management

Member Organizations

- **Kansas Resource Conservation and Development Councils**
- **Kansas Corn Growers Association**
- **Kansas Grain Sorghum Producers Association**
- **Kansas Association of Wheat Growers**
- **Kansas Electric Power Cooperative**
- **Kansas Forage and Grasslands and Society for Range Management**
- **Kansas Livestock Association**
- **Kansas Farm Bureau**
- **Kansas Rural Center**
- **Kansas Association of Conservation Districts**
- **Kansas Department of Agriculture**
- **State Conservation Commission**
- **Kansas Department of Health and Environment**
- **USDA Natural Resources Conservation Service**
- **USDA Farm Services Agency**
- **Kansas Sate University**

Current Interest in KS

- Chicago Climate Exchange
  - USDA grant
  - Offer sheet
- Environmental Defense
- AgCert

- Focus first on well-documented actions with clear ownership
- CCX Special Committee on soil carbon provided guidance on annual carbon gains, geography
- Simplified crediting: verify practices, credit at discount
  issuance quantities:
  - Continuous no-till/low-till (2003-06) in central U.S.:
  - 0.5 metric tons CO_2/acre/yr
  - Grasses, planted after 1-1-99, central U.S.:
  - 0.75 metric tons CO_2/acre/yr

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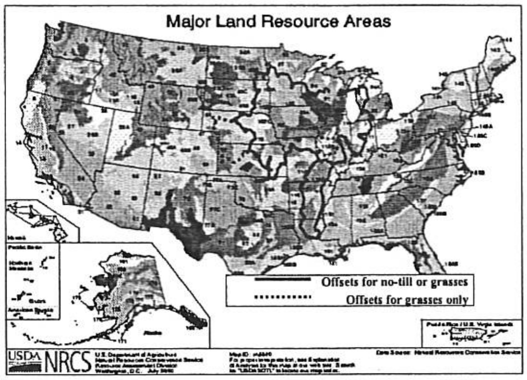
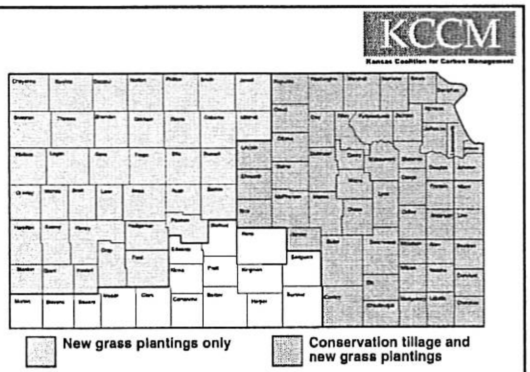
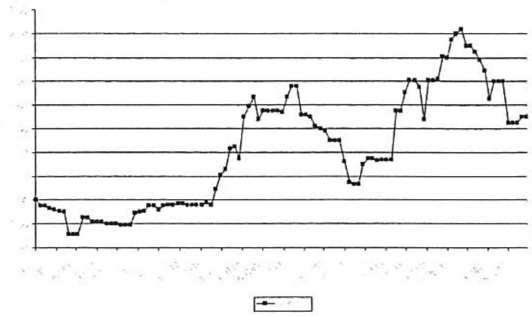




Carbon Contracts with Iowa Farm Bureau

- 200 contracts in Iowa (60 counties)
  - 83,000 acres (67,000 acres No-till)
- 224 contracts in Nebraska (18 counties)
  - 175,000 acres (170,000 acres No-till)
- 72 contracts in Kansas (24 counties)
  - ~75,000 acres (74,000 acres No-till

Carbon Offset Prices



Sales to-date

- Began sales in April 2005
  - ~21,000 tons sold
  - Average price: $1.20
  - Range: $1.50 - $1.10

- Websites
  www.oznet.ksu.edu/kccm
  www.soilcarboncenter.k-state.edu/
  www.oznet.ksu.edu/ctec
  www.casmgs.colostate.edu/

KCCM

K-State Research and Extension

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K-STATE
Kansas State University
Research and Extension

Agriculture's Role In Reducing Atmospheric Carbon Levels

It is a known fact that greenhouse gases, such as carbon dioxide and methane, are increasing every year in the earth's atmosphere. This buildup may well be leading to global warming. Scientists say there are two main ways of reversing this trend: (1) reducing fossil fuel emissions, and (2) taking more carbon out of the atmosphere and storing it in natural "sinks" on earth, a process known as carbon sequestration.

Agriculture can help in both ways. With sufficient economic incentives, producers can use currently accepted management practices to help store more carbon and reduce emissions, and this will help the U.S. meet greenhouse gas reduction goals. This can be done on cropland, grazing land, and set-aside ground. It is estimated that up to 20% of U.S. carbon emissions can be sequestered back into agricultural soils.

Agricultural soils represent one of the best sinks for carbon storage in the Earth's ecosystem. Deep ocean storage and deep geological storage are other potential carbon sinks, but are more costly and less practical than using agricultural soils.

How can producers increase carbon storage in agricultural soils? This is being studied by a federally-funded team of scientists at 10 universities and government laboratories known as the Consortium for Agricultural Soils Mitigation of Greenhouse Gases (CASMGS, pronounced "chasms"). CASMGS brings together the nation's top researchers in the areas of soil carbon, greenhouse gas emission, conservation practices, computer modeling, and economic analysis.

With the current state of knowledge, it is known that carbon sequestration can be accomplished by the following means:

Cropland
1. No-till or reduced-till systems
2. Increased crop rotation intensity by eliminating summerfallow
3. Buffer strips
4. Conservation measures that reduce soil erosion
5. Using higher residue crops, such as corn, grain sorghum, and wheat
6. Using cover crops
7. Selecting for varieties and hybrids that store more carbon

Grazing land
1. Improving forage quality
2. Regular use of prescribed burning to increase forage productivity
3. Reducing overgrazing

Set-aside land
1. Growing high-yield grasses, such as switchgrass or eastern gamagrass on Conservation Reserve Program land

Estimates of the carbon sequestration potential are available for some of these practices:

Agricultural practice	Amount sequestered (tons/acre/year)
Conservation tillage	0.12 - 0.20
Summer fallow elimination	0.05 - 0.15
Rotation with winter cover crops	0.05 - 0.15
Fertilizer management	0.025 - 0.075
Conservation Reserve Program	0.15 - 0.35

Many of these practices involve additional costs for producers, and would require some financial incentives to implement on a wide-scale basis. Part of that cost could be accomplished through a private system of "carbon credit" trading. It is estimated that producers who implement one or more practices proven to store carbon in agricultural soils might be able to sell carbon credits to utilities and other industrial concerns for about $2 per acre per year on the open market. This type of trading system is in its infancy now, so there's no way to know how much producers can realistically expect to get from selling carbon credits.

Additional tax incentives or "green payments" from the government would probably be needed, especially for implementing practices with higher costs and limited returns. This would include such practices as buffer strips, most soil conservation measures, and the use of cover crops.

Other practices, such as no-till, increasing crop rotation intensity, manure application, and improved forage production, may be more profitable for producers in themselves. Where this is the case, the increased profitability will help get the practices implemented.

As an example, research at Kansas State University has shown that no-till grain sorghum in western Kansas is about $30 per acre more profitable than conventional-till grain sorghum. The profitability of wheat is largely unaffected by tillage system, according to the research. The biggest benefit in western and central Kansas comes when no-till is used in combination with increased rotation intensity. For example, a long-term study in Hays showed that wheat-sorghum-fallow is about $10 per acre more profitable than either wheat-fallow or sorghum-fallow. In eastern Kansas, no-till has not shown any increase in profitability in K-State research, so other economic incentives would be more important in this area to get farmers to adopt no-till.

The additional amount of carbon that can be stored in agricultural soils through the adoption of no-till and increased crop rotation intensity is estimated to be between 400-500 pounds of carbon per acre per year. Nationwide, this could total anywhere from 80 to 300 million tons per year.

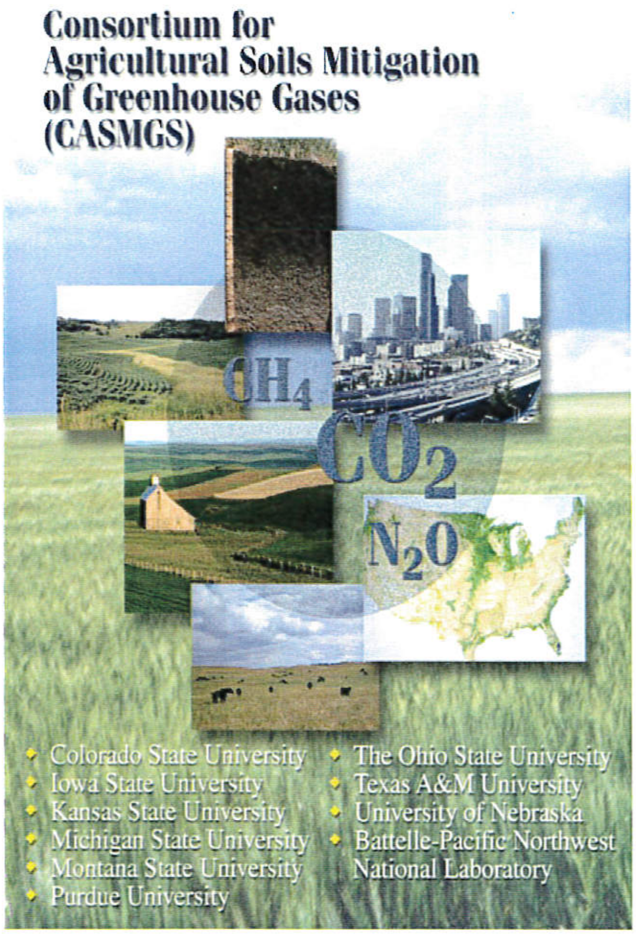
No-till also involves less field work. By reducing the number of trips over the field from 8 to 4, carbon emissions would be reduced by 50%.

The amount of carbon that can be sequestered and the amount of emissions that can be reduced through the adoption of other potential practices, such as the use of buffer strips, requires further research.

If producers can be induced to adopt more practices that store carbon, there will be many benefits to the nation other than just helping to solve the problem of increasing greenhouse gases. Additional benefits include:

1. Improved soil structure and quality
2. Improved soil productivity through increased organic matter
3. Reduced erosion through improved soil structure
4. Improved water quality through reduced erosion

To sum up, changes in practices used on agricultural land can play a role in solving the problem of greenhouse gas buildup at very little cost to the economy. These same practices can also result in several long-term benefits related to the improvement in soil quality.



Background

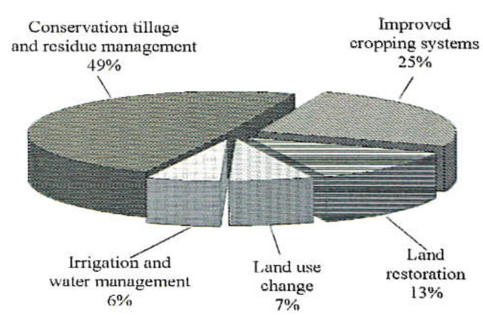
Soil carbon sequestration will reduce the buildup of greenhouse gases in the atmosphere while improving America's farmland and the nations agricultural economy. The Consortium for Agricultural Soil Mitigation of Greenhouse Gases (CASMGS - pronounced like chasms) will provide the information and technology necessary to develop, analyze and implement carbon sequestration strategies.

Concern has been mounting about the considerable buildup of carbon dioxide (CO_2) in the atmosphere. At present, the amount of CO_2 in the air is increasing exponentially, by over 3 billion tons of carbon per year. This atmospheric buildup has been greatly accelerated by industrialization and the burning of fossil fuels (coal, oil and natural gas). Crops and other plants remove carbon dioxide from the atmosphere and, as they are harvested, their residue and roots are deposited into the soil where portions can remain for long periods. Carbon accumulation in agricultural soils can be greatly improved by various forms of conservation management, such as no-till and replanting with grasses. This carbon sequestration occurs because there is less soil disturbance and more carbon is added to the soil. Corollary benefits of carbon sequestration are increased soil fertility, reductions in erosion and increases in soil quality.

To help reduce greenhouse gases, a new plan is emerging; sequester carbon in U.S. agricultural soils, which helps the soil and air and benefits the U.S. agricultural economy. It has been estimated that 20-40% of targeted emission reductions can be met by agricultural soil carbon sequestration. Under a private emission trading strategy, U.S. farmers, practicing appropriate conservation practices, could sell carbon "credits" to carbon emitters. Alternatively, government policies might be implemented to directly support farmers for implementing conservation management practices. Either strategy would help mitigate carbon dioxide rise (the dominant greenhouse gas) while the needed long-term technical solutions are found for producing clean energy. Recent estimates of the potential for U.S. agriculture, using existing technologies, are on the order of 75-200 million metric tons C per year (see figure below).

Early estimates indicate that the potential for a carbon "credits" market for U.S. agriculture is $1-5 billion per year for the next 30-40 years. Carbon markets are already emerging, as shown by recent contracts from Canadian and American utilities to purchase 6 million metric tonnes of sequestered carbon from Iowa farmers. If farmers are getting credit for their storage of carbon, they can better afford to adopt more environmentally friendly management practices.

Contribution of different conservation practices to carbon sequestration potential in the U.S. (From Lal, Kimble, Follett and Cole. 1998. The Potential of U.S. Cropland to Sequester Carbon and Mitigate the Greenhouse Effect. Ann Arbor Press)



Goals and Objectives

The goal of our consortium 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 farmers and improving the soil.*** *Such benefits include an increased and stable agricultural production and an overall reduction of soil erosion and pollution by agricultural chemicals.*

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The Consortium brings together the nation's top researchers in the areas of soil carbon, greenhouse gas emissions, conservation practices, computer modeling and economic analysis. Sophisticated information technology will be used to organize U.S. agricultural data, collected over decades, at a cost of millions of dollars, on soils, climate and management, and apply it to the problem of carbon sequestration. Powerful computer models of agricultural ecosystems and economic systems are already being used by CASMGS for preliminary predictions of the potential for carbon sequestration, carbon trading markets and verification schemes.

The keys to successful implementation of carbon sequestration programs are accurate quantification and verification methods and tools to assess the impacts of policies and economic factors on carbon sequestration rates and the farm economy. Furthermore, policies to foster soil carbon sequestration will need to consider their economic impacts, as well as the potential collateral effects (both positive and negative) on other greenhouse gas emissions (e.g., nitrous oxide (N_2O) and methane (CH_4)), nitrate and pesticide leaching and soil erosion.

Our specific objectives include:

- Evaluate management practices for carbon sequestration rates for grassland and agricultural lands.
- Identify other environmental benefits of carbon sequestering practices for air, soil and water quality.
- Provide measurement and modeling tools to quantify and verify soil carbon sequestration rates to support CO_2 emission reduction programs.
- Provide assessment models to evaluate alternative national and global economic and policy strategies for carbon sequestration and greenhouse gas reductions. These models will provide insights on the impacts of such programs on crop production potential, food security and environmental quality.
- Provide a standing capability to meet the rapid-response needs of Federal agencies, Congress and the White House, for information, data and analysis on issues relating to soil carbon sequestration and soil greenhouse gas emissions.
- Participate in the transfer to and adoption of technology by other countries for quantifying and verifying carbon sequestration rates.
- Provide information to each of the following stakeholder groups: policy makers, agricultural sector, energy and transportation industries, the scientific community and the general public, through annual and special reports, scientific and trade journals, popular publications and an Internet website.

The magnitude of the greenhouse gas mitigation problem is huge and requires an effort of matching proportions. When correctly instituted, the benefits will be substantial and long-lasting. The CASMGS is a consortium of expert scientists from **Colorado State University, Iowa State University, Kansas State University, Michigan State University, Montana State University, The Ohio State University, Purdue University, Texas A&M University System, University of Nebraska, and Battelle-Pacific Northwest National Laboratory**, in conjunction with research groups within the **USDA's Agricultural Research Service, Economic Research Service and Natural Resource Conservation Service.**

For further information visit the website: http://www.casmgs.colostate.edu or contact:

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Consortium for Agricultural Soils Mitigation of Greenhouse Gases

Kansas State University
Consortium for Agricultural Soils Mitigation of Greenhouse Gases (CASMGS)

Research, Outreach, Teaching: Progress Report, August 2005

During the past several years, the CASMGS research team at Kansas State University has made significant contributions to the understanding of soil carbon sequestration. We have advanced that understanding into the national debate over global warming and how to mitigate the problem most economically and effectively. In the marketplace, we have provided the research base needed to help get a carbon credit exchange started in which agricultural producers can participate.

