Iowa Water Center
at Iowa State University

Getting Into Soil & Water 2012

Soil & Water
Conservation Club

Letter from the Soil & Water Conservation Club President

Hello Reader,

On behalf of the Iowa State Soil & Water Conservation Club, I would like to introduce you to 2012 Getting into Soil & Water. Every year our club creates a publication in order to educate people on issues that affect soil and water from floods and droughts to conservation efforts. These issues not only affect Iowa but the world. Iowa State University Soil & Water Conservation Club members are able to witness conservation practices at work or discover areas that would need conservation practices implemented.

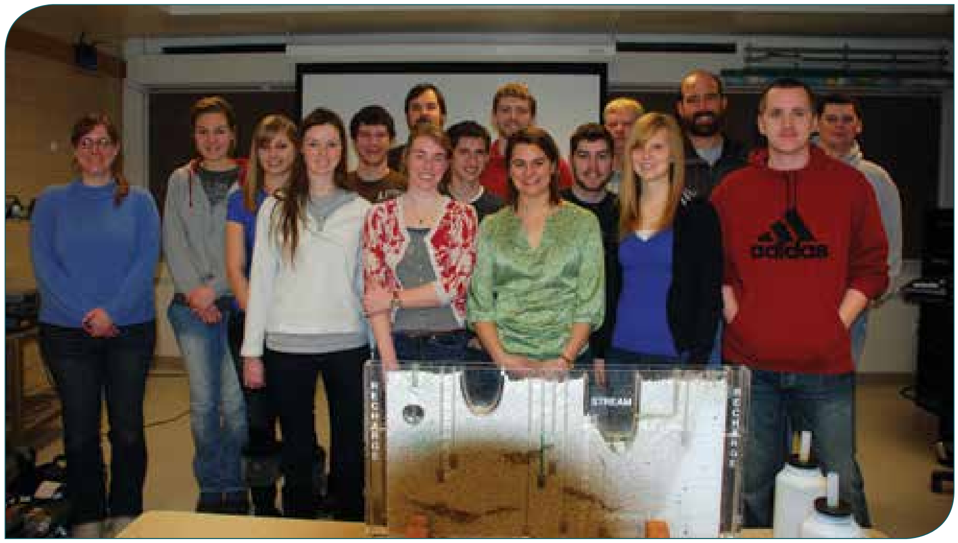
The Iowa State Soil & Water Conservation Club is a group of students from various majors and backgrounds but have the common interest of learning and promoting soil and water conservation. To help present our message to the public, we've created a groundwater flow model to demonstrate how pollution affects water quality which is presented at various conferences and outreach events.

This publication could not have been possible without the help of our publication committee led by the publication editor Deborah McDonough as well as the authors of the contributing articles that you will find within this publication. The Soil & Water Conservation Club would not be able to promote conservation without dedication from its members and faculty advisors Dr. Rick Cruse and Dr. Amy Kaleita-Forbes.

Sincerely,

Andrew Paxson

2011 SWCC President



2012 Soil & Water Conservation Club members.

2012 Soil & Water Conservation Club publication committee.

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A Message from the Editor

Deborah McDonough

Life as an undergraduate student feels extremely confusing sometimes because you are being pulled in a multitude of directions. Along with furthering oneself academically and trying to select courses that will fulfill university, college, and degree requirements, there are extra-curricular activities promoting scholarly pursuits and social events for you to participate in. All of this should keep a student's calendar full until graduation; however, most people do not find student loan money a sufficient means of paying the bills while at school, so a part-time job is a must-have for many.

After all is said and done, students receive their degree and either go on to graduate school or head out into life to discover their career. Either path will bring you to a formal interview accompanied by the one question everybody dreads: "Do you have any practical work experience?"

Realistically, the part-time jobs that would afford such sought after work experience are difficult to come by because most college campuses have enrollment in the thousands and these jobs are few in number. But the irony is that most students assume these jobs are already taken by people presumably more qualified than themselves.

