BREAKING NEW GROUND: Carbon Management at the Farm Scale

Final Report

Background:

This project is about carbon and changing attitudes about carbon. Carbon is everywhere in our environment. In the air it is carbon dioxide (CO_2), formed by animal respiration and decay or combustion of animal and vegetable matter. It is absorbed from the air by plants and processed into plant material through photosynthesis. As plant material, it is stored, or sequestered, in the soil. Plants are made up of about 45% carbon.

Carbon is taken up by plants during the growing phase, but much of it is released again as the plant decomposes. The above ground portion of the plant can be used as feed for animals, and returned to the soil in the form of manure. The roots, the below ground portion of the plant, decomposes and builds soil carbon or soil organic matter (SOM). The challenge is to keep as much carbon as possible in the soil.

Carbon is as common as charcoal and as rare as a diamond. A carbon function not common to the general public is its role in the soil as a contributor to soil quality. It is the decomposition process by microbes that converts plant and animal material into soil organic matter (SOM). As a function of soil organic matter, carbon is the mineral that binds the soil particles together creating pores for moisture to soak in. Carbon also serves as a docking station for nutrients to attach so they remain in the root zone.

Carbon is released from the soil when microbes combine oxygen and carbon to form carbon dioxide. The rate of conversion back into CO_2 is determined by the degree of oxygen added to the soil (mainly through tillage and erosion) and soil temperature. As exposure and temperature increase, the rate of conversion increases.

Carbon dioxide in the atmosphere has an insulating affect. Some insulation is needed but as the concentrations of CO_2 have increased, so has the earth’s temperature. Record high concentrations of greenhouse gasses have coincided with record high global temperatures that threaten the basic human needs of food and shelter.

Global warming and climate change efforts focus on sequestering (storing) carbon in the soil as a way to slow down the concentration of carbon dioxide in the air, thus slowing the rate of climate change. Also, it is important to build soil organic matter levels now because, as the earth's temperature increases, the ability to sequester carbon diminishes. The more carbon in the soil, the better chance we have of producing food as we master and incorporate new technologies that can eventually reverse the trend of increased greenhouse gasses.

Carbon-storing practices promote higher quality soils for the future but also deliver benefits for present-day farmers and ranchers. Building organic matter levels now will lessen the need for irrigation, since soils are better able to capture and hold soil moisture. Increased organic matter levels also promote the soils ability to produce its own fertilization. Higher organic matter soils hold more moisture so are able to withstand short drought periods. Adopting carbon sequestration practices is a win-win situation for present and future farmers.

Project Focus

Much research is being conducted to learn how carbon is sequestered in the soil and how to keep it there. Policy makers argue over who should get paid for it, how much, and if it should be used to off-set emissions, but no one was looking at what it takes to get farmers and ranchers to adopt practices that enhance soil carbon.

The Center for Rural Affairs approached the Nebraska Environmental Trust with the idea that changing farm practices would have a beneficial environmental impact on the soils of Nebraska far into the future. A three-year study was funded in the Lewis and Clark Natural Resources District (NRD) to show the benefits of improved soil carbon and how to incorporate practices to improve soil carbon levels.

The purpose of the project is to:

- Provide farmers and ranchers a workable knowledge of the value of soil carbon.
- Provide a working knowledge of how soil carbon is gained and lost in the soil.
- Provide examples of practices that encourage carbon sequestration.
- Familiarize farmers/ranchers with the skills needed to measure soil quality.
- Have farmers and ranchers monitor changes in soil carbon.

Measuring Change

Although soil carbon measurements were taken before and after the 3-year project, the physical change emphasis will be on indicators of soil carbon - infiltration rate, moisture holding capacity, and residual nitrogen rather than actual carbon. These are things farmers can see and appreciate long before changes in soil carbon can be measured.

The other important measure is changes in farmer attitudes and knowledge. Without changes in attitude, changes in practices will not follow, and practices have been shown to make more difference on carbon sequestration than either climate or soil type.

The planning phase follows an attitude change. Time is needed to cipher how practice changes will meet current needs while addressing future goals. The planning exercise in this project reinforces that the participants have a sound knowledge base and provides a window into the future to see what these farmers plan for their land for 5-10 years in the future.

PROJECT DESIGN

Farmer Selection:

Farmer selection was based on recommendations from University of Nebraska Extension (UNL), Natural Resources and Conservation Service (NRCS), Lewis and Clark Natural Resource District (NRD), and the Center for Rural Affairs (CFRA). Candidate selection was based on ability to participate for three years, willingness to try new practices, location in the district, public access, practices considered, soil type, and willing to attend 5 meetings per year.