Research Activities

* The effect of tillage, crop rotations, manure, and fertilization on soil carbon levels, energy use, and economics have been evaluated from several long-term studies throughout the state, including Hays, Hesston, Manhattan, Tribune, and Parsons. A brief summary of results:
-- No-till resulted in the highest levels of total soil carbon, especially in the upper layer of the soil. This was true for all rotation systems, in all regions of Kansas.
-- Rotations that include wheat result in the greatest amount of total soil carbon. Grain sorghum and corn also add considerable amounts of carbon to the soil. Soybeans add the least carbon to the soil.
-- More intense rotations, that reduce or eliminate fallow periods, result in the greatest increase in soil carbon. This is especially important in the western half of Kansas. In the western areas, soil carbon levels do not increase much, if at all, when a fallow period is included in the rotation – even in a no-till system.
-- Economics of the various management practices varies by region. Where no-till is more profitable than conventional tillage, it will be easier to encourage producers to switch to no-till and increase carbon sequestration rates within the state.

* No-till and manure tend to result in a relative increase in soil fungi levels. This tends to favor better soil structure and long-term carbon storage.

* Mycorrhizal fungi in soil help plants obtain nutrients. Mycorrhizal fungi help stabilize macroaggregates and thus carbon in soil. This information can be used to design crop and soil management systems to stimulate fungal development.

* Grain sorghum hybrids have been tested to determine if certain hybrids will be better at adding carbon to the soil. Preliminary tests on four genetically distinct hybrids have shown that there are differences among hybrids in the chemical composition of their stalks. Some hybrids will provide a more stable source of carbon than others.

* Using recommended grazing rates, as opposed to the common practice of overgrazing, has been found to increase forage productivity and belowground root production. Using recommended grazing rates has been found to have a small, but positive, effect on increasing soil carbon.

* Annual burning of grazinglands has also had a small, but positive, effect in increasing soil carbon.

* Carbon flux "eddy towers" and automated chambers have been devised and placed on native prairie land near Manhattan. These instruments are giving us data on whether long-term prairie systems are net carbon sinks or sources, and how management practices (such as grazing intensity) affect the carbon balance of prairie ecosystems.

* Standardized protocol for soil sampling has been developed for SOC measurements that can be verified throughout the industry.

Outreach Activities

* An electronic newsletter has been published since 2003 that focuses on state, national, and international activities in carbon sequestration and global warming. This newsletter goes primarily to producer groups, policymakers, educators, and researchers within Kansas. K-State has a carbon sequestration web site (http://soilcarboncenter.ksu.edu) and CASMGS has a national web site (http://www.casmgs.colostate.edu).

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Teaching Activities

* We have 12 graduate students, and have employed 20 undergraduate students on various CASMGS-related projects since 2002.

*Guest lectures in courses on 1) providing science for policy makers, and 2) international aspects of greenhouse gas mitigation.

Successes

* K-State and CASMGS organized the Third USDA Symposium on Greenhouse Gases and Carbon Sequestration in Agriculture and Forestry, held in Baltimore, Maryland, March 21-24, 2005. Over 300 participants attended this conference from 18 countries. Presentations from this Symposium are maintained on our website: http://soilcarboncenter.ksu.edu

* We have determined that agricultural soils under no-till management will sequester about 0.82 tons of CO_2 per acre per year.

* We have communicated these results to agricultural producer organizations, industry representatives, and policymakers through producer meetings, an electronic newsletter, and our web sites.

* K-State CASMGS researchers are members of the Kansas Coalition for Carbon Management (KCCM). KCCM is an organization of producer groups, NRCS Resource Conservation and Development Region associations, and many other state and federal agencies. KCCM relies on information and data provided by the K-State CASMGS team for its educational materials.

* Environmental Defense (ED) and the Chicago Climate Exchange (CCX) regularly come to the K-State CASMGS research team to provide them with data on carbon sequestration rates. Both ED and CCX are actively working to establish links between carbon credit buyers and producer groups to sell (or lease) carbon credits. K-State CASMGS researchers have helped facilitate the first pilot project that will allow producers to sell carbon credits on the CCX national exchange.

*K-State will evaluate new technology to measure soil carbon. One instrument relies on Laser-Induced Breakdown Spectroscopy (LIBS) developed by Los Alamos National Laboratory. Hosting this instrument will lead to opportunities for international collaboration.

Impact

Kansas State University: Kansas State University is becoming known as the center for soil carbon. This will translate into additional funding support. To date we have leveraged additional $800,000 dollars to support research and outreach activities. Part of the International Forum on Measurement and Monitoring in October 2003 was held on the K-State campus and available to all students.

Kansas: There are currently about 3.4 million acres of no-till in Kansas. This means that on no-till acreage alone, Kansas agricultural soils are sequestering about 2.8 million tons of CO_2 per year. We hope to increase the acreage of no-till in Kansas in the future. Current payments for carbon credits for no-till are somewhere between $0.50 and $2.00 per acre per year. As research continues to prove the value of agricultural soil carbon sequestration to U.S. industry, this could potentially bring millions of dollars per year to agricultural producers.

National: Agricultural soil carbon sequestration is the most cost-effective method of carbon sequestration available to industry, and could help industry in the U.S. meet initial CO_2 reduction targets economically. The cost of a ton of CO_2 credits from agricultural soil sequestration is about $1, compared to an estimated cost of $100-200 per ton from geological carbon sequestration pilot projects currently underway in this country. Power companies looking to buy carbon credits are finding that agricultural soil carbon sequestration is by far the most affordable type of credits at this time. KSU-CASMGS scientists are regularly called upon to provide briefings to industry and policy makers.

International: CASMGS has been collaborating with organizations in other countries (Argentina, Australia, Brazil, Canada, and New Zealand) on research and outreach efforts. Several scientific exchanges have occurred between the five countries and K-State.

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Consortium for Agricultural Soils Mitigation of Greenhouse Gases (CASMGS) International Activities, Progress Report August 2005

The Consortium for Agricultural Soils Mitigation of Greenhouse Gases (CASMGS) comprises scientists at 10 U.S. institutions studying the role that agricultural soils can play in mitigating greenhouse gases and global warming. The institutions are: Colorado State University, Iowa State University, Kansas State University, Michigan State University, Montana State University, Ohio State University, Pacific Northwest National Laboratories, Purdue University, Texas A&M University, and the University of Nebraska. CASMGS is currently funded through USDA-CSREES under Public Law 106-224 and is authorized in the 2002 Farm Bill.

CASMGS's main focus is on research and outreach programs related to agricultural soil carbon sequestration, along with nitrous oxide and methane mitigation efforts in the U.S. One outreach and technology transfer mission of CASMGS is to collaborate with scientists, economists, and policy makers to develop internationally a scientific understanding on mechanisms, measurement, monitoring and verification of greenhouse gas mitigation strategies in agriculture. Since its inception in 2002, through the U.S. Department of State, Office of Global Change's bilateral program on climate change, CASMGS has been collaborating with organizations in other countries (Australia, Brazil, Canada, and New Zealand) on research and outreach efforts. The following is a brief description of CASMGS bilateral activities from 2002-2005.

Australia

Lead Australian Contact Organizations:
Australian Greenhouse Office, Cooperative Research Centre (CRC) Greenhouse Accounting; and Queensland University of Technology.

Topic Area: Greenhouse gas accounting and soil-based mitigation in agriculture.

Activities and Accomplishments:

* Dr. Peter Grace, Queensland University of Technology in association with Michigan State University:
    - County-level estimates of soil carbon change in the U.S. North Central Region.
    - Simulated changes in soil carbon in corn production systems of the Midwest.
    - Development of a web-based greenhouse gas emissions calculator for cropping systems.
    - Presented information at a symposium of the joint U.S. - Canada Soil Science Societies meeting in Seattle, WA in November 2004.
    - Presented information at Third USDA Symposium on Greenhouse Gases and Carbon Sequestration in Agriculture and Forestry, held in Baltimore, Maryland, March 21-24, 2005.
* Dr. Jeff Baldock, CRC, Dr. Baldock is working with Dr. Rice's graduate student at Kansas State University on chemical changes in crop varieties as it relates to changes in soil carbon cycling.
* Dr. Charles W. Rice, CASMGS-Kansas State University, visited Australia in December 2004 and again July 2005 to present research results and discuss further collaboration. The July 2005 trip was in conjunction with the U.S. State Dept.'s bilateral negotiations. Future collaboration will include work on methodology framework at field scale, provide experience with producer group organization in voluntary partnerships and facilitate private sector interests and social and economic implications of on-farm actions to reduce greenhouse gas emissions.
* The Australian government is interested in becoming involved with work in the U.S. on Laser Induced Breakdown Spectroscopy (LIBS) technology developed by the Los Alamos National Laboratory. CASMGS researchers plan to test LIBS technology in the U.S.

Brazil

Brazilian Contacts: EMBRAPA: Dr. Alexandre Cadoso, Dr. Carlos Cerri, Universidade de Sao Paulo; Robert M. Boddey, EMBRAPA-Agrobiologia; Dr. Joao Carlos de Moraes Sa, Universidade Estadual de Ponta Grossa; Dr. Telmo Amado, University of Santa Maria.

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Topic Area: Soil carbon sequestration and nitrous oxide emissions in agriculture.

Activities:

* Dr. Rattan Lal (Ohio State Univ.) organized a symposium in Brazil on soil carbon sequestration in Central and South America held in June 2004. Dr. Lal , Dr. Izaurralde (PNNL) and Dr. Rice participated in the symposium and a publication will be released later this year.
* Dr. Rice participated in the 15th Brazilian Soil and Water Conservation meeting in July 2004 in Santa Maria, Brazil. And at the National No-Till meetings in Iguassu Falls, Brazil.
* Dr. Cerri participated in the symposium on agriculture mitigation at the joint U.S. and Canadian Soil Science Societies meeting in November 2004.
* Dr. Telmo Amado (Univ. of Santa Maria) presented information at Third USDA Symposium on Greenhouse Gases and Carbon Sequestration in Agriculture and Forestry, held in Baltimore, Maryland, March 21-24, 2005.
* K-State and the University of Santa Maria has signed an agreement for faculty, student and research exchange. This agreement between the two universities was supported by the farmer in southern Brazil.

Canada

Lead Canadian Contact Organization:

National Soil Carbon and Greenhouse Gas Accounting and Verification System (NCGAVS).

Topic Area: Measurement and monitoring of soil carbon and greenhouse gas emissions in agriculture.

Activities and Accomplishments:

* Carlos Monreal, NCGAVS, presented information at the joint U.S. and Canadian Soil Science Societies meeting in November 2004.
* Bert VandenBygaart presented information at Third USDA Symposium on Greenhouse Gases and Carbon Sequestration in Agriculture and Forestry, held in Baltimore, Maryland, March 21-24, 2005.

New Zealand

Lead New Zealand Contact Organizations:

New Zealand Climate Change Office; Landcare Research; Lincoln University, AgResearch; National Institute of Water and Atmosphere.

Topic Areas: Soil carbon sequestration; nitrous oxide emissions; measurement and modeling techniques.

Activities and Accomplishments:

* Dr. Charles W. Rice, CASMGS-Kansas State University, visited New Zealand in July 2005 to present research results in conjunction with the U.S. State Dept.'s bilateral negotiations. Future collaboration will include work on measurement and modeling of nitrous oxide emissions and new technologies for soil, micrometeorological and atmospheric measurement of GHG emission at the farm and regional scales.
* Dr. Rice presented a seminar at Massey University on Soil's Role in Mitigation of Greenhouse Gases in July 2005.

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CAS MGS
Consortium for Agricultural Soils Mitigation of Greenhouse Gases

The Many Environmental Benefits Associated with Soil Carbon Sequestration

Among the challenges facing agricultural producers in Kansas are profitability, high energy costs, soil erosion, soil organic matter levels and soil quality, protecting water quality, and water use efficiency. It is vital to encompass as many of these concerns as possible into a comprehensive set of soil and crop management systems. To accomplish this, there are three primary goals of current and future research on soil and crop management systems in Kansas: (1) to provide sustainable profitability for producers and landowners in the short- and long-term; (2) to help protect and improve surface and ground waters in Kansas; and (3) to protect and improve soil quality in Kansas. It is important to develop a combination of practices that can accomplish all of these goals. It is equally important that the practices are sufficiently profitable, and environmentally beneficial enough to encourage government incentives and/or market rewards.

Focusing on the goal of **increasing soil organic matter levels** is perhaps the most effective way to achieve all of these objectives. Increasing organic matter levels improves not only soil quality, but increases short- and long-term soil productivity, improves water quality, increases the sustainability of the ecosystem, and increases the economic value of the land. Higher organic matter levels are directly tied to soil fertility and crop production capacity. William Richards, former Chief of USDA's Natural Resources Conservation Service, estimates that for every one percent increase in soil organic matter content (e.g. going from 2% to 3% organic matter), the value of farmland in Ohio increases by $250 per acre. Soil and crop management practices that increase soil organic matter levels provide collateral benefits by **reducing soil erosion, conserving water, and improving water quality**.

Now is the time for agriculture to position itself to provide services that offer substantial environmental benefits to society at large, and potentially receive income for those beneficial services. These services would be in addition to, and a direct result of, management practices that protect short- and long-term profitability. Such services include:

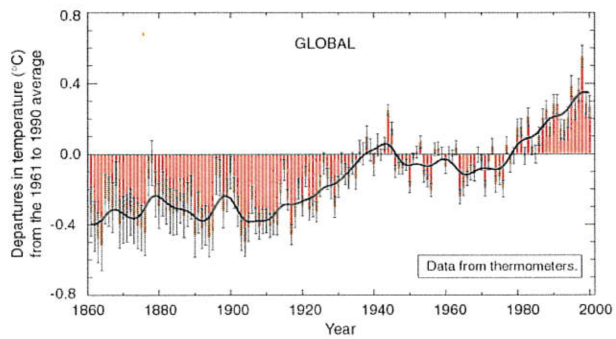
* Soil carbon sequestration
* Water quality improvements
* Biofuel production
* Improved wildlife habitat

Soil carbon sequestration is the most immediate result of practices designed to increase soil organic matter levels. It is estimated that 20% or more of targeted greenhouse gas emission reductions can be met by agricultural soil carbon sequestration, at a cost lower than other methods of greenhouse gas mitigation.

In addition, soil carbon sequestration is uniquely positioned to provide multiple benefits to producers and society. Additional benefits of carbon sequestration practices include improved soil and water quality, and greater efficiency and profitability of the agricultural enterprise. Soil carbon sequestration will reduce the buildup of greenhouse gases in the atmosphere while improving American's farmland and the agricultural economy.

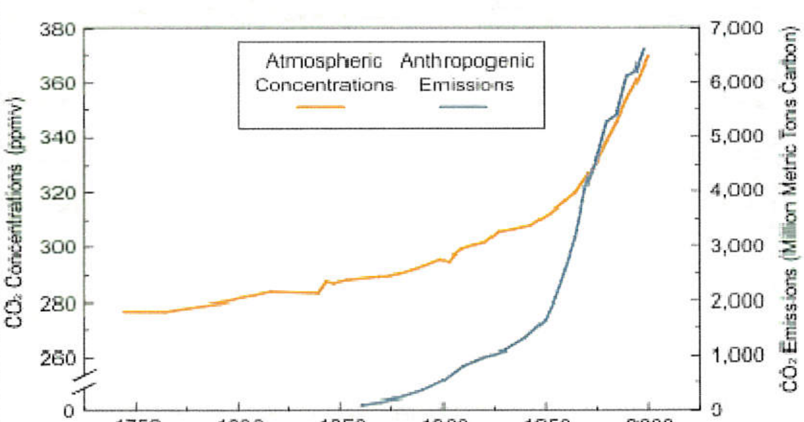
Global Warming and the Role of Terrestrial Soil Carbon Sequestration

Global temperatures have been increasing over the past 150 years. There are fluctuations from year to year, but the trend is definitely upward. This warming trend is generally referred to as the greenhouse effect.