To compound the problem, students fail to realize that the university is one giant networking event. Speaking to your professors, teaching assistants, and other faculty and staff will almost surely get your foot in the door to that same laboratory job or field labor position assumed to be out of reach. Even if it isn't a glamorous job, every scientist will tell you that their first jobs were stepping stones to the penultimate goal of acquiring the elusive practical work experience.

I am a Senior in both Environmental Science and Biology with a wildlife emphasis. I carry a full course load, hold down two jobs, and am a member of the Soil and Water Conservation Club. Being a member of the Soil and Water Conservation Club has afforded me myriad opportunities, one of which is having the privilege of being this year's editor of Getting Into Soil and Water. If this list of activities appears time consuming, the fact that I am a non-traditional student with a family immediately lengthens the "to do" list.

I have taken great care to fill my schedule with activities that are both fun and goal-oriented. Working two part-time jobs may not seem fun to the outside observer either, though it very much is, not to mention is rewarding. I started out being a research assistant for one of my favorite professors and when the work slowed down, he helped me acquire a position at the Soil and Plant Analysis Laboratory in Iowa State University's Agronomy Department.

My job there is to operate the LECO TruSpec® CN machine which analyzes the total carbon and total nitrogen (TC/TN) contained within soil and plant samples. Farmers from across Iowa, as well as researchers and graduate students from ISU, send their samples to my lab be analyzed for TC/TN and other analyses we perform.

Prior to working at the Soil and Plant Analysis Lab, I had absolutely no experience working in a laboratory setting or on a machine such as the TruSpec®. But guess what? Now I do. And that's one more accomplishment I am able to add to my résumé, telling potential employers that I not only have lab experience, but I'm able to operate a complex machine like the TruSpec®.

Each and every one of the scientists who authored an article for Getting Into Soil and Water are accomplished and talented in their field of study, but they didn't arrive at their destination without a lot of hard work and dedication to making their dreams become a reality. Like me, they all had to start somewhere: At the beginning.

You'll find lots of beginnings at Iowa State University—about 30,000 of them in fact, all of whom are students like those of us who produced this publication, taking their first steps of discovery. Just imagine the future potential being shaped and harnessed here in Ames, Iowa…

"Science" is a verb. It is an action and you cannot simply read about science and become a scientist. By becoming engaged in science you allow yourself the opportunity to do science. And that's what we're all about here at ISU and the Soil and Water Conservation Club: Engaging in and doing science. We're getting those life and labor skills, ultimately obtaining that elusive "practical work experience," and someday we'll change the world for the better.

I sincerely hope you enjoy this year's publication. A lot of time, effort, and care has been poured into these pages by the authors, the publisher, the publication committee, and myself, the editor. It is my belief that each of the articles clearly illustrates the knowledge these authors have in their field but also speaks to the level of commitment and devotion they have towards achieving their dreams and making this a better world to live in.

Sincerely,
Deborah C. McDonough
Getting Into Soil and Water, 2012
Executive Editor
Soil and Water Conservation Club
Iowa State University