The farmer list was intentionally diverse. The list included, beginning and retirement-age farmers, organic and conventional-minded farmers, livestock and grain farmers, and irrigated and rain-fed systems.

The plot size of 40 acres/farm will facilitate field-size machinery and whole farm decision-making. Farmers will receive $50 per acre stipend and reimbursement for travel expenses.

Curricula:

The project began in the fall of 2001 with a series of five meetings annually. Meeting topics and schedule included:

Year-one

- Meeting-one: Review project expectations; Conduct base-line survey.
- Meeting-two: Focus on soils, properties, capabilities, expectations; Identify farm's soils; Farmers identify 40acre test plot.
- Meeting-three: Focus on soil-building crops - rotations, cover crops, green manures.
- Meeting-four: Focus on tillage - chemical and non-chemical no-till
- Meeting-five: Farmers give practice plans for the year; Conduct exit survey.
- Spring work: Map plots to determine deep and shallow EC reading and altitude.
- Identify sites and take soil samples.

Year-two

- Meeting-one: Review survey information; Focus on function of soil life/microorganisms.
- Meeting-two: Review soil life information and function.
- Meeting-three: Decision-making process - values, priorities.
- Meeting-four: Plans; Program evaluation,
- Meeting-five: Farm tours; Visit group farms; Compare soils/test kit experience.

Year-three

- Meeting-one: Review experiences and observations; Outcome based planning
- Meeting-two: Discussion of carbon values for practices; Draft planning exercise
- Meeting-three: Final planning exercise
- Meeting-four: Farm tours
- Meeting-five: Final gathering; Project wrap-up
- Soil re-sampling in '05 (3 growing seasons)

PARTNERS AND DUTIES

ARS (USDA Agriculture Research Service):
John Doran, Lincoln, design the project, provide instruction on benefits of soil carbon.

UNL (University of Nebraska)
William Waltman, Soil Scientist, provide mapping and farm planning, resources.
Charles Shapiro, Soil Scientist, Soil test kit instruction.
Paul Jasa, Extension Engineer, Plot mapping with Veris machine.
Dale Flowerday, UNL retired, chemical no-till, practices and management
Terry Gompert, Knox County Extension, grazing and alternative livestock forages
Paul Swanson, Adams County Extension, Holistic decision making.
James Peterson, Washington County Extension, soil-life processes.
Gary Lynne, Agriculture Economist, Decision-making and values.

NRCS (Natural Resources and Conservation Service):
Steve Grube, Soil Conservationist, provide basis soils information – maps, types.
Gary McCoy, Soil Conservationist, sampling and analysis.

Lewis and Clark NRD (Natural Resources District):
Tom Moser, manager, technical expertise, solicit farmer cooperators.

SAN (Sustainable Agriculture Network)
Publications and manuals

NSAS (Nebraska Sustainable Agriculture Society)
Provide farmer speakers: topics include:

- Using cover crops in a corn/bean rotation
- No-till in a corn/soybeans rotation
- Incorporating a small grain and/or a legume in a corn/soy rotation.
- Adding alfalfa to a corn/soybean rotation
- Comparing managed forage grazing systems to an idle forage (CRP) situation.
- Comparing grazing a fall cover crop with turnips to an ungrazed cover crop.
- Compare a small grain harvested field with an animal harvested field.
- Compare different cover crops (oats, buckwheat, sweet clover, red clover).

LESSONS LEARNED:

Much of the project's work was to learn how and why farmers make decisions about carbon sequestration and farm practices. Based on interviews and observations, we learned farmers and ranchers make decisions based on four main factors: economics, environment, social pressure, and control needs.

The Factors.

Economics is what powers the farm. Without money, the farm would not be able to exist. Decisions are made to generate cash in both the short and long term. Farmers learned how increased soil carbon levels will affect their bottom line.

The environment plays a big part in the decision making since it is the soil and climate that make production possible. Understanding how crops can continue to be grown while carbon is being sequestered will help farmers adopt crop sequences that satisfy their needs while improving the soil environment.

Social or peer pressure often affects farmers decisions. By working through a group, much of the peer pressure was minimized and the support system created encouraged higher adoption rates.

Farmers and ranchers all need a certain amount of control. How strong that need for control will influence their need to "master" their operation or allow other systems or cycles to dictate what practices are used. The challenge is to understand how these factors interact to produce change.