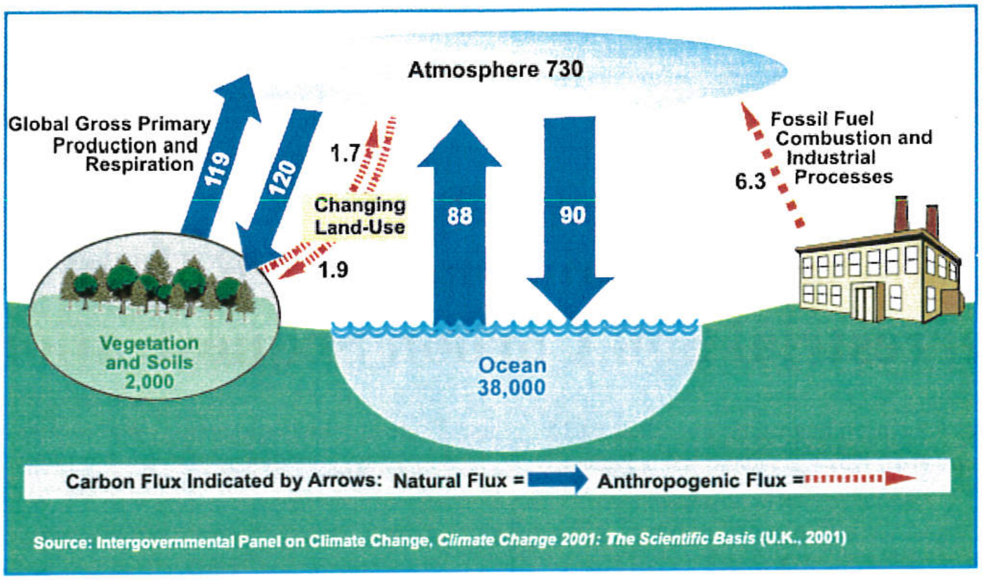
Source: Climate Change 2001: The Scientific Basis, Report of the Intergovernmental Panel on Climate Change

The rise in global temperatures has corresponded with an increase in levels of several important greenhouse gases, such as carbon dioxide, methane, and nitrous oxide. CO_2, for example, has increased by about 25 percent since large-scale industrialization began around 150 years ago. During the past 20 years, about three-quarters of human-made CO_2 emissions were from burning fossil fuels.

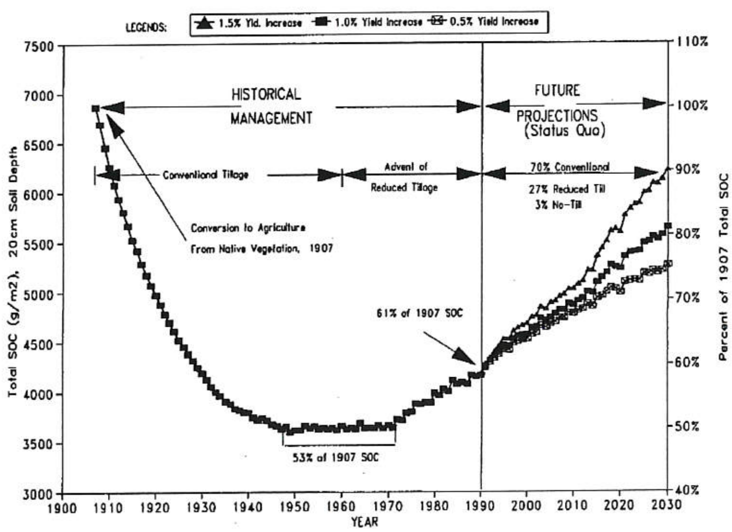


Source: Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center, http://cdiac.esd.ornl.gov/.

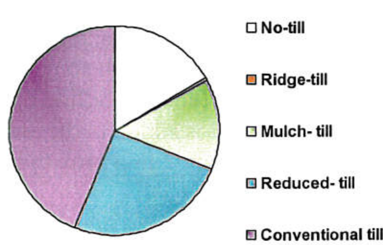
Carbon dioxide in the atmosphere is in a constant state of flux within the ecosystem. This is called the Carbon Cycle. The movement, or "flux," of carbon between the atmosphere and the land and oceans is dominated by natural processes, such as plant photosynthesis. While these natural processes can absorb some of the net 6.3 billion metric tons of anthropogenic carbon dioxide emissions produced each year (about 2 billion by the ocean and 1 billion by terrestrial systems), that leaves an estimated 3.2 billion metric tons that is added to the atmosphere annually. The Earth's positive imbalance between emissions and absorption results in the continuing growth in greenhouse gases in the atmosphere.



The goal of terrestrial soil carbon sequestration is to increase the amount of CO_2 that is absorbed from the atmosphere by vegetation and soils. It is estimated that with improved agricultural practices such as no-till, grass plantings, conservation measures, and improved grazing management that agriculture could increase terrestrial soil carbon sequestration enough to mitigate about 20 percent of the increase in CO_2 emissions. Nearly all of the soils that have been under cultivation have less soil carbon now than 150 years ago, and could hold more soil carbon if improved management practices were implemented. There is considerable room for improvement within Kansas in agricultural management to increase terrestrial soil carbon sequestration. As of 2002, only about 20 percent of the acreage in Kansas was under no-till management. With ongoing research and outreach efforts, K-State's CASMGS team will continue to help mitigate greenhouse gases by encouraging producers to use no-till and other practices that sequester more soil carbon.



Percentage of the total planted area (acres) under different tillage systems in Kansas 2002



Consortium for Agricultural Soils Mitigation of Greenhouse Gases

State Initiatives to Control Greenhouse Gases

There have been some important initiatives by certain states, and coalitions of states, to address the global warming issue. A new regional effort by seven Northeastern states to limit greenhouse gas emissions is one example.

At the heart of the Regional Greenhouse Gas Initiative (RGGI) is a "cap and trade" program that sets a fixed limit on CO_2 emissions. The right to emit the gas then becomes a tradable commodity on Jan 1, 2009. Companies that produce less carbon dioxide can sell their credits to others, giving an economic incentive to cut emissions and sell, rather than buy, credits.

The RGGI caps regional CO_2 emissions at 121.3 million short tons through 2014, then cuts them to 10 percent below that level by 2018. Each state in the group - Delaware, Connecticut, Maine, New Hampshire, New Jersey, New York, and Vermont - will get an emissions budget. Massachusetts and Rhode Island backed out of the agreement, though they may join later.

Most companies that emit CO_2 prefer cap-and-trade to regulatory approaches, which they say can require installing costly technologies, or to carbon taxes paid to the government. Cap-and-trade has been credited with helping cut power-plant emissions of smog-forming nitrous oxides and sulfur dioxide in the 1990s.

The Northeast pact is different from the strategy of the Bush administration, which has not endorsed using cap-and-trade for CO_2 emissions control, preferring instead to promote research into emissions-control technology.

Some hope the Northeast pact will be a model for other regions and, in the end, build pressure for a uniform, national program.

Oregon, Washington, and California are one possible regional combination. Minnesota, Wisconsin, and other states in the upper Midwest tier are another.

In other state actions, California and New York have adopted new greenhouse gas emissions standards for cars. The most recent action was taken by New York and Vermont. All 2009 and later model cars sold in New York will have to meet higher fuel efficiency standards, under new carbon dioxide emissions guidelines approved by the state's Environmental Board.

New York becomes the second of six Northeastern states considering similar rules to adopt emissions standards like those in California -- the only state with stricter guidelines than the federal government. Vermont recently adopted the guidelines.

California, which adopted the new law last year, plans to force automakers to limit greenhouse gas emissions from cars and trucks sold in the state beginning in 2009. The regulations would require new vehicles in 2012 to emit 22 percent less carbon dioxide than today's vehicles. GHG reductions of up to 30 percent would be required by 2016. Automakers have sued to overturn the new rules. The auto industry has said that only the federal government should be allowed to regulate such standards."

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Soil Organic Carbon and the Global Carbon Cycle

Department of Agronomy **MF-2548** **Carbon Series**

Carbon is the fundamental building block of all life. Carbon is present in the atmosphere, in plant and animal life, in nonliving organic matter, in fossil fuels, in rocks, and dissolved in oceans. Movement of carbon molecules from one form to another is known as the carbon cycle (Figure 1). Plants acquire carbon from the atmosphere through photosynthesis. Using carbon dioxide (CO_2) from the atmosphere and energy from sunlight, plants convert CO_2 to organic carbon as they produce stems, leaves, and roots. The cycle of life and death of plants results in accumulation of decomposing plant tissue, both aboveground and belowground (plant roots), and produces a significant amount of soil organic carbon.

Soil Organic Carbon

Soils vary in the amount of soil organic carbon[1] they contain, ranging from less than 1 percent in many sandy soils to greater than 20 percent in soils found in wetlands or bogs. Kansas soils had a native soil organic carbon content ranging from 1 to 4 percent. Most Kansas cultivated soils now have soil organic carbon levels of 0.5 to 2 percent.

In Kansas, native prairie grasses, such as big bluestem (*Angdropogon gerardii* Vitman) and Indiangrass (*Sorghastrum nutans* (L.) Nash), helped develop deep soils. Roots of these and other grass species are fibrous, and can grow to great depths, producing a majority of their annual biomass belowground. Consequently, the significant organic carbon level in soils that developed under native grasses occurs to a depth of several feet. The dark black color associated with rich, fertile soil is largely a measure of its organic carbon content. As a soil's organic carbon content drops, the soil's color lightens and reflects its mineral content. Thus the red soils of southeastern Kansas and northeastern Oklahoma are indications of higher iron concentration and lower soil carbon levels.

Soils that form under forests tend to accumulate high levels of soil organic carbon near the surface and have lower carbon levels in the subsoil. This layering of soil, is primarily due to the accumulation of leaf litter and decaying wood from limbs and trees that accumulate at the soil surface. But soil layering is also a function of higher annual rainfall and the accelerated weathering process that enriches the subsoil with clay.

Atmospheric Carbon

Scientists using ice core data, combined with long-term monitoring of CO_2 in the atmosphere, have verified tremendous fluctuations in atmospheric CO_2 over the past 200,000 years. Looking at the past 1,000 years, atmospheric CO_2 levels have increased significantly (Figure 2). The current level (2000 A.D.) of CO_2, approximately 369 ppm, is now higher than at any time in the past 1,000 years. More importantly, this unprec-

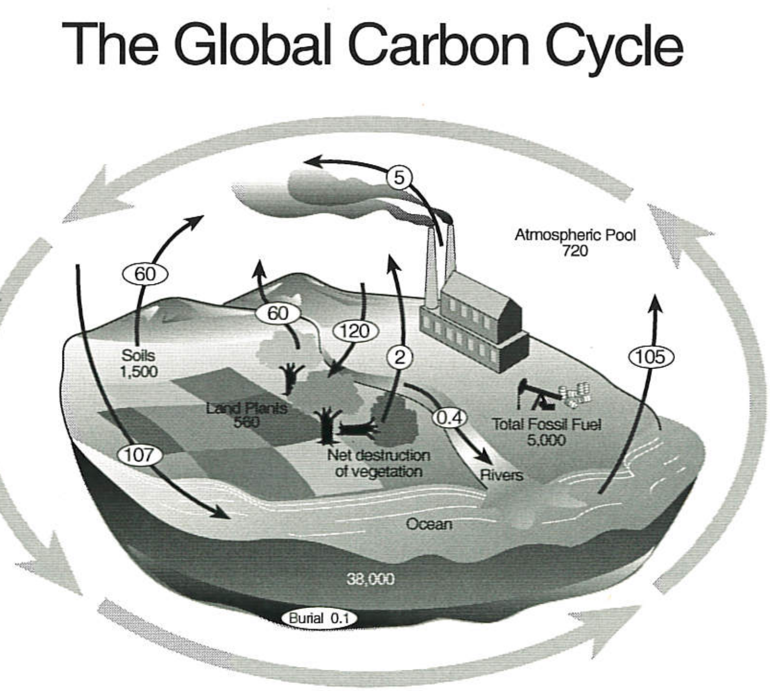

Figure 1. *The present-day global carbon cycle. All pools are expressed in units of gigatons of carbon, and rates are gigatons of carbon per year. (from: Schlesinger, 1991)*

[1] *Note: The chemical formula for soil organic matter is very complex, but consists primarily of organic carbon, nitrogen, and hydrogen. To convert soil organic matter (%OM) as reported in most soil tests to just soil organic carbon, divide percent organic matter by 1.7.*

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edented rate of increase has accelerated so quickly that the ecosystem may be unable to adapt.

This rise in CO_2 corresponds with the use of fossil fuel, land clearing, and land use change as seen here in the Great Plains and around the world. The most significant factor that explains rising atmospheric CO_2 levels is fossil fuel use. At the current use rate of 5 Gt carbon per year, (Gt stands for a gigaton, which equals 2.2 trillion pounds), the total reserves of fossil fuel will likely be exhausted during the next 300 to 400 years.

As the fossil fuel inventory is expended, carbon that has been out of the cycle for millions of years is moved directly to the atmosphere. Atmospheric carbon will eventually cycle back into organic carbon, or into the oceans and reach a new equilibrium, but the process may take thousands of years to occur.

In the short-term, this "new" carbon will remain in the atmosphere as CO_2. Current atmospheric models predict that the complete expenditure of the fossil fuel reserves will drive peak concentrations of atmospheric CO_2 to levels near 1,200 ppm. Some scientists believe even higher concentrations will occur. This increased level of CO_2 has led some scientists to believe that the average global temperatures may begin to increase. In the popular press this is referred to as global warming. The so-called greenhouse gases, CO_2, methane (CH_4), and nitrous oxide (N_2O) that exist in the atmosphere, help retain heat that normally radiates away from the earth's surface. With greater concentrations of these gases, heat may not be able to escape, resulting in increased global temperatures. Changes in global temperatures so far are slight and show no definite trend, but changes in atmospheric CO_2 levels are well documented and are accepted by most scientists.

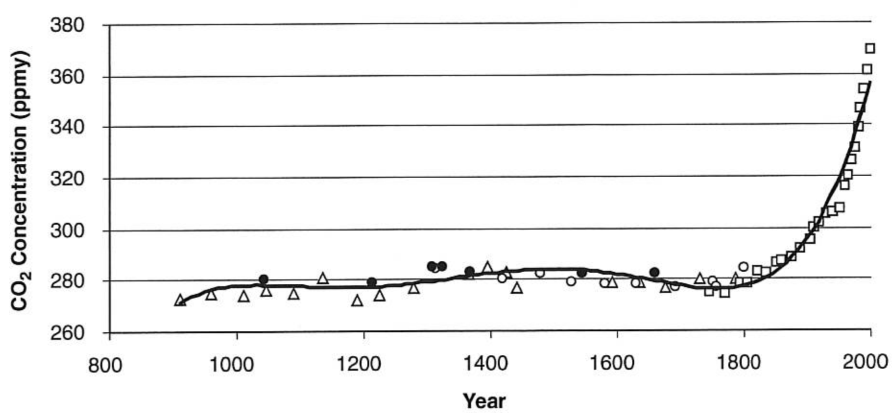


Figure 2. Changes in atmospheric carbon dioxide levels. (Note: This graph shows CO_2 levels from ice core data from Greenland, and Antarctica (various symbols represent different sampling sites) + monitoring at Mauna Loa, through ~2000. (Adapted from IPCC, 1995, and from CDIAC, U.S. Department of Energy, 2002)

Managing Carbon

What can be done to slow or reverse the increase in CO_2? Thinking in terms of sources, where CO_2 is produced, and sinks, where CO_2 is removed, an obvious solution is to reduce input of the source, by reducing fossil fuel use. This would limit the input of CO_2 to the atmosphere. Eventually, cleaner and more efficient energy sources will be required, but the current economics of fossil fuel limits the adoption and development of alternative energy sources. In the interim, as we develop alternative energy technologies, increasing the use of sinks may help stabilize atmospheric CO_2 levels.