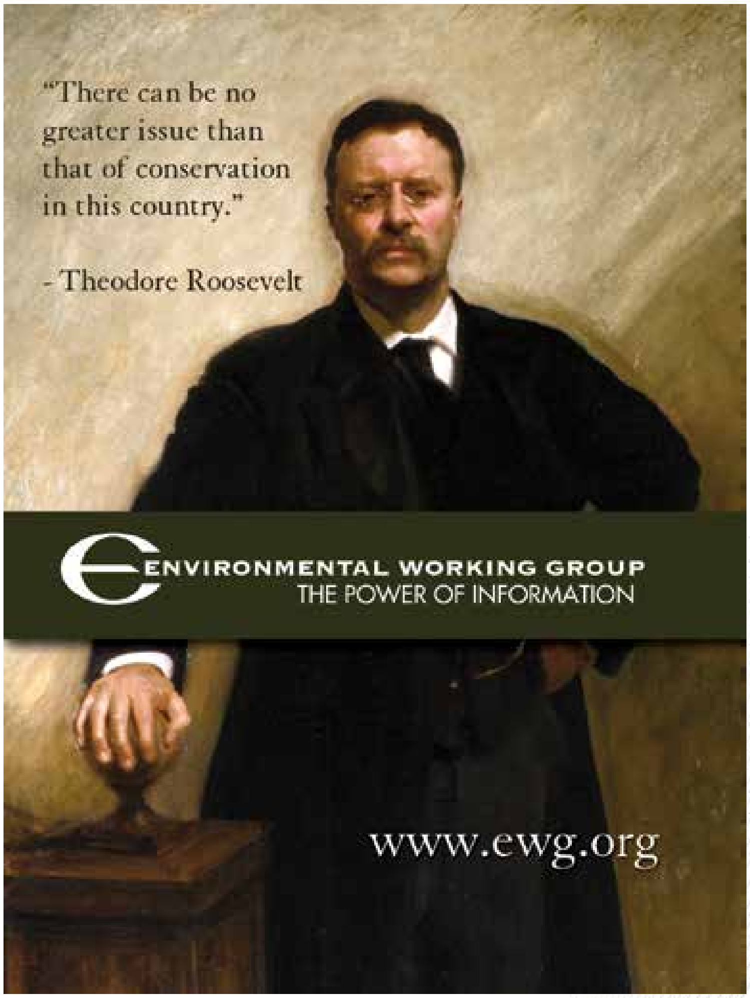

Photo by Deborah McDonough

Soil Erosion: Who Controls Its Future?

A Message from the Iowa Water Center

Rick Cruse
Director

With rising commodity prices and increasing recognition of land as a stable investment, agricultural land values have experienced unprecedented increases as evidenced by Iowa recently documenting a $20,000 per acre agricultural land sale. Rising land values and high commodity prices have many implications ranging from limiting opportunities for beginning farmers to devaluing the implementation of conservation practices; potential income losses associated with either real or perceived reduce commodity production drive the conservation practice devaluation. In selected situations, conversations suggest practices are removed simply for operator convenience. From a myopic economic perspective conservation is a cost to the producer or land owner and not an investment in the property.

Logically, one would think that a property of higher value would be treated with increasing care by the owner. Land (ultimately soil), though, seems a bit different than other personal property. That is, unlike other replaceable personal property such as a house, car or a combine, soil is a natural resource. And once degraded it is virtually impossible to replace in a human lifetime. Inability to replace a depleted privately-owned high value resource from which the owner derives an income should be sufficient incentive to place soil conservation high on an owner's priority list. However, this logic simply does not seem to hold universally when it comes to land ownership. Nationally, two million acres of Conservation Reserve Program (CRP) acres were retired, removing this erodible land from government supported conservation practices in 2011. This is occurring while the Iowa

> There is a growing need to manage Iowa's land responsively and responsibly. Private owners play a key role in this process.

Daily Erosion Project (http://wepp.mesonet.agron.iastate.edu/) estimates about 25% of Iowa's row crop farmland eroded at more than twice the tolerable soil loss rate in 2007. Frequency of heavy rainstorms is increasing while area of perennial cover that offers our best soil protection against soil erosion is decreasing. There is a growing need to manage Iowa's land responsively and responsibly. Private owners play a key role in this process.

As a society, private land owner rights and responsibilities are extremely important. Issues related to landowner rights can be found in the popular press often. Unfortunately, land owner responsibility, which arguably is equally important, seems to have been conveniently lost, ignored, or simply forgotten. A perspective that use of responsible production or conservation practices should be purchased through government payments seems to have become an operational default. Yet, the underlying rational of using tax dollars to pay landowners/managers to employ practices that favorably impact his/her own personal property seems logically counter intuitive even though it is done in the name of reducing off site environmental impacts. Maintaining private property and managing that property such that the owner benefits have been an owner's responsibility for nearly all properties in this country, except land. And more challenging, as land and commodity prices increase, purchasing favorable management behavior becomes increasingly costly while anticipated federal budget cuts will further trim funding for conservation practices on privately held land. Stemming the tide of unacceptable soil loss from many of Iowa's fields will require increased land owner responsibility as failure in this arena continues to inch us closer to the other "r" word, something that few of us in agriculture want to experience.