The Learning environment:

Background information is important.
Before practices are changed, farmers and ranchers need to feel comfortable with their decision. There are a limited number of seasons and a limited number of resources farmers and ranchers can risk. The background information on soil carbon provided the confidence for the project participants to want to learn more and try new practices. Knowing what carbon is, how to it, how to keep it, and what it does gave them a reason to try something new.

Provide a financial incentive.
Farmers and ranchers are busy people with schedules that fill more than an eight-hour day. Juggling livestock and crop needs with personal and family schedules on a seasonal basis in a less than optimum financial environment is a full time job. Although most farmers said the knowledge gained in the project far outweighed the financial incentive, they agreed that with

out that "carrot" they may not have agreed to participate in the project. They said the incentive showed someone else cared about what they were doing and would share in the risk they were taking by trying something new.

Group learning is important.
All the farmers valued the group learning process. It provided a learning atmosphere where ideas could be exchanged freely and members could learn from the experience of others. It also served as a support group. Knowing there were others interested in the same things provided the confidence to try something new even if it meant ridicule by peers.

Publications are important.
Using a basic text as the basis for instruction gave the farmers a reference to study and refer to when making decisions and formulating farm and ranch plans.

Learning from others makes it believable.
Using farmer/rancher testimony added credibility to the learning process. Knowing other farmers and ranchers had tried the practices made the practices seem "doable". Farmer and rancher speakers also use language and techniques that inspire confidence with others. Using respected experts in the field added importance and credibility to the process also. Just knowing that someone important thought the farmers contribution would make a big difference made a big difference to them.

Change is slow.
Changing practices is a slow process that only happens after many conditions are satisfied. There needs to be a good reason and guidance on how to make the changes. Given the limited number of seasons and the narrow margins for profit, each acre and each practice is important. It is truly a learn-as-you-go process.

Observations are important.
Seeing is believing. Promising changes in soil qualities is one thing, but being able to see the changes reinforces the value of the process. Training on the use of the soil test kit gives the farmers and ranchers the opportunity to actually see changes on their land, rather than merely talk about possible outcomes. Armed with the skills and equipment, they made the tests and observed sol differences.

Success cannot always be measured.
Carbon sequestration is not always measurable. Since sequestration is dependant on nature, doing all the right things can be voided by changes in temperature and moisture. Some things are beyond human control. Practices that depend on beneficial weather conditions fail in a poor environment.

MEASURABLE CHANGE

Changing practices on a farm or ranch is a relatively long-term process. Farmers and ranchers adopt practices have to meet current day-to-day needs and satisfy current goals while affecting future outcomes. After only two growing seasons little change is expected in the long-term goal of increasing the carbon levels in the soil. Soils will be re-sampled in the spring of 2005 to document increases in soil carbon.

Changing practices is a lengthy process, but it begins with a change in the knowledge base, which affects a change in attitude. Through surveys and interviews, project staff identified the following changes as direct results of the carbon management project.

Knowledge base changes:

- Farmers sharpened their understanding that:
  - Soil carbon is important to moisture infiltration and holding capacity.
  - Holding moisture means less chance of nutrient leaching into the ground water.
  - Tillage practices are fundamental to carbon releases from the soil.
- The farmers have a better understanding of greenhouse gasses and global warming.

Attitude is affected by what people know. Increasing the farmers' information level of soils and soil processes changed the way they looked at the land. Most never considered what was happening below the surface and observed crop health as a measure of soil health. Most said they measured soil health by its ability to produce. The following changes in attitude were attributed to increased knowledge of soil processes and carbon sequestration practices.

Attitude changes:

- Farmers showed a greater willingness to work with the nature cycles, and were more willing to relinquish some control on the farming process.
- Farmers were influenced less by peer pressure and were more confident in their decisions.
- Each farmer was asked to use a 40-acre plot to try new practices, but on average, adopted practices on and additional 122 acres per farm.
- Most farmers adopted more than one practice.

The final step before practice adoption is the planning stage. Farm and ranch operators weigh the benefits and risks of adding new practices, while meeting current needs with current skills. Plans are often made years in advance of implementation because of seasonal timing, machinery and labor needs, and skill building.

The following exercise was developed to insure the participants understood the carbon sequestration process and the relative benefit and/or consequence of the different practices. This exercise is intended to project what practices the group may adopt in the future. It is not intended to project the amount of measurable carbon in the soil.