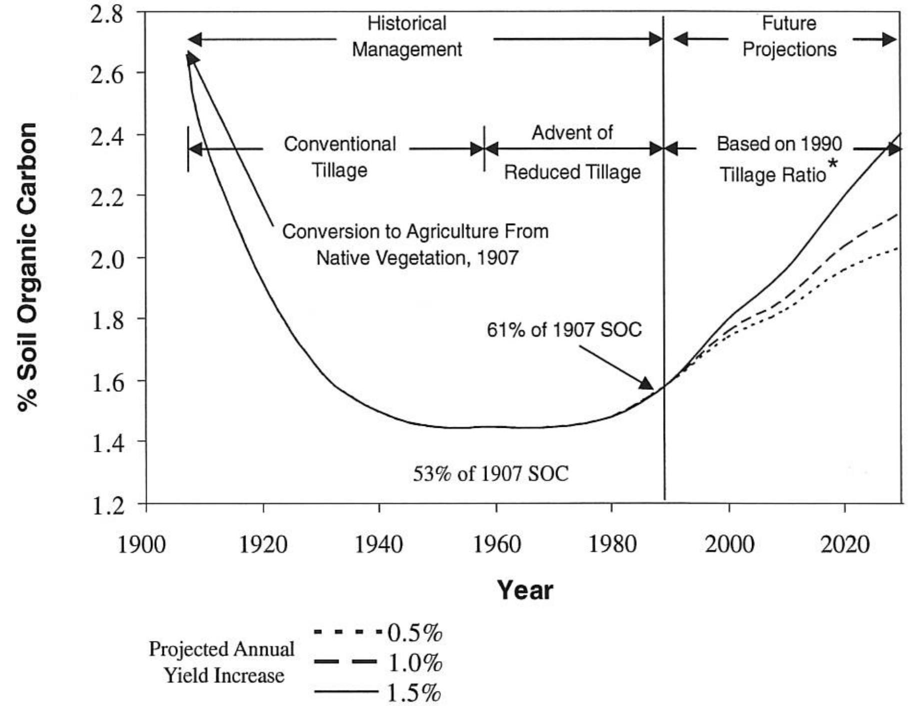
An inventory of the world's carbon reservoirs (Figure 1) illustrates that carbon storage in the deep oceans is the major reservoir, but changes to this pool can take millions of years. In addition, our ability to manipulate that pool is limited. The next biggest pool is soil organic carbon. Soil organic carbon constitutes more than twice as much stored carbon as that of the earth's vegetation (plants, trees, crops, and grasses). One way to help stabilize atmospheric CO_2 would be to adopt practices worldwide that increase soil carbon levels.

How much carbon can be stored in a given Kansas soil? It's a simple question, but there is no simple answer. Storage potential for the soil is a function of the soil's current organic carbon level, atmospheric CO_2 concentration, and soil-management practices. For many Kansas soils, significant topsoil losses due to erosion, and frequent tillage operations have reduced carbon levels to less than half of their native values. With proper management, soil organic carbon of most soils can be increased.

Losses of soil carbon over the first half of the 20th century were partly recovered in the second half as soil conservation practices improved and cropping systems intensified (Figure 3). Proper fertility practices and improved hybrids and cultivars have also played a role in building soil organic carbon levels. Higher yields and greater cropping intensities increase the amount of biomass returned to the soil, providing a larger input that can become soil organic carbon. The right-hand side of Figure 3 shows future projections of soil organic carbon levels assuming 1990 tillage and cropping practices.

Soils that are managed with no-tillage and intensified cropping systems could increase soil carbon at the rate of 0.1 percent per year. Currently in Kansas 10 percent of the 21 million acres of cropland is under no-tillage management and should be sequestering an additional 21,000 tons carbon per year. Increased adoption of no-tillage and intensified cropping systems would sequester more carbon.

Worldwide, the potential to use soil as a carbon sink does exist, but remains a short-term solution. After some period of time, likely 30 to 50 years, a new soil organic carbon equilibrium level will be reached, where further gains in carbon storage will be difficult to achieve. The long-term solution to stabilizing atmospheric CO_2 levels will involve reducing our dependence on fossil fuel for energy.



*1990 levels = 70% Conventional; 27% Reduced Till; 3% No-Till

Figure 3. *Measured and predicted changes in soil organic carbon content of a prairie soil throughout the period of cultivation. (from: Donnigan et al., 1998)*

Summary

Carbon is the building block of plant life and a major constituent of soil organic matter. Carbon dioxide is the gaseous form of carbon and is a greenhouse gas. Since the beginning of the industrial revolution, CO_2 levels have risen at a rate of approximately 1.5 percent per year. The continued rise of atmospheric CO_2 concentration could lead to global warming. Fixation of CO_2 by plants into soil organic carbon is one possible mechanism for reducing the rise of CO_2 concentration in the atmosphere. A long-term reduction in atmospheric CO_2 levels will require a reduction of fossil fuel use and development of alternative energy sources.

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Plan Gives Farmers a Role in Fighting Global Warming

THE NEW YORK TIMES, TUESDAY, NOVEMBER 25, 2003

By DAVID BARBOZA

MANHATTAN, Kan. — In an unlikely alliance, Kansas Republicans and the advocacy group Environmental Defense are supporting an effort here that seeks to use agriculture as a weapon against global warming.

While the Bush administration and some Republican lawmakers have expressed skepticism about human causes of global warming, Senator Pat Roberts, a Kansas Republican and an ardent supporter of President Bush, has helped Kansas State University win part of a $15 million grant for a group of institutions to study whether a form of farming called "conservation tillage" can really help combat the effects of global warming.

In an interview, Mr. Roberts said he saw evidence of global warming for himself in 1998, when he was part of a Congressional delegation that visited the South Pole.

Now, Mr. Roberts and Environmental Defense, the group best known for fighting on behalf of wetlands and threatened species, like the red-legged frog, speculate that if farmers change the way they farm their land, they can pull carbon out of the atmosphere and help mitigate the effects of global warming, and get paid for doing so.

There are already proposals to trade carbon credits like hog or cattle futures.

Some big corporations operating in countries that signed the international climate treaty known as the Kyoto Protocol are planning to use the carbon credit system that the protocol established, if the protocol takes effect. They intend to pay farmers in participating countries for carbon credits while they search for other ways to cut their carbon emissions. President Bush has rejected the Kyoto agreement. Congress is now considering a system that will cap national carbon emissions and allow the trading of carbon credits among farmers.

"This is an enormous opportunity for farmers," said Richard Sandor, who helped pioneer Chicago futures trading in the 1970's and now leads the Chicago Climate Exchange, the start-up venture that will soon begin trading the rights to emit gases associated with global warming. "They can now grow two crops: one above the ground — food; and one below ground — carbon."

Mr. Roberts wants the federal government to offer incentives to farmers who help improve the environment and replenish the soil with much-needed carbon.

"It's simple: carbon in the air — bad; carbon in the soil — good," Mr. Roberts said recently in a telephone interview. "We've got to get more out of the air and into the soil."

Catching and holding carbon is called sequestration. It keeps the carbon from being incorporated into carbon dioxide or other greenhouse gases that contribute to global warming.

In agriculture, sequestration involves using an array of land management techniques, like no-till farming, in which tractors do not plow the land before planting, that improve the soil and that allow plants to better absorb carbon from the atmosphere.

> 'The Kansas prairie is a great big carbon sponge.'

About 10 percent of Kansas farmers already practice no-till farming (largely because of the soil benefits), but experts say that this technique and some others, like the new forms of crop rotation and the use of "cover crops" during the winter, could help alter the environmental landscape.

One way to reduce carbon in the atmosphere is to cut emissions from cars and power plants. Using agriculture to pull carbon from the atmosphere is an alternative.

"It's estimated that American agriculture can offset about 20 percent of carbon emissions in the U.S.," said Dr. Charles Rice, a professor of soil microbiology at Kansas State, which is part of a consortium of universities studying carbon sequestration. "If we had to switch from coal and oil to hydrogen immediately, we couldn't do it. It's not economically or technologically feasible."

There are, of course, some scientists and environmental groups, like Greenpeace, that are critical of carbon sequestration. They favor sticking to stricter controls on power plant and industrial carbon emissions as a way to combat global warming. They say land management techniques may let heavy industries off the hook and prevent them from curbing emissions.

Other experts doubt that trustworthy ways can be found to measure how many tons of carbon are banked, and thus how many credits a farmer may earn.

Then there is the question of permanence, some say. What if a farmer gets credits that are sold to a utility, and then the soil is mismanaged and carbon lost?

But scientists and environmental experts say whether or not heavy industry curbs emissions, carbon sequestration is a powerful tool in the effort to improve degraded soils and the combat global warming.

"We just see this as a tremendous opportunity for farmers and the environment," said Melissa Carey, a climate change policy expert at Environmental Defense. "You can get atmospheric benefits, water quality, soil quality, local air quality benefits. That's a pretty attractive package."

In pushing the benefits of conservation tillage, and the work being done at Kansas State, Environmental Defense has also scored some big political points: an alliance that means that a prominent Republican is involved in global warming issues.

Indeed, Senator Roberts is leading a spirited push here in Kansas, a state dominated by agriculture.

"The Kansas prairie is a great big carbon sponge," Mr. Roberts said. "If you pay the farmers to maintain these conservation projects, you'd be able to clean up the environment."

Carol T. Powers for The New York Times

Senator Pat Roberts wants to pay farmers who replenish the soil.

To reap these benefits, however, farmers will have to change the way they farm the land.

One of the most significant changes would be moving to no-till farming. Soil experts say plowing the soil releases carbon stored underground, it degrades the soil and contributes to soil erosion and other problems.

"Tillage is one of the worst things you can do to the soil," said Dr. Rice at Kansas State. "Spraying the soil with a chemical is often less harmful."

By not tilling the soil, and allowing plant life and natural debris to decompose, agricultural experts say, the soil will strengthen and more readily absorb carbon from the atmosphere through plant photosynthesis.

Researchers say that for centuries farmers have depleted soils by constant plowing, typically to kill weeds.

By some estimates, about 50 percent of the carbon stored under agricultural lands has been lost over the last 200 years because of plowing and turning over the soils.

Pulling that carbon back into the soil, and keeping it trapped there by simply planting in the dead plant debris after winter will not only improve the soils, experts say, it will help solve a host of other environmental problems as well, like soil erosion.

"Soil degradation is the No. 1 environmental problem," said Dr. Rattan Lal, a professor of soil science at Ohio State University and one of the leading authorities on carbon sequestration. "It leads to water quality problems, soil problems and the release of greenhouse gases into the atmosphere," he said. "We now have six billion people; by 2050 we'll have nine billion. To do that we'll have to double food production. And to do that we're going to have to put nutrients back into the ground. Conservation tillage is one way to feed the people, and it also leads to carbon sequestration and mitigates global warming."

Of course, farmers have been reluctant to abandon age-old traditions of plowing the soil, but new equipment and chemicals are making no-till farming more popular around the world.

With conservation tillage, herbicide use to control weeds does increase, but some researchers say the additional herbicides are not more harmful because the reduction of erosion leads to less runoff and because water filters through the soil better, leading to better degradation of the chemicals.

Dr. Rice has several experimental plots where he is evaluating soil from plowed land and soil from no-till land. "Look, there's carbon trapped inside of these," he says after picking up chunks of no-till soil and cupping them in his hand.

Researchers here and at other universities are now trying to find ways to measure carbon absorption in the soil. But they warn that even if America's agricultural land is made super-absorbent, the soils can only absorb so much carbon before they become saturated.

That could take 30 or more years. But after that, researchers here say, big industry will either have to cut emissions, or find new ways to combat global warming.

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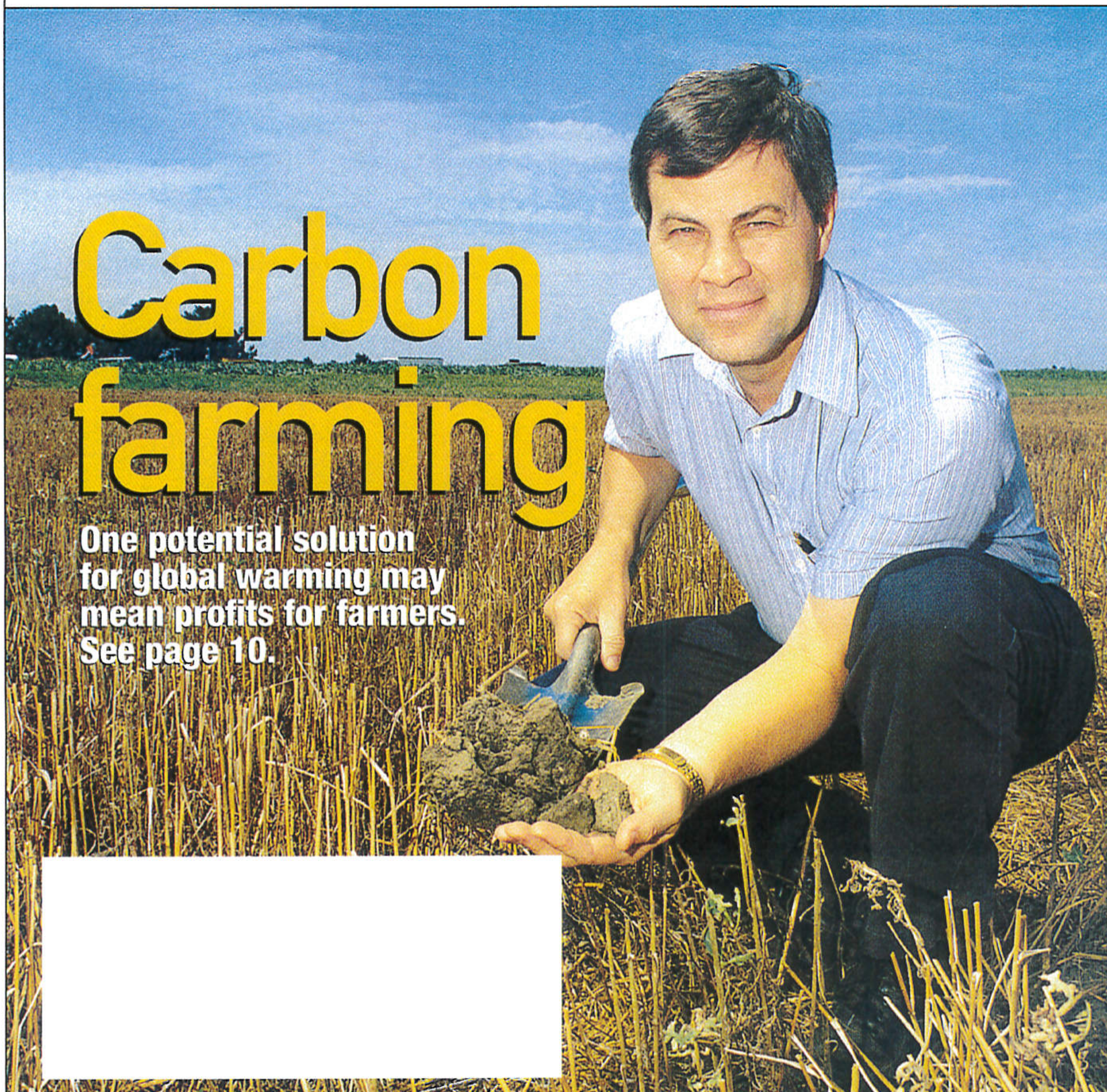

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COVER STORY

Carbon farming

One potential solution for global warming could mean profits for farmers. ■ *By Bill Spiegel*

So entrenched are farmers in tradition that the notion of getting paid for something other than grain or livestock production seems a tad askew. A new and growing concept of being paid for practices that could reduce global warming seems almost too good to be true.