Iowa's Nutrients: Agricultural Inputs and Exports

Aaron Lee Daigh
PhD candidate, Agronomy Department, Iowa State University

Iowa soils have given way to 92,000 farms across 48,100 square miles (86% of Iowa's total land area) that lead the U.S. in two of the most versatile grains; corn and soybean. Meanwhile, Iowa also leads the U.S. in hog meat and egg production. Corn and soybeans, hog meat, and eggs annually produce a multi-billion dollar export industry. However, life vital nutrients from Iowa's land are also exported in tremendous quantities with these agricultural exports. To sustain Iowa's agriculture productivity, these nutrients, such as nitrogen (N) and phosphorus (P), must continually be replenished to the soil.

> To address our question regarding sustaining productivity and our natural resources we need to consider Iowa's land as a whole including both soil and water.

In 2011, approximately 3.2 billion lbs. of N and 545 million lbs. of P were exported in corn and soybean grains from Iowa's soil (IDALS, 2011; Libra and Wolter, 2004). For 2012, farmers will apply nearly 2.6 billion lbs. of N to 93% of corn acres and 5% of soybean acres in anticipation of sustaining production goals (USDA-NASS, 2010). Meanwhile, nearly 570 million lbs. of P will also be applied to 65% of corn acres and 10% of soybean acres (USDA-NASS, 2010). One can quickly conclude that a lot of N and P are involved with sustaining Iowa's agriculture legacy. With common N fertilizer costs ranging from $20 to $100 per acre, these quantities translate into a several hundred-million-dollar fertilizer demand.

As the U.S. currently endures its economic and environmental concerns, you might rationally ask: How efficient is our use of resources (i.e. fertilizers) for sustaining productivity of our natural resources? To address this question we need to look at all the inputs and exports of these nutrients even beyond fertilizers and budget them like a check book. This task was conducted and reported by Libra and Wolter (2004) and will be the bases for this article. However, soil and water are connected. In nature, nutrients jump back and forth between being adhered to soil particles and suspended in soil water. This soil water flows back and forth with groundwater. Additionally, groundwater is connected to surface waters, such as rivers. Groundwater is to rivers as the kitchen sink is to the drain. If a river is flowing, then groundwater is being drained and anything contained in that groundwater drains or moves to the river and flows with the river water. Thus, to address our question regarding sustaining productivity and our natural resources we need to consider Iowa's land as a whole including both soil and water.

Phosphorus fertilizer recommendations are based on maintaining optimum soil-P levels, so we will assume that soil-P levels generally don't change over time. Therefore, Iowa's P budget generally includes inputs derived from mineral/manure fertilizers and human/industrial waste while exports of P are found in grain harvest, grazing, and flowing rivers. The breakdown of inputs and exports in the P budget is shown in Figure 1. Generally, the budget appears to show good use of P fertilizers with 98% of P fertilizers being used and exported with harvest and grazing. Total P exports to Iowa's rivers are 4% of P inputs where 2% is derived from fertilizers and 2%

Image 1. No-till soil management in a corn-soybean cropping system. Photo by Aaron Lee Daigh.