CARBON EXERCISE:

To compare historical practices with future plans, participating farmers were asked to establish a base value, (before the project) using the carbon values (below) to calculate field values for all the land farmed in 2000-02. Field values were determined using the formula: **crop x acres x slope x tillage x soil x water**. The crop value was the summation of values for crops, secondary crops, practices, or manure (corn with solid manure applied becomes 2.5 + 3 (5.5); oats with turnips becomes 2 + .75 (2.75) etc. The field values were totaled to get the farm score for each year. Using the same process for years 2004-08, the farmers predicted how carbon values might change on their farms as a result of planned changes in crops, tillage and farm management.

These carbon values were selected by project staff and farmers as representative numbers to show a comparison between crops and practices rather than real pounds or tons of carbon.

Crop	Carbon value	Crop	Carbon Value
Alfalfa yr 1	3.5	Grass, yr 1	3
Alfalfa yr 2-3	4.5	Grass, yr 2	5
Corn	2.5	Oats	2
Rye	4	Soy	.5
Sunflowers	1	Wheat (spring)	2.5
Oats re-growth	.5	Wheat (winter)	4
Turnips	.75	Weeds (cover crop)	2
		Rye Cover crop	2

Tillage	Carbon value	Slope	Carbon Value
No-till	2	Steep	1
Chisel/Disc	1	Moderate	2
Moldboard	.5	Flat	3

Water: Irrigated	2	Soil Quality: Poor	1
Dryland	1	Average	2
		High	3

Manure: Liquid Manure 1 Grazing 2 Solid Manure 3

The results of the exercise were positive. On the 5,000 acres managed by farmers in the project, a total of 107,083 units were stored annually during the base-line years. This value increased by 49,119 (46%) because of planned practices in the years after the project.

Carbon increases were due to a reduction in tillage (chemical no-till), conversion to grass or permanent forage (non-chemical no-till), extending the growing season by adding additional forage and/or cover crops (turnips, oats, winter wheat and rye), and increasing the use of animals to harvest forage and grain crops (grazing).

Farmer interviews:

This section is a collection of notes arising from farmer interviews during the project. It includes comments by the farmers and observations by the author. The farmers' names have been changed to preserve their confidentiality.

Adam –

Adam is and older farmer who was strongly considering retirement until he got involved in the project. He said, "I found it so interesting to learn about the soil, I just had to keep farming to see if I could still make a difference". Adam is the oldest farmer in the project but says it is good to involve folks his age. " They may be a bit more set in their ways", he says, "but they can also try more risky things since they have the financial security to withstand some mistakes and failures."

Like most in the group, Adam says he has learned as much from the group interaction than from the presentations. He likes talking to other farmers about different farming practices and admitting his mistakes and getting ideas and feed-back. With out the learning environment and the group structure provided by the project, these conversations would not be happening. Adam's farm has steep slopes with light soils. His challenge is to control both wind and water erosion.

Because of the project, Adam incorporated these practices:

- Adam tried some turnips and oats to try to build a cover for the soil and still provide feed for the cattle.
- He purchased an Aerway machine to loosen the soil instead of tilling it.

Bill –

Bill is an established farmer, interested in soil conservation who has been no-tilling corn and soybeans for at least ten years on his 3,000-acre rolling hills farm. He commented, "I never understood what was happening in the soil. I focused on maintaining the surface. I didn't realize how important it was to have a strong nutrient recycling system, or what was needed to make that happen."

No changes were made to Bill's farm except that an Aerway machine was purchased to loosen the soil without tilling it. Bill says it fits well with his philosophy and practices.

Bill says he:

- Enjoyed the group discussions.
- Gained knowledge on soils and how carbon is captured.
- The project reinforced his commitment to no-till.

Chuck –

Chuck is the seventh generation to farm this land. He is the only farmer in the group that uses hoop structures and solid manure systems for his hogs. His goal was to note differences in soil carbon between field sections being fertilized with manure and that fertilized with chemical nutrients. Chuck's practices include add oats as a cover crop after corn silage harvest, and using the oats as forage for the cows after the pasture failed.

Chuck says the project has made him more aware of:

- Soil properties, and how that affects crop performance.
- The value of working with a group of farmers.
- The number of ideas and plans different farmers have.
- The chance to visit other farms to see different practices in place.

Dave -

Like many in the project, Dave continued in the footsteps of his father immediately after highschool, gathering new ideas from industry sales representatives, magazines and experience. Converting a crop field to grass was the first step in changing the grain system for his milk herd. Dave's cows now graze oats re-growth and turnips. Oats has returned to Dave's rotation providing grain and straw, then second-cropped with turnips and/or millet to extend the growing season.