This concept — called carbon sequestration — is gathering momentum. In June, the USDA announced a plan to invest $3.9 billion in 2004 alone in agriculture and forest conservation on private land with the goal to eliminate more than 12 million metric tons of greenhouse gas emissions each year by 2012. And in October, a company called the Chicago Climate Exchange will begin trading carbon credits in an environment similar to brokers trading corn and wheat contracts.

Farmers may eventually get paid to practice farming methods that store carbon in the soil, but researchers say farmers will be rewarded with benefits other than money. Preserving crop residue improves soil organic matter, which is just good agronomics.

WHAT IS CARBON SEQUESTRATION?

Carbon sequestration is a term used to describe the process of transforming carbon currently in the air — carbon dioxide — into stored soil carbon. Carbon dioxide is taken up by plants through photosynthesis. As plants die, the carbon-based leaves, stems and roots decay in the soil and become organic matter.

Capturing carbon in the soil is good for building up organic matter, but it also means less carbon escapes into the atmosphere. Scientists believe that carbon dioxide in the atmosphere is one cause of global warming; so, capturing carbon in the soil is just one way to help prevent global warming.

"As a compound, carbon dioxide absorbs heat," explains Chuck Rice, soil microbiology professor at Kansas State University. "The amount of carbon dioxide in the atmosphere has increased from 280 parts per million in the late 1800s to about 360 parts per million today. That number continues to increase at an exponential rate." Rice says the amount of carbon dioxide in the atmosphere increases by more than 3 billion tons of carbon each year.

THE EFFECT OF GLOBAL WARMING

It's difficult to prove the phenomenon of global warming. But there is no mistaking that around the world, strange weather occurrences abound: in Canada, lakes freeze later and thaw earlier than in the past; glaciers in Antarctica are melting and in Europe, the climate is more variable than ever before.

Scientists believe the blame for carbon sequestration is multifaceted. "We are a carbon-based economy," Rice says. "We use extraordinary amounts of fossil fuels."

Automobiles, factories — even agriculture shares the blame, he continues. Merely turning over native prairie to plant crops released huge amounts of carbon dioxide in the atmosphere.

"We've lost half our carbon due to plowing and tillage," he explains. "Now we have the opportunity to increase the amount of soil-stored carbon."

The Consortium for Agricultural Soils Mitigation of Greenhouse Gases (CASMGS) estimates that 20 to 40% of targeted emission reductions can be met by agricultural soil carbon sequestration. It is anticipated that farmers using conservation practices could sell carbon "credits" to those

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industries that emit large amounts of carbon in the atmosphere.

A pilot program between Entergy, a Louisiana-based energy company and the Pacific Northwest Direct Seed Association (PNDSA) is under way. Under terms of this agreement, Entergy pays the farmers in the PNDSA a small stipend — about $2 per acre — for conservation practices. The farmers — all no-tillers — will agree not to till the soil for 10 years.

Rice estimates that farmers could receive $10 or more per acre for carbon sequestration eventually. Someday farmers may plant crops and use tillage systems designed to capitalize on carbon credits.

Chuck Rice, agronomist at Kansas State University, is director of the Consortium for Agricultural Soils Mitigation of Greenhouse Gases, a group of 10 land-grant universities searching for methods to sequester carbon in the soil.

THE NO-TILL EFFECT

Sequestering carbon in the soil is just good agriculture practice, says K-State's Rice.

"If we're doing agriculture right, we always want to maintain organic matter in the soil," he says. "A large part of organic matter is carbon. There's always been a concern to maintain organic matter."

Science proves that farmers practicing no-till have greater amounts of carbon in the soil. "Tillage, or mixing soil with crop residue, adds oxygen to the soil, which feeds soil microbes and breaks down residue," Rice says. "No-till slows the process. Carbon is trapped in the soil particles and is not available for digestion by soil microbes."

There are additional benefits to farmers that apply practices that conserve carbon.

"We would like farmers to sequester carbon for other reasons, including the increase in organic matter and the improvement in soil conditions," says Brian Lindley, coordinator of No-Till on the Plains Inc., a Kansas no-till organization. "Those are ultimately more beneficial reasons at this time than the money farmers will get from carbon sequestration. But it all works together."

OTHER APPROACHES

There are other methods of sequestering carbon. In extreme cases, factories filter carbon out of smokestacks and pipe it deep into the soil, an approach called geologic sequestration. In ocean sequestration, businesses channel filtered carbon deep into the bowels of the Earth's oceans, where the combination of extreme cold and water keep the carbon from reaching the atmosphere.

None of these options, however, is as inexpensive as biologic sequestration, or counting on the world's farmers and foresters to use crops, grassland and forests to sequester carbon into the earth.

But Rice says farmers must work together to be attractive to carbon traders. Carbon traders are looking for thousands of acres in which to buy carbon credits rather than small tracts of land. Because of that, an effective system of checks and balances must be enabled. For starters, verification of agricultural practices must take place. It could be as simple as drive-by spot checks, measurement of carbon in the soil or computer models.

"The verification process is likely to be a combination of the three testing methods," Rice says. "You just can't cost-effectively measure carbon in every field. You must use good science."

Rice adds that soils cannot hold infinite amounts of carbon. "Thirty to fifty years down the road, the soil could be saturated with carbon," he says. When that happens, carbon again will return from soil to the environment. By that time, however, new, non-fossil fuel dependent sources of energy will be found.

"[Carbon sequestration] buys us time," Rice explains. "We have a window of opportunity to enhance our energy policy."◆

Editor's note: Next month we'll examine in more detail how farmers may capitalize on trading carbon credits, and investigate how the Chicago Climate Exchange works.

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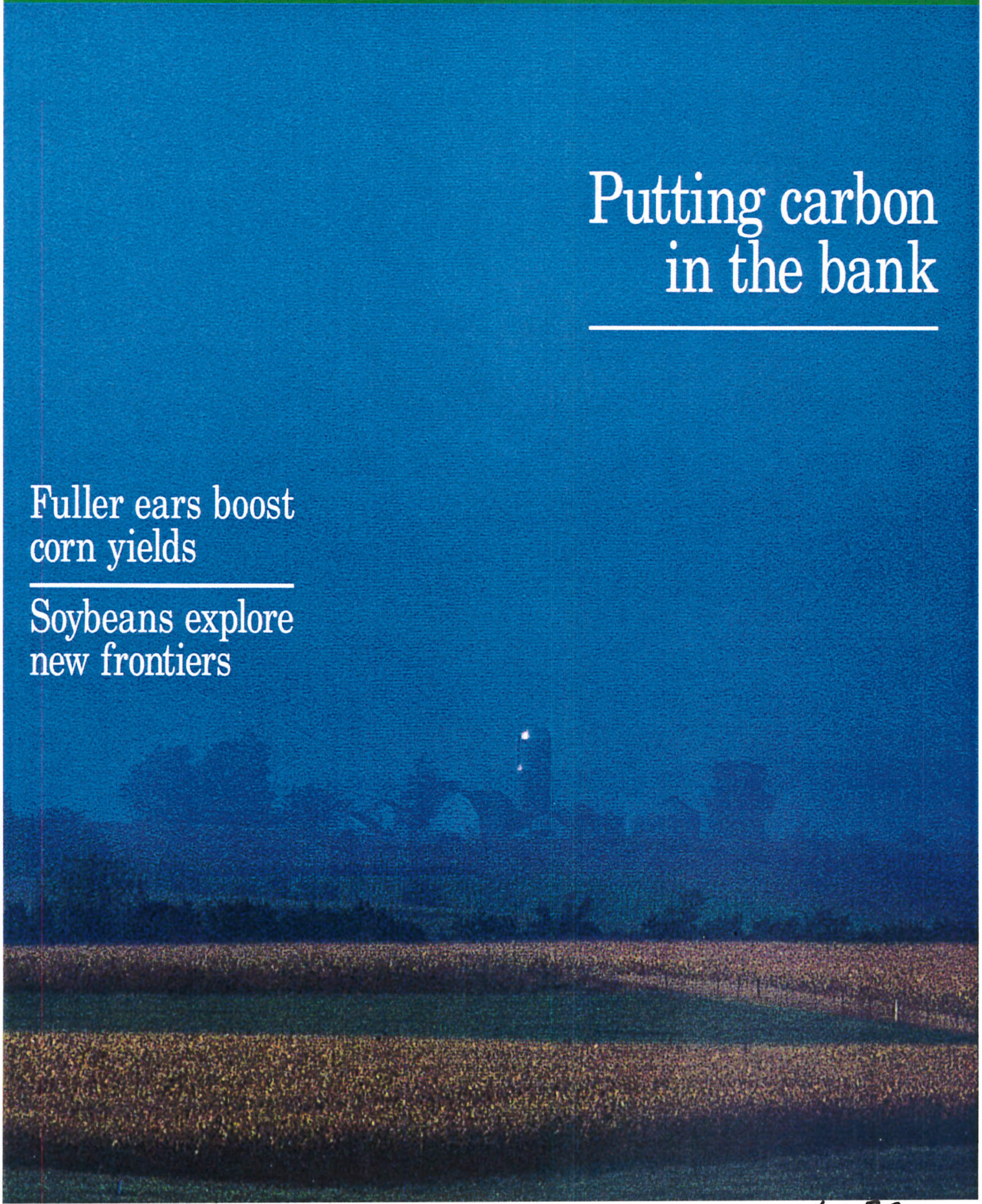
THE FURROW
SPRING 2002



Putting carbon in the bank

Fuller ears boost corn yields

Soybeans explore new frontiers

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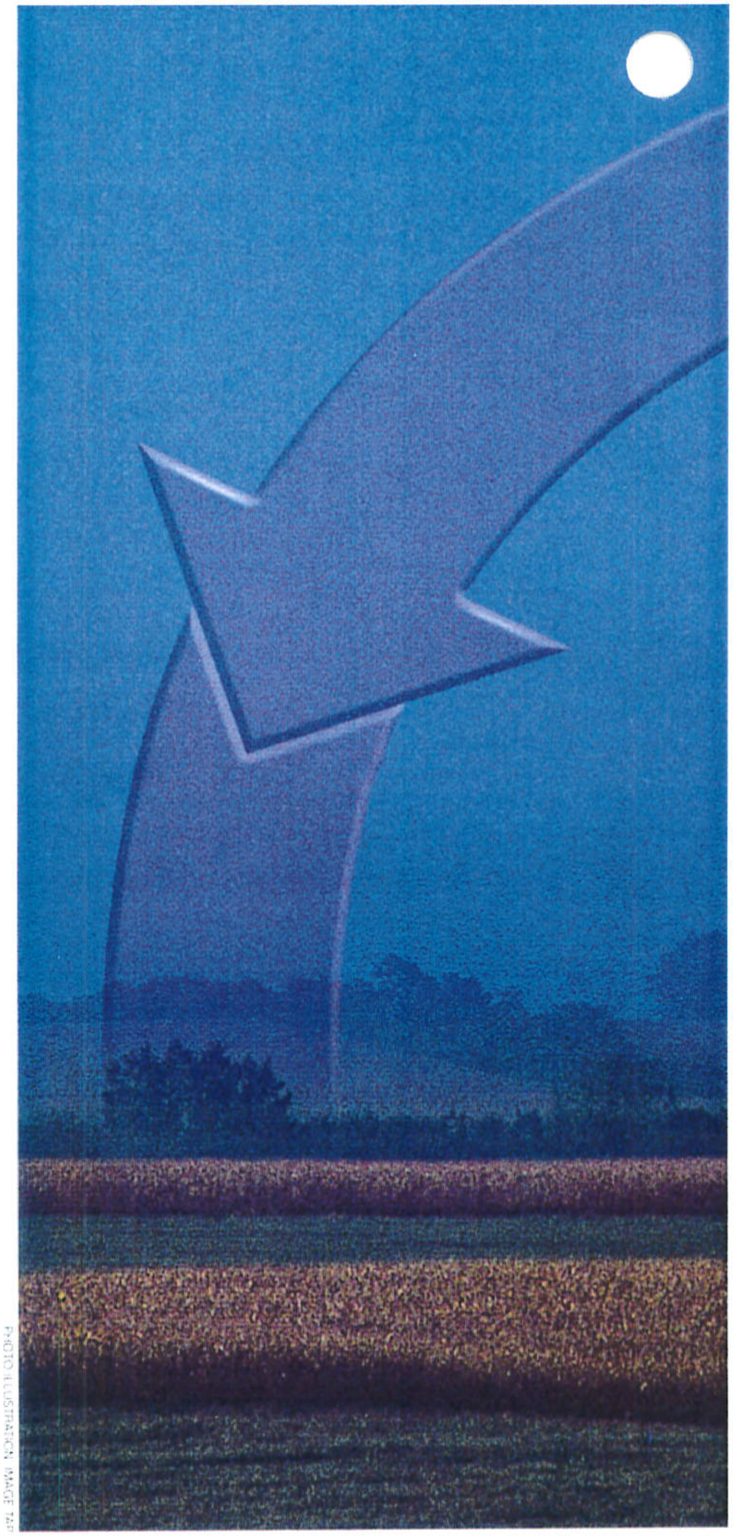
By Karl Kessler

CARBON WHAT?

Carbon sequestration can help clean up the earth's atmosphere, and add to your bottom line as well



Carbon sequestration hasn't become an everyday term in coffee shops and grain elevators yet, but the next time you hear it, you might want to listen up.

There's been more than a little talk about farmers and ranchers actually getting paid to sequester carbon, and at least a couple of fledgling programs are trying their wings. But even if a full-scale program never materializes, practices that sequester carbon can benefit your farm, the environment, and your bottom line.

Big word. Sequestration is a big word that basically just means putting carbon in the soil as organic matter and storing it there. Nature's primary tools for doing that are trees and the crops and grasses that blanket agricultural lands.

Through the process of photosynthesis, plants take carbon dioxide out of the air and use part of the carbon in it to build biomass. When the plants die and decompose, that carbon is returned to the soil as organic matter. The soil then becomes, in effect, a bank where the carbon can be safely kept to earn dividends for producers.

Carbon dioxide is the most abundant of greenhouse gasses. Removing it from the atmosphere is thought to be one way to help slow global warming.

Most atmospheric carbon dioxide comes from burning fossil fuels for transportation or to generate power. The only way to keep the troublesome gas from building up in the atmosphere is to reduce emissions or tie it up and store it—to bank it if you will.

New interest. Sparked by concerns about global warming, and by international negotiations aimed at reducing greenhouse gases, the concept of paying farmers to sequester carbon has gained momentum over the past few years.

Scientists have recently calculated that U.S. farm and grazing lands are currently sequestering roughly 20 million metric tons of carbon a year. With improved management, the scientists say, that total could be boosted to some 200 million metric tons annually. Altogether, that would be 12 to 14 percent of total U.S. carbon emissions.

Similar estimates have been made for Canada. Experts there suggest that the nation's 60 million hectares of farm fields and grasslands have the potential to soak up as much as 34 million tons of carbon per year for the next two decades.

The primary banks, or sinks as they are often called, would be forests, farms, and grasslands. The way they sequester carbon is to keep it tied up in organic matter. Exposing soil to the air allows soil microbes to oxidize some of the carbon, turning it back into carbon dioxide. The gas can then escape back into the atmosphere.

Undisturbed grasslands and CRP ground form a huge carbon sink. On cropland, practices that sequester carbon include conservation tillage, cover crops, rotations with alfalfa and other legumes, and planting trees and grass buffers.

Incentives. In view of the vast acreages of agricultural land, various programs have been proposed to encourage farmers to sequester more carbon. The prevailing thought is that power companies and other major carbon dioxide emitters could be required to pay farmers and ranchers to store offsetting amounts of carbon.

Another approach would be to give farmers direct government payments for sequestering carbon, but most discussion and the programs devised so far favor having private industry foot the bill.

In either scenario, the payments probably would be based on scientific estimates of how

much carbon, or how many carbon dioxide equivalents, various tillage and other practices could be expected to sequester.

Looking ahead. Anticipating future regulation, a consortium of Canadian energy companies known as GEMCo has already initiated a carbon-offset program. Since announcing the program in late 1999, GEMCo has arranged to purchase 500,000 tons of carbon credits, and aims to contract for up to 2.8 million tons by 2008.