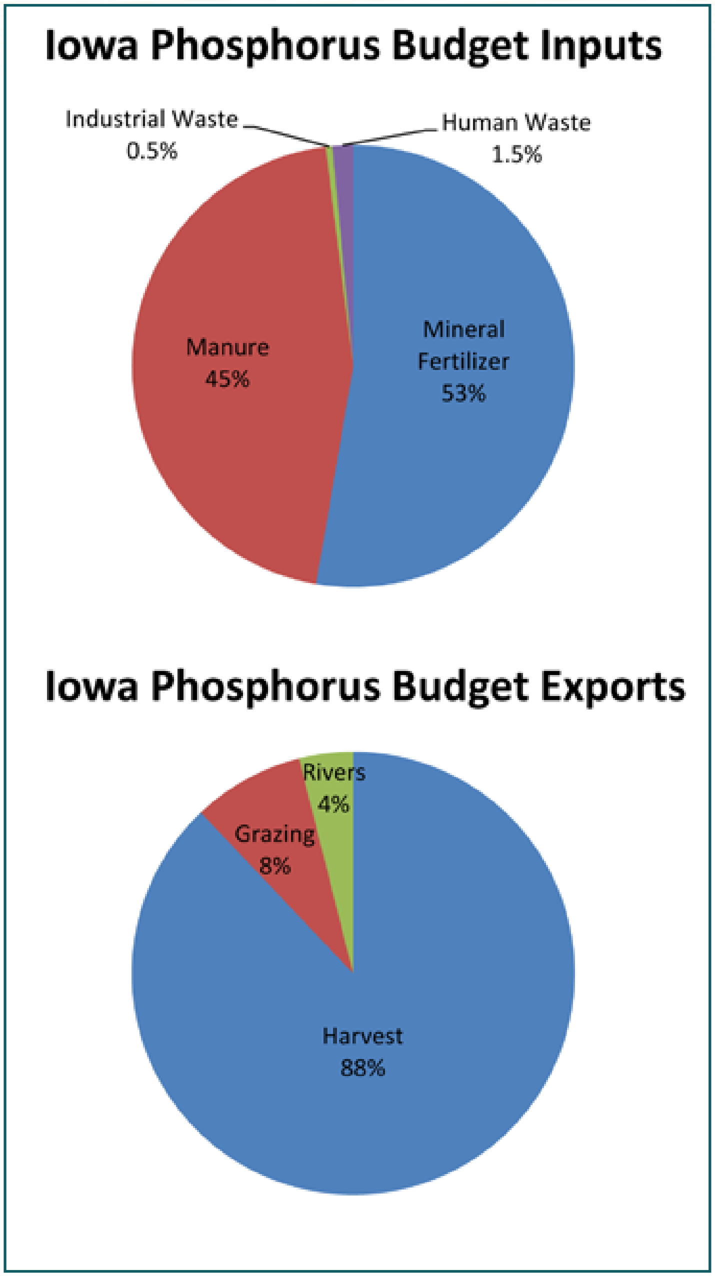

Figure 1. Iowa phosphorus budget estimates for a typical rainfall year. (Recreated and modified from Libra and Wolter, 2004)

Image 2. Perennial buffer incorporated into drainage ways of corn and soybean fields. Photo by Aaron Lee Daigh.

from human/industrial waste.

The N budget components include inputs derived from synthetic/manure fertilizers, legumes (plants that obtain their own N from the atmosphere and can store N in the soil), wet deposition (N contained in rainfall), dry deposition (wind-deposited N and aerosols), and human/industrial waste while exports of N are found in grain harvest, grazing, crop/soil/fertilizer gaseous losses, and lost to rivers. Similar to soil P, we can assume soil-N levels generally don't change over time. The breakdown of inputs and exports in the N budget is shown in Figure 2. The budget shows fair use of N with 78% of agricultural inputs (synthetic fertilizer, manure and legume N) being used and exported with harvest and grazing and leaving 22% of agricultural N inputs lost to the atmosphere and rivers. Total N exports to Iowa's rivers are 7% of that applied, of which only 0.7% results from point source human and industrial waste.

Although the use efficiency of N and P in Iowa generally tend to be favorable, the use efficiency of N needs improvement. An estimated loss of 22% of agricultural N inputs can be translated into a $70 million to $240 million loss in N fertilizer for Iowa farmers, depending on N-fertilizer costs. Additionally, N loss to Iowa's rivers appears to be small until you

Image 3 (not listed in text). Fall N application of anhydrous ammonia fertilizer. Photo by Aaron Lee Daigh.