Dave credits the project for these insights:

- Unlike the coffee-shop mentality, the group model provides and opportunity to share ideas and learn from each other's experience. Life is too short to make all the mistakes on your own.
- The publications provided are useful to home study crops, soils and practices.
- Good advice and counsel will help keep small farmers in the area.
- Tillage on steep slopes puts soils at risk. It is better to lose water than soil. It will rain again. If the soil is not there, the rain will do no good.

Earl -

Having recently purchased the farm from his father, Earl needs to make the best use of his time and resources. With an off-farm job, reduced labor is important. Focusing on his cowherd as the main income stream instead of low-priced commodities, he switched his rotation from "corn and soybeans" to "corn and cattle", replacing the bean crop with oats and turnips to feed livestock. The oats grain is fed to calves. The straw is sold or worked into the soil. Turnips are planted in the stubble and grazed in the fall and winter along with some standing corn.

The project helped Earl to:
Consider different production options for the farm.
Want to "Survive on the farm in a way that promotes the well-being of his community".
Make decisions based on dollars, future benefits, conservation, and carbon affect on the soil .

Frank -

Frank, also farming his father's land, is focusing his efforts on alternative forages for grazing and managing an historical wet spot on the farm. He abandoned the long-term corn soybean rotation and returned oats and small grains to the farm. He sowed oats for grain and straw, tilled the stubble to kill weeds and re-sowed it with turnips for fall/winter grazing. Frank is developing some alternative income streams of: farm tours, birdseed sales, Christmas trees, and freelance writing to generate income and fulfill personal goals.

Frank credits the project for:

- Increasing his awareness of the value of soil carbon for fertility, moisture infiltration and holding capacity.
- Providing a better understanding of microbial processes and requirements in the soil.
- Raising in his mind the importance of soil building practices and soil quality issues.
- He now includes carbon sequestration as a factor in designing a cropping sequence.

George -

George is an organic farmer who already had a quite diverse mix of solid seeded crops and row-crops in his rotation when he joined the project. Few changes were made to his operation. One exception is the use of sweet clover as a nitrogen-fixing crop in his small grain. The sweet clover has been replaced with turnips and re-seeded oats to provide a higher quality forage for the livestock and ease the transition to row crops the following year.

The project provided George with a better insight into:

- Why the organic agencies require crop rotations and encourage cover crops and green manure crops.
- The role microbes play in the nutrient recycling process.
- Why soil properties are improved with increases in carbon.

Henry -

In conjunction with a water quality study, Henry converted irrigated cropland to pasture to monitor changes in nitrate levels in irrigation water. Henry is a corn and soybean farmer with experience fattening cattle, but now custom grazes a cow-calf herd. Test plots of corn, soybeans, grass, and a small (under different management practices) provide insight into how different crops affect water quality.

Henry says the project helped him to:

- Understand how organic matter levels affect nitrate levels in the soil.
- Learn grass growth and management practices that build organic matter and increase production levels.
- Understand why soil quality differences affect production even under irrigation.
- Learn from other farmers in a safe learning environment.

Irvin -

As a farmer in transition (with an off-farm job), Irvin split an 80-acre crop field and converted half to grass as an attempt to reduce labor, increase livestock production, and build soil carbon. He will compare production (grain vs. beef) to measure profitability, while monitoring changes in infiltration rates and holding capacity. He says he likes the look of the grass, the cattle condition, and is getting a lot of comments from neighbors and friends on his practice change. Irvin adopted more herbicide use to reduce tillage, control weeds, and save time, labor, and moisture.

Irvin says being part of this project showed him:

- How important carbon is to the production system.
- How to manage soils to increase carbon levels.
- Why diversity is important to soils.
- Building soil quality is insurance for the future.

Joe -

Joe is a beginning farmer with a full-time off-farm job. He harvested oats for hay from his test plot and no-tilled soybeans into the stubble. He likes the no-till practice to reduce his commitment to time and labor while conserving moisture. Although his plot is irrigated, it has some very light/sandy soils that are low in organic matter that showed up with the double-crop soybeans – identifying areas where manure could be placed to boost organic matter levels. He is searching for ways to grow more things for longer periods of time. He says, “The irrigation will provide the water and the plants will add the organic matter I need to make this a better farm.”

Joe says he:

- Learned the principles of long-term land management.
- Gained an understanding of soil functions and properties not taught in any magazine.
- Appreciates the group atmosphere for advice and insight to farm management
- He now watches the crops, weeds, and moisture levels with a different view than before.
- He realizes no-till management takes management skills and practice to be successful.