Above: Agricultural lands can help significantly reduce carbon dioxide overload in the earth's atmosphere.

Right: Chuck Rice heads a coalition of scientists organized recently to study carbon sequestration in depth.

A U.S. environmental firm, Chicago Climatic Exchange, is developing a pilot program to assess the feasibility of a carbon market. Field representatives for American Agrisurance, the nation's largest crop insurer, will help farmer clients establish carbon credits for the project. ◊

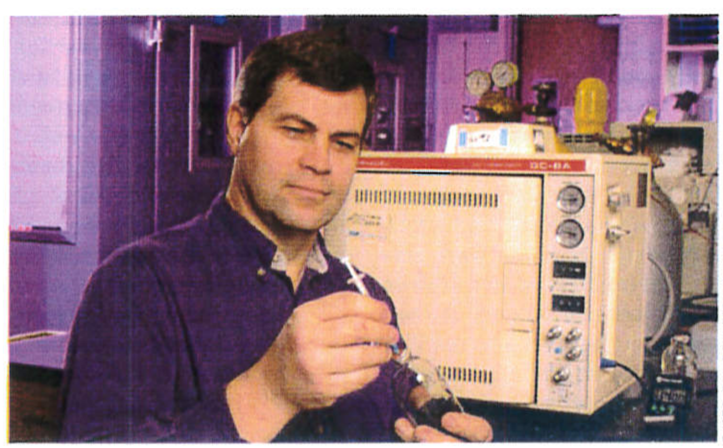


PHOTO DAN DONNERT, KANSAS STATE UNIVERSITY

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Greg Livingston, who heads the insurance company's part of the effort, says they expect to roll the program out in seven Midwest states later this year. "Our goal is to make it available to farmers across the U.S. in 2003, and to go international with it by 2004," he adds.

Hangup. Livingston says many details remain to be worked out, but he thinks a carbon market is quite feasible. "The main hangup is an incentive for buyers," he says, "We don't see a full-scale market developing until there's some type of regulation that requires companies to limit carbon dioxide emissions or buy carbon credits to offset them.

"If the pilot project succeeds, we hope Washington will get behind this and that we'll eventually see a program that will put a few more dollars per acre in farmers' pockets."

Alberta's provincial government has already stepped in. Last December, utility companies there were put on notice that offset credits will have to be purchased as a condition for approval to build any new power plants. In the U.S., Washington and Oregon are considering similar regulations.

On a federal level, many proponents had hoped to see significant provisions regarding carbon sequestration in the 2002 U.S. farm bill. New priorities driven by the events of Sept. 11 dashed those hopes, but as the bill neared completion while this article was being written, it included funding authorization for carbon-sequestration research, along with demonstration projects and outreach.

Research. A good number of researchers have already gotten involved. At the National Soil Tilth Laboratory in Ames, Iowa, microbiologist Tim Parkin is heading a team that's measuring carbon gains and losses that result from various farming practices. They plan to use the data to create models for predicting changes in soil carbon when different practices are

Above: John Haas says practices that sequester carbon increase farm profits with or without carbon credits.

Right: Fragments of plant biomass, shown here at 25 times normal size, return locked-up carbon to the soil.

used on various types of soil.

Scientists at more than 25 locations throughout the U.S. are collecting data to use in developing and improving the models, and additional models are being developed by scientists in other locations.

Chuck Rice, a Kansas State University soil microbiologist, is heading up a group of scientists who will be studying the potential for storing carbon in agricultural land and coming up with better ways to get the job done.

Consortium. The recently formed task force, known as the Consortium for Agricultural Soils Mitigation of Greenhouse Gases, includes researchers from nine land-grant universities and the U. S. Department of Energy's Battelle-Pacific Northwest National Laboratory. USDA will fund their studies.

"Basically, we'll focus on determining how much carbon can be stored in agricultural land and what management practices sequester carbon most effectively under various conditions," Rice says.

"Discussions of carbon sequestration and carbon-storage programs have raised a lot of questions that need to be answered," he adds. "In another three to five years, we should know a great deal more than we do now."

PHOTO: JULIE JASTROW, ARGONNE NATIONAL LABORATORY

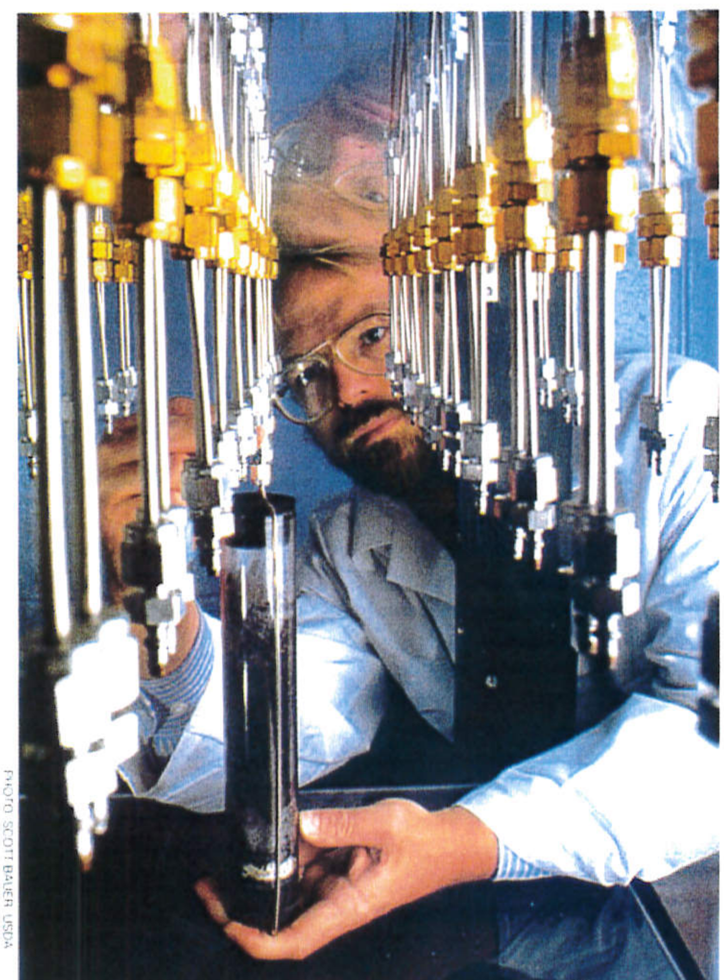
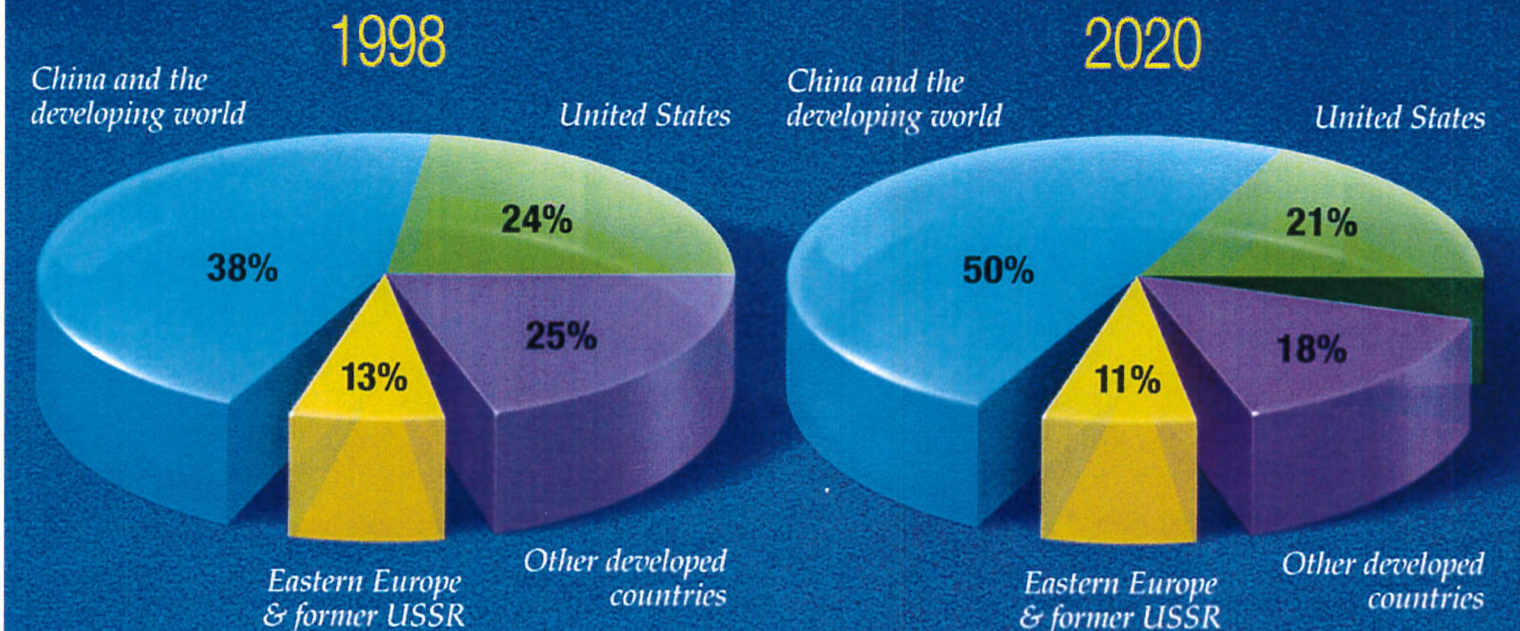


PHOTO: SCOTT BAUER, USDA

CARBON EMISSIONS



Increasing amounts of carbon dioxide, the most abundant greenhouse gas, are expected to come from developing countries. Experts believe U.S. farmers can help offset some of the increase by sequestering cabon.

Illustration: Image Tap/Source: U.S. EPA

Don Reicosky, a soil scientist at USDA's North Central Soil Conservation Research Laboratory near Morris, Minn., says he's begun to preach the message that carbon sequestration is good for everyone, not just for farmers.

Reicosky ticks off more than a dozen benefits soil organic matter provides. "Carbon is the primary energy source for soil microorganisms and that makes it the key for all of the physical, chemical, and biological processes in the soil," he says.

Other pluses. He adds that organic matter improves soil structure and tilth, and helps keep pesticides from leaching through soil and into ground water. It also increases water-holding capacity, infiltration rates, and fertility, and reduces soil compaction and erosion.

Reicosky says these and other benefits add up to a positive environmental impact that goes well beyond carbon sequestration. "Farmers and the public alike need to understand and appreciate that," he adds.

Microbiologist Tim Parkin is researching biological processes that release carbon from soil organic matter.

John Haas is one farmer who does. He began reducing tillage in the early '90s and now no-tills most of the 3,800 crop acres he farms near Larned, Kan. Hass says he's producing bigger yields at lower cost than he used to. At the same time, he has reduced erosion and improved the structure and organic-matter content of his soil.

"When I found out about carbon sequestration three or four years ago, I realized that's basically what I was doing," Haas says. "And when I learned that I was helping the environment as well as myself, I wanted to do even more."

Haas, who has appeared before the U.S. Senate's agriculture committee to provide a farmer's perspective on carbon-sequestering practices, says he thinks there's a good chance farmers eventually will be able to get some sort of direct financial reward for banking carbon.

"That would be wonderful, but it would just be a bonus as far as I'm concerned," he adds. "I'm already raising better crops and making more money than I did before I started using carbon-sequestering practices.

PHOTO: ALAN WILTS USDA

USDA scientists use this custom-built machine to study the impact of various tillage practices on soil carbon.

"We still don't totally understand this phenomenon, but we know that it's something that happens in nature," he says. "If we can help nature clean up the air and make more money at the same time, then I'm all for it."

Buying time. Carbon sequestration isn't widely viewed as a long-term solution to the problem of carbon dioxide overload in the earth's atmosphere, but advocates say it's a place to start, and something that needs to be done.

Chuck Rice speaks for many when he says other alternatives such as biofuels and cars that are more fuel-efficient are needed, but it will take time to make them economically viable. "Carbon sequestration is something we can do now, and it will buy us time to come up with better technologies," he says.

Storing Carbon in Soil

Charles W. Rice

Carbon is a primary element of all organic life forms on Earth. Carbon also is distributed in geologic material, oceans and the atmosphere. Concern has been mounting about the rapid buildup of carbon dioxide in the atmosphere — which is increasing by more than 3 billion tons per year. Industrialization and the burning of fossil fuels (coal, oil and natural gas) have accelerated this buildup. Carbon dioxide is a gas that absorbs heat, and thus contributes to the greenhouse effect.

The potential ramification of elevated atmospheric carbon dioxide on climate change makes it necessary to reduce carbon dioxide emissions — through increased energy efficiency and greater use of non-carbon energy — or to sequester carbon dioxide by injecting it into geologic formations and oceans or enhancing its uptake by terrestrial and aquatic ecosystems.

Terrestrial ecosystems, both plants and soils, provide an attractive mechanism for carbon sequestration because we can manage them. We can manage plant growth to increase plants' capacity to uptake carbon dioxide. And we can manage plant growth so that soils in turn store carbon for long periods of time. Agricultural lands are a good example.

Why soils?

The estimated amount of carbon stored in world soils is about 1,100 to 1,600 petagrams (one petagram is one billion metric tons), more than twice the carbon in living vegetation (560 petagrams) or in the atmosphere (750 petagrams). Hence, even relatively small changes in soil carbon storage per unit area could have a significant impact on the global carbon balance.

Carbon sequestration in soils occurs through plant production. Plants convert carbon dioxide into tissue through photosynthesis. After the plants die, plant material is decomposed, primarily by soil microorganisms, and much of the carbon in the plant material is eventually released through respiration back to the atmosphere as carbon dioxide.

But some of it remains when organic materials decay and leave behind organic residues, often called humus. These residues can persist in soils for hundreds or even thousands of years. At the same time, many factors can slow the decay of organic materials and, as a result, affect a soil's capacity for storing carbon. Inherent factors include climate variables (temperature and rainfall), clay content and mineralogy.

It is possible to manage agricultural lands to maximize the amount of carbon those soils can store. The work my colleagues and I have undertaken on the agricultural lands of Kansas attempts to map the benefits of such soil management.

Staying in the soil

Climate affects soil carbon sequestration in two ways. First is the production of organic material entering the soil. Warm, moist climates generally have greater plant productivity. Cooler climates limit plant production. Hot climates may limit production because of reduced water availability, making water the limiting factor. Climate also affects the rate of microbial decomposition of plant material and soil organic matter. As temperature increases, microbial activity generally increases.

Soil water content also is important. Optimal microbial activity occurs at or near field capacity — the maximum amount of water that soil can hold against gravity. As soil becomes waterlogged, decomposition slows and becomes less complete. Peat soils are a common result. Decomposition also slows as soils dry.

Clay content stabilizes organic carbon by two processes. First, organic carbon chemically bonds to clay surfaces, which slows degradation. Clays with high adsorption capacities, such as montmorillinitic clays, retain the organic molecules. Secondly, soils with greater clay contents have a higher potential to form aggregates, which trap organic carbon and physically protect it from microbial degradation.

Generally, ecosystems that provide high quantities of plant material have the greatest potential to store carbon. Tropical ecosystems often provide some of the highest amounts of plant biomass, although these amounts are bal-

Why and How?

anced by high rates of decomposition. Soils formed under tallgrass prairie, such as those my colleagues and I are studying on the Konza Prairie Biological Station near Manhattan, Kan., have high amounts of soil carbon. These amounts partly result from a high rate of plant productivity, with approximately 60 to 80 percent occurring below ground. The amount of carbon stored in these soils is equivalent to soils of tropical forests.

Even in one handful of soil, not all carbon is the same and differs by its degradability. Soil organic carbon often is divided into three pools: active, intermediate or slow, and recalcitrant. These three pools

Charles Rice of Kansas State University displays a carbon-rich soil sample from the Konza Prairie Biological Station near Manhatten, Kan. The soil's dark color shows the presence of organic material.

Dan Donnert, Kansas State University

have different rates of turnover with the active pool on the order of months to y the slow pool decades, and the recalcit. pool hundreds to thousands of years. The active pool includes microbial biomass and labile organic compounds that make up less than 5 percent of the soil organic carbon. The slow pool usually makes up 20 to 40 percent, the recalcitrant 60 to 70 percent.

The goal of sequestering carbon in soils is to promote carbon transformations into the intermediate and recalcitrant pools. If more of the carbon ends up in the slow or recalcitrant pool, then it is less subject to loss and can remain in the soil for hundreds or thousands of years.

Carbon in soils under natural ecosystems often is at high levels and is considered at equilibrium, thus unable to sequester additional carbon. However, we have shown that in the soil beneath a native tallgrass prairie, soil carbon increased by 6 percent as deep as 50 centimeters when the tallgrass prairie was exposed to elevated carbon dioxide. The extra carbon dioxide increased plant production, which in turn increased how much carbon was incorporated into the soil. Most of the carbon was sequestered into a relatively slow pool, but some of the carbon was integrated into recalcitrant fractions, indicating longer-term storage.

The amount sequestered over the eight-year experimental period was equivalent to 6 megagrams per hectare. If one million acres absorbed this much carbon, it would store the same amount released by burning 4.3 million tons of coal. Furthermore, much of the carbon that was added from plant material was stored in macroaggregates larger than 250 micrometers, supporting the theory that physical protection of soil carbon is an integral part of carbon sequestration.

The potential of a tallgrass prairie

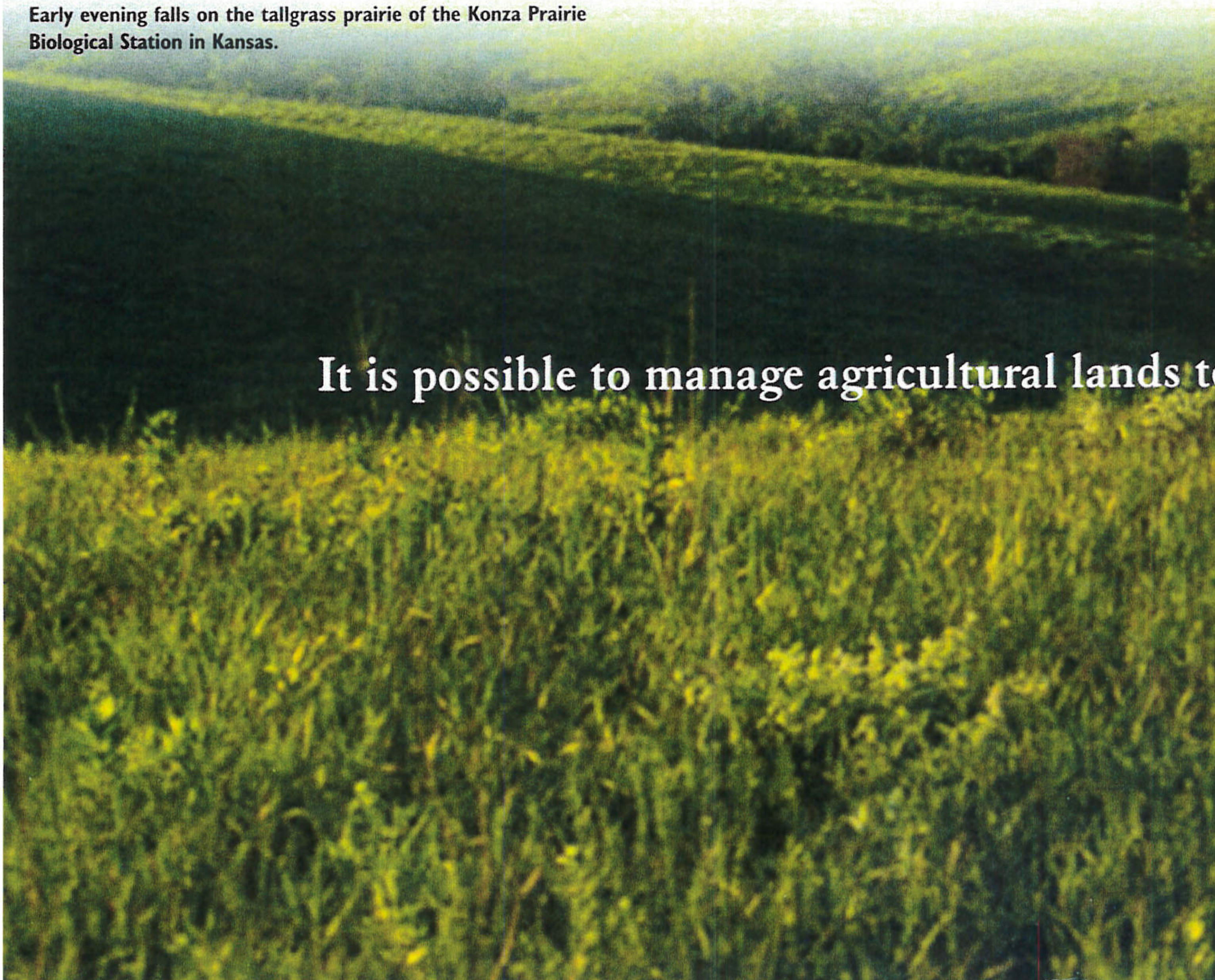
Agriculture in the 1800s and early 1900s relied on plowing the soil with low crop yields and on removing crop residues. This combination of agricultural practices resulted in reduced replenishment of organic material (carbon) to the soil. As a result, approximately 50 percent of the soil organic carbon (soil organic matter) has been lost over a period of 50 to 100 years of cultivation. However, this loss of soil carbon leaves space for new carbon. In recent decades, higher yields, retention of crop residues and development of conservation tillag[illegible]tices have begun to increase soil carb[illegible]vances in crop and soil management practices can potentially allow soils to store more carbon.

No-tillage is one management practice that often preserves or increases soil carbon. My colleagues and I performed a study in western Kansas in which native sod was planted to a winter wheat-grain, sorghum-fallow rotation using either no-tillage or tillage to prepare the seedbed and plant the seed. After 10 years, the mass of aggregates larger than 2,000 micrometers in the top 5 centimeters was reduced and redistributed into aggregates of less than 250 micrometers when native sod was converted to cropping. The amount of carbon in macroaggregates of greater than 250 micrometers in native sod was double that observed in conventional tillage. No-tillage conserved the same amount of macroaggregates that naturally occur in native prairie soil. The organic carbon associated with the macroaggregates was preferentially lost with cultivation. No-tillage soils have a higher potential for storing injected carbon for a long time.

In addition to preserving soil carbon from native conditions, no-tillage can increase soil carbon in soils that were previously cultivated and contained reduced levels. In my study of maize that ran continuously for 10 years at Kansas State University, no-tillage increased soil carbon by 9 percent when compared with tilled soil. Water-stable aggregates increased in no-tillage compared with tillage, especially in aggregates larger than 2,000 micrometers. The number of macroaggregates greater than 250 micrometers increased, as did the carbon associated with the aggregates, preferential to the smaller size aggregates. When manure was added as a nitrogen source, no-tillage also held more of the manure's carbon: the no-tillage soil h[illegible]2 percent more carbon from the m[illegible]e than the tilled soil. Thus, manure added both nitrogen and carbon.

More frequent planting of crops (almost year-round) infuses the soil with extra plant material and increases the amount of carbon stored. In western Kansas, intensifying cropping systems by conversion from wheat-fallow rotation to wheat-grain, sorghum-fallow rotation has increased soil carbon levels.

Another factor that determines storage capacity is the quality of plant carbon entering the soil. Our research shows that carbon from roots may contribute more to soil organic matter formation than does carbon from straw. The reason for this difference between roots and above-ground material is not clear, but roots have a higher ratio of carbon to nitrogen, which would slow



Early evening falls on the tallgrass prairie of the Konza Prairie Biological Station in Kansas.

decomposition and encourage formation of hum[illegible]is conversion of carbon into humu[illegible] important because humus is part of the recalcitrant pool and the carbon in humus lasts longer in the soil. This quality factor suggests that plant breeding may provide avenues for increased carbon sequestration, either by changing plant composition of carbon compounds so that more carbon will be converted to soil organic matter, or by altering ratios of roots to shoots.

Microorganisms convert plant carbon into soil organic carbon. Differences in the soil microbial community can affect the ratio of carbon converted to carbon dioxide vs. to soil organic carbon. In research on the Konza Prairie that changed water relations in a tallgrass prairie, the soil microbial community was changed to favor fungi. Because bacteria tend to respire more plant carbon to carbon dioxide, while fungi tend to retain more carbon in the soil, the result was a greater retention of carbon into microbial products in the soil. Further research needs to be conducted on potential manipulation of the soil microbial community to find biogeochemical transformations of carbon that remain in soil.

Other pluses to soil carbon

Managing agricultural soils for sequestering carbon will yield additional benefits. When carbon is part of the soil organic matter fraction, the soil's capacity to hold basic cations increases, which in turn improves soil fertility. Soil organic matter also improves water holding capacity, thus increasing plants' ability to withstand short droughts. Soil carbon improves the structure of the soil, which results in improved drainage and aeration and better root growth. For the microbial community, carbon provides an energy source resul[illegible] greater nutrient cycling and biodivers[illegible]. In addition, management practices that increase soil carbon also tend to reduce soil erosion, reduce energy inputs and improve soil resources. Increasing a soil's capacity to store carbon means increasing how much carbon it contains, which in turn increases crop productivity and enhances soil, water and air quality.

Rice is a professor of soil microbiology at Kansas State University. Email: cwrice@ksu.edu

Learn more about the Konza Prairie Biological Station at www.konza.ksu.edu

Geo*times*
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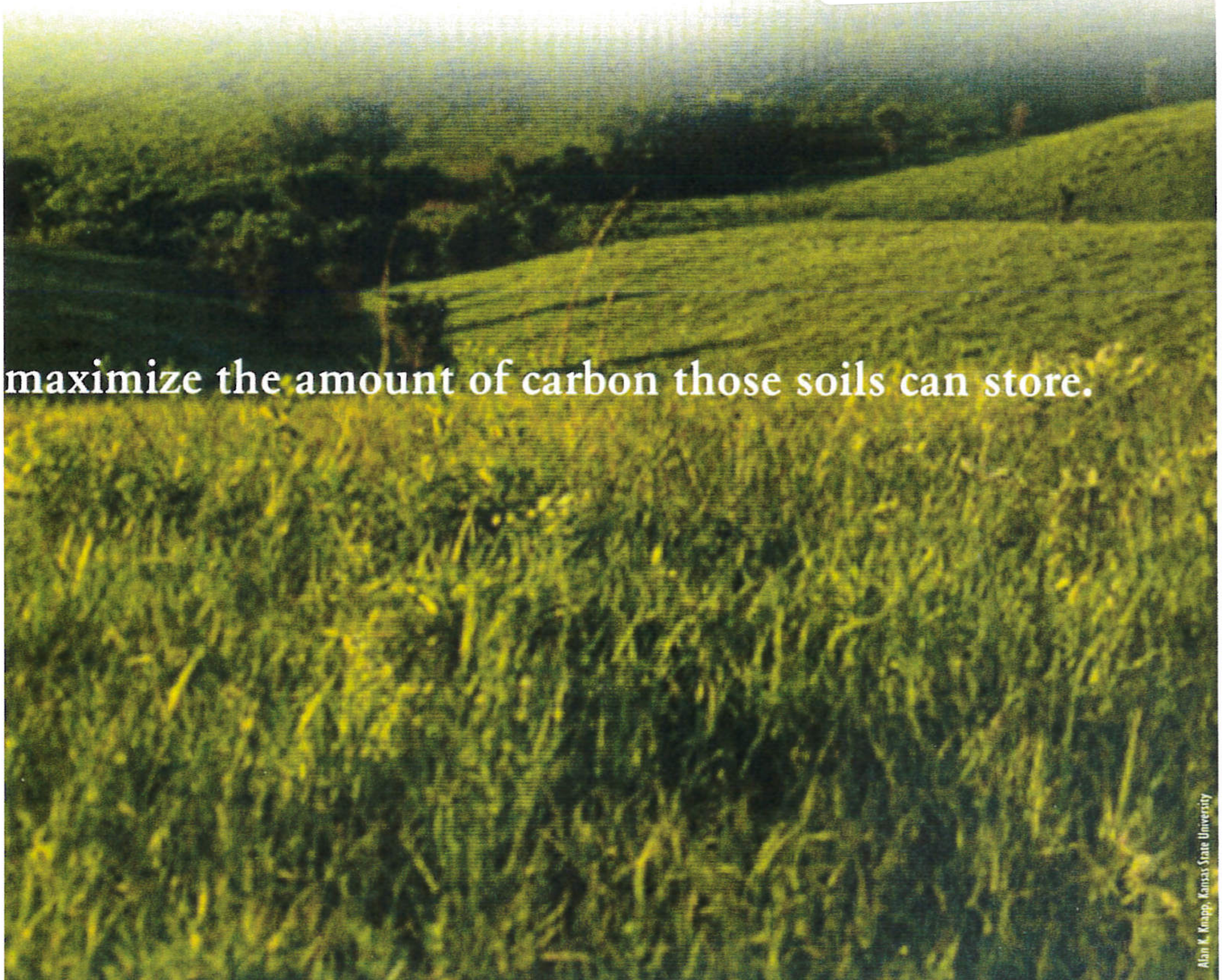
www.geotimes.org



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KCCM

Kansas Coalition for Carbon Management

Top 12 Questions & Answers: Carbon Credit Pilot Project for Kansas

1. Who is running this pilot program?
The pilot program is being offered and managed by the Chicago Climate Exchange (CCX), a commodity exchange for greenhouse gases. The aggregator, or organization that serves as the middleman between the CCX and participating producers/landowners, is the Iowa Farm Bureau. In Kansas, the Kansas Coalition for Carbon Management is helping to ensure that eligible producers/landowners in Kansas have an opportunity to participate.

2. What are the basics of the program?
The Iowa Farm Bureau will be contracting with producers/landowners in parts of Kansas until early spring, 2005, for land that is under continuous conservation tillage or is in new grass plantings (including CRP and CSP). This land is considered to be accumulating "carbon credits" through a process called carbon sequestration. These carbon credits can be leased to potential buyers for a set period of time. Under terms of the contract in this program, the land must remain in conservation tillage or grass for a 4-year period -- 2003 through 2006. The Iowa Farm Bureau will aggregate all the credits they have under contract and sell them in one or more large units on the CCX board. The price of credits fluctuates daily depending on supply and demand, as with any other commodity exchange. Once the Iowa Farm Bureau sells the credits on the CCX, the Iowa Farm Bureau will send the money to those who signed contracts.

3. What is a "carbon credit"?
A "carbon credit," or Exchange Soil Offset (XSO), is a market term. When power companies or other entities that emit carbon dioxide into the air need to reduce those emissions, they may buy a carbon credit from someone who is engaging in a practice (such as conservation tillage or grass planting) that removes carbon from the atmosphere on a long-term basis. A carbon credit is normally quantified in terms of "carbon dioxide equivalent (CO2e)." A CO2e is just a way of converting the different forms of carbon into a common unit -- carbon dioxide.

4. Do I have to be a Farm Bureau member to sign up?
No, you do not have to be a Farm Bureau member.

5. Do I need my landlord's approval?
No, the landowner's approval is not necessarily required. The contract is between the Iowa Farm Bureau and either the owner or operator -- whoever has functional control of the land and signs the contract.

6. What land is eligible for the pilot program?
To be eligible, the land enrolled in the XSO certification program must be capable of being cropped – that is, the land could be utilized for row crop or small grain production even though it may currently be in a non-grass hay crop. If such lands are farmed with row crops during the pilot project period, such crops need to be produced in a compliant no-till manner. XSOs (carbon credits) will be issued at the rate of 0.5 metric tons CO_2 equivalent per acre per year to farmers who commit to continuous conservation tillage (defined as continuous no-till, strip-till, or ridge-till) on the enrolled land from 2003 through 2006. XSOs will be issued at the rate of 0.75 metric tons CO2e for new grass plantings.

7. How about land that was put into grass prior to Jan 1, 1999?
Land that had grass established on it prior to Jan 1, 1999 is not eligible for the pilot program.

8. For purposes of this pilot program, what is the definition of no-till?
The CCX uses the definitions found in the USDA Natural Resources Conservation Service National Handbook of Conservation Practices. These definitions are: No-till/Strip-till - Managing the amount, orientation, and distribution of crop and other plant residue on the surface year-round while growing crops in narrow slots or tilled or residue-free strips in soil previously untilled by full width inversion implements; Ridge-till - Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while growing crops on preformed ridges alternated with furrows protected by crop residue.

Tillage equipment that is definitely classified as a "full width inversion implement" includes:

- Moldboard plow
- Chisel plow
- Tandem disk
- Offset disk
- Field cultivator

Equipment that is allowable within the pilot program includes:

- No-till, strip-till, and ridge till planters
- No-till drill
- Ridge-till cultivator
- Rolling harrows
- Liquid manure injector (See general guideline below)
- Anhydrous ammonia applicator
- Sub-soiler/ Ripper with at least a 24-inch shank spacing

A general guideline is that after the implement has been through the field, there must still be a substantial amount of surface residue present and the soil disturbance must not be full width. If use of the implement would require that a leveling or smoothing activity follow, it would probably result in too much soil disturbance.

9. How much will I get paid?
The Iowa Farm Bureau will sell the aggregated carbon credits on the CCX board at the time of its choosing. The exact amount depends on market conditions at the time of the sale. During late 2004, prices ranged from $1.00 to $1.90 per metric ton, but these prices may go up or down from there. The Iowa Farm Bureau retains 10 percent of the selling price as a service fee.

10. When will I get paid?
You'll probably get paid sometime before the end of 2005 for the 2003 and 2004 vintage year credits.

11. If I till the ground before the contract is up, do I have to repay the money?
Yes, plus interest and other costs.

12. How will the CCX or Iowa Farm Bureau verify that I'm upholding the terms of the contract?
CCX contracts with local entities to visually verify that land under contract is in conservation tillage or grass. Not all land will be verified every year. In large part, the program relies on self-certification. CCX will rely on your word of honor.

If you have further questions, please contact:
Dave Miller, Iowa Farm Bureau, 515-225-5430 damiller@ifbf.org, or
Glacial Hills RC&D, Valley Falls, Kansas 785-945-6292
For more information on KCCM, see: www.oznet.ksu.edu/kccm

Kansas Producer Participation in the Carbon Credit Pilot Project

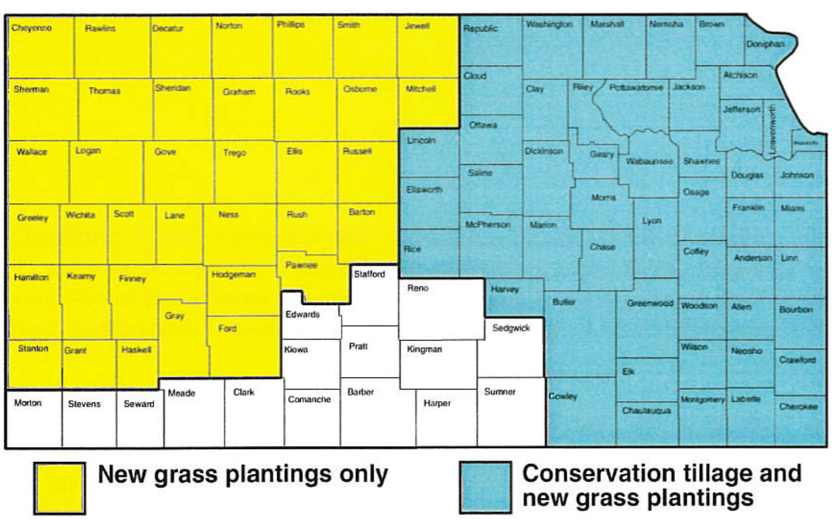
In February 2005, a series of 12 meetings were held in various counties in Kansas to educate producers about carbon sequestration. As part of those meetings, a member of the Kansas Coalition for Carbon Management explained the details of the carbon credit pilot project offered by the Chicago Climate Exchange, through a contract with the Iowa Farm Bureau. This pilot project offered no-till producers and those with new grass plantings the chance to pool the carbon credits from that land in with credits from other Kansas producers and offer them for lease on the board of the Chicago Climate Exchange.

The meetings were sponsored by the Kansas Coalition for Carbon Management (KCCM), an organization consisting of K-State Research and Extension, Kansas Resource Conservation and Development Councils (RC&Ds), many Kansas commodity organizations, Kansas Farm Bureau, and many state and federal agricultural agencies.

The pilot project was offered by the Chicago Climate Exchange (CCX), a voluntary, multi-sector market for reducing and trading greenhouse gas emissions. The program is being administered by the Iowa Farm Bureau, serving as the "aggregator" -- an entity that acts as a middleman between the CCX and producers/landowners. An aggregator pools many separate parcels of qualified acreage into one large block for purposes of carbon credit trading on the CCX. This pilot project includes credits from 2003, 2004, 2005, and 2006.

At the educational meeting, K-State Research and Extension personnel explained the basic concepts of carbon sequestration. "We explained what carbon sequestration is, why it's important, and how it can help reduce greenhouse gases in the atmosphere while improving soil and water quality. We also explained what practices producers can use to increase carbon sequestration in their soils," said Chuck Rice, K-State professor of agronomy and national director of the Consortium for Agricultural Soils Mitigation of Greenhouse Gases (CASMGS).

KCCM personnel then explained the pilot program being offered by CCX and administered by the Iowa Farm Bureau. In this program, producers or landowners were given an opportunity to contract with the Iowa Farm Bureau to sell carbon credits for them on the CCX exchange. The acreage eligible for this program included conservation tillage (no-till, strip-till, and ridge-till) and grass plantings made on or after Jan. 1, 1999 (mostly CRP, CSP, or conservation buffer strip plantings) in the eastern half of Kansas. In the western half of Kansas, only recent grass plantings were eligible. The map below shows how the state was divided for purposes of this project.



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Chuck Rice at the Hiawatha meeting

There were some requirements made of those who sign these contracts, which was explained by KCCM representatives at the meetings. Payments for carbon credits were not established in the contract, said David Miller, Iowa Farm Bureau director of commodity services. The payment is going to depend on the price on the CCX board at the time the credits are sold by Miller. Payments have been averaging anywhere from $0.50 to $1.00 per acre per year, but this fluctuates. More than 80,000 acres were already under contract in Iowa at the time these meetings were held.

As a result of the educational meetings, 72 contracts were signed between Kansas producers and the Iowa Farm Bureau, representing 24 counties and a total of 75,462 acres. Of this total, 74,256 acres were from no-till production. All of these acres must be verified and certified by SES Consulting, working in conjunction with the Iowa Farm Bureau.

<u>Number of Contracts by County in Kansas</u>

Anderson - 5	Lyon - 2
Brown - 5	Marion - 2
Butler - 4	Marshall - 15
Chase - 1	McPherson - 5
Cloud - 1	Miami - 5
Coffey - 1	Nemaha - 2
Cowley - 1	Ottawa - 1
Dickinson - 4	Pottawatomie - 1
Greenwood - 2	Republic - 3
Harvey - 1	Rice - 1
Jackson - 1	Riley - 4
Kearney - 1	Washington - 1
	Woodson - 1

It should be noted again that only counties in the eastern half of Kansas were allowed to enroll no-till acres in this pilot project, according to guidelines established by the Chicago Climate Exchange. Most other counties in Kansas, except some of those in southcentral Kansas, were allowed to enroll acres in new grass plantings. It is hoped that all of Kansas would be allowed to enroll no-till acres in any future carbon credit projects.

As of August 15, Miller was still waiting on SES Consulting and CCX to complete the initial verification of the pool and certification of the 2003 and 2004 credits. "When they complete this, the CCX will credit our account and we can begin trading. Until then, I am on hold. On the first pool, the certification process took nearly a year from first submission. I am hopeful that this pool will only take 6 months or so. Hopefully, we will be able to start trading the credits sometime this fall (2005)."

arbon Sequestration

Carbon sequestration is a natural way to store carbon dioxide from our atmosphere. Through photosynthesis, plants take carbon dioxide out of the atmosphere and sink it in plant material above and below the soil surface. Emissions of carbon dioxide into the atmosphere have been increasing rapidly in recent years, both in the U.S. and around the world.

Our Goal is to reduce atmospheric carbon levels through sound agricultural practices.

The KCCM is promoting carbon sequestration as a natural way to improve soil, water and air quality while also yielding economic benefits for land managers. In addition, it offers one way to reduce greenhouse gases, which are linked to global climate change.

Our Action Plan

Inform and educate land managers on carbon management practices.

Explore and disseminate marketing opportunities as they develop.

Investigate the legal boundaries around carbon sequestration.

urage research of greenhouse gas emission reduction and alternative energy uses.

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Kansas Coalition for Carbon Management

Reducing greenhouse gases which are linked to global climate change

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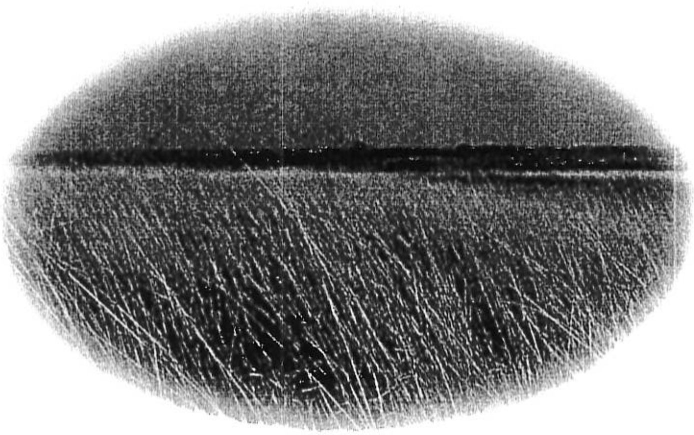
Kansas Coalition for Carbon Management



Land Management Practices for Increased Carbon Sequestration

- Use No-till or reduced tillage methods
- Increase crop intensity by eliminating summerfallow
- Plant and maintain buffer strips
- Adopt conservation measures that reduce soil erosion
- Use high residue crops such as corn, grain sorghum and wheat
- Use cover crops
- Select varieties and hybrids that store more carbon
- Improve forage quaility on grazing land
- Regular prescribed burning to increase forage productivity
- Reduce over grazing

Coalition Members

Kansas Alliance for Wetlands and Streams
Kansas Assoc. of Conservation Districts
Kansas Assoc. of Wheat Growers
Kansas Corn Growers Assoc.
Kansas Electric Power Cooperative
Kansas Farm Bureau
Kansas Forage and Grassland Council
Kansas Forest Service
Kansas Grain Sorghum Producers Assoc.
Kansas Rural Center
No Till on the Plains, Inc.
Pheasants Forever
Society for Range Management
State Assoc. of Kansas RC&D Councils

The Kansas Coalition for Carbon Management will inform, educate and motivate land managers to apply management practices that result in reduced atmospheric carbon levels.

Advisory Agencies

Kansas Dept. of Agriculture
Kansas Dept. of Health & Environment
Kansas Forest Service
Kansas State University Research & Extension
USDA Farm Service Agency
USDA Natural Resources Conservation Service
State Conservation Commission

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reduced as soil organic carbon levels are increased. If the soil organic carbon is undisturbed, then it can remain in the soil for many years as stable organic matter. This carbon is then sequestered, or removed from the pool available to be recycled to the atmosphere. This process reduces CO_2 levels in the atmosphere, reducing the chances of global warming.

3. How much impact can carbon sequestration have on greenhouse gases?

It has been estimated that 20 percent or more of targeted CO_2 emission reductions could be met by agricultural soil carbon sequestration.

4. What can agricultural producers do to enhance carbon sequestration?

There are several practices that can increase carbon sequestration, including:

a. No-till or reduced-till

b. Increased crop rotation intensity by eliminating summer fallow

c. Buffer strips

d. Conservation measures that reduce soil erosion

e. Using higher residue crops, such as corn, grain sorghum, and wheat

f. Using cover crops

g. Selecting for varieties and hybrids that store more carbon

5. What can grazingland managers do to enhance carbon sequestration?

Grazingland managers can increase carbon sequestration by:

a. Improving forage quality

b. Regular use of prescribed burning to increase forage productivity

c. Reducing overgrazing

6. Will agricultural producers get paid for carbon sequestration?

It is possible that a private system of trading for carbon credits will be established, which could pay producers about $1 to $2 per acre. A few utility companies have already begun buying or leasing carbon credits in some cases, but this is not yet a widespread practice. It is also possible that the government will provide certain incentives for producers to sequester carbon. But even if there were no payments for carbon sequestration, it would still pay for agricultural producers to implement practices that would increase soil organic matter due to:

a. Improved soil structure and quality

b. Improved soil productivity through increased organic matter

c. Reduced erosion through improved soil structure

d. Improved water quality through reduced erosion

7. What is soil organic matter, where does it come from and where does it go?

Soil organic matter consists of decomposed plant and animal matter. It helps bind soil mineral particles together into clumps, called soil aggregates. Higher levels of soil organic matter lead to more stable soil aggregates, better soil infiltration capability and aeration, better water-holding capacity, more resistance to wind erosion, reduced potential for compaction, and better overall soil fertility. Organic matter helps hold soil nutrients in place, so they are not lost to runoff or leaching. If left undisturbed, soil organic matter can eventually be transformed into long lasting humus, a very stable form of organic matter. However, if the soil is tilled, soil organic matter will be oxidized and carbon will be lost to the atmosphere as CO_2. If the soil erodes, organic matter will be removed with runoff water.

8. What affects the level of soil organic matter?

Native levels of soil organic matter for any particular site are determined largely by the latitude location on the earth, and by the annual precipitation received. Native soil organic matter levels will generally increase as you move either north or south from the equator. In the Great Plains of the United States, organic matter levels increase from west to east following the precipitation gradient. Management by man can change the soil organic matter level. In general, as cropping intenity increases, soil organic matter tends to increase. As tillage frequency increases, soil organic matter tends to decrease. For Kansas producers, eliminating periods of fallow and using no-tillage provides the greatest potential to increase soil organic matter level at a given location.

9. What is K-State doing to promote carbon sequestration?

K-State scientists are working to develop best management practices that will promote carbon sequestration. Research is being done to test the effect of tillage, various crop rotations, soil conservation practices, and several grazingland management practices on soil carbon levels.

10. What is CASMGS?

A team of scientists at 10 universities and government laboratories has recently formed the Consortium for Agricultural Soils Mitigation of Greenhouse Gases (CASMGS, pronounced "Kaz-ums"). With federal funding, this group will provide the science and technology necessary to help our nation realize this benefit. CASMGS brings together the nation's top researchers in the areas of soil carbon, greenhouse gas emission, conservation practices, computer modeling, and economic analysis. CASMGS is also working with international scientists on carbon mitigation efforts. Charles W. Rice, soil microbiologist in the Department of Agronomy at K-State, is the national CASMGS coordinator.

For more information on carbon sequestration:

www.oznet.ksu.edu/kccm
www.oznet.ksu.edu/ctec
www.casmgs.colostate.edu
Soil Organic Carbon and the Global Carbon Cycle, MF-2548

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Kansas State University
Agricultural Experiment Station
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Carbon Sequestration: Top 10 Frequently Asked Questions

1. What is meant by carbon sequestration?

Carbon sequestration is essentially the process of transforming carbon in the air (carbon dioxide, or CO_2) into stored soil carbon. Carbon dioxide is taken up by plants through the process of photosynthesis, and incorporated into living plant matter. As the plants die, the carbon-based leaves, stems, and roots decay in the soil and become soil organic matter. This is the basic process called carbon sequestration.

2. How can carbon sequestration help reduce global warming problems?

Atmospheric carbon dioxide, and other greenhouse gases act to trap heat that is reflected from the earth's surface. This buildup of heat could lead to global warming. Through carbon sequestration, atmospheric carbon dioxide levels are

Kansas State University Agricultural Experiment Station and Cooperative Extension Service