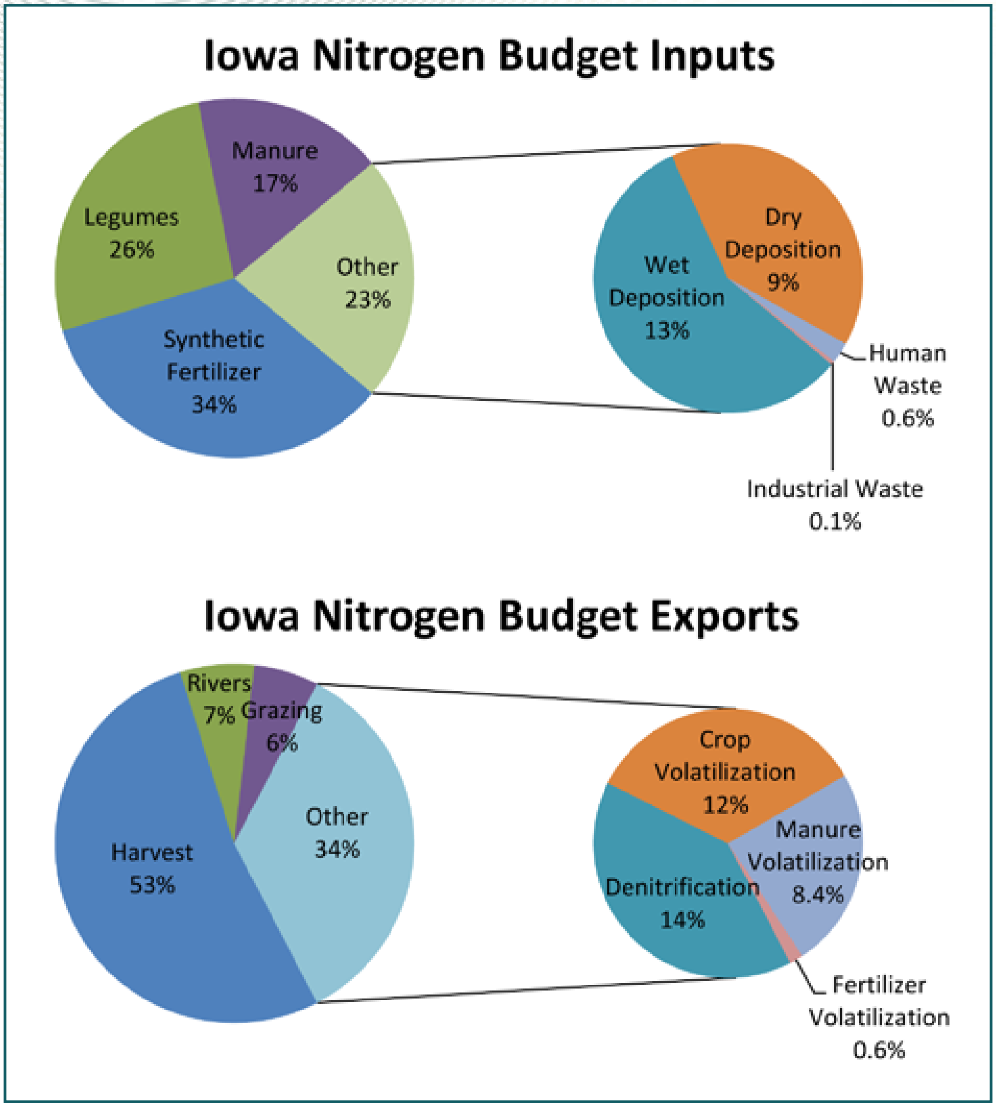

Figure 2. Iowa nitrogen budget estimates for a typical rainfall year. (Recreated and modified from Libra and Wolter, 2004).

consider of how many lbs. equivalent (400 million lbs. of N) equals the 7% N loss. This 7% N loss from the 55,800 square miles of Iowa results in 20% of the N exports out of the 1.15 million square mile Mississippi River Basin to the Gulf of Mexico (Libra and Wolter, 2004). Additionally, research at Iowa State University indicates an increased frequency of intense rainfall events and high rainfall years for Iowa. Studies also report that though the quantity of agricultural water drainage many vary substantially from year to year, the water drainage's N and P concentrations stay the same (Daigh et al., 2011). This means those years with greater rainfall and drainage will increase the amount of N and P loss to rivers. Nitrogen fertilizer losses in agricultural drainage water reached 50% in traditional corn-soybean rotations during the high rainfall year 2010 (Daigh et al., 2011).

Fertilizer use efficiency can be increased by using best management practices. These include reduced tillage to decrease runoff/erosion (i.e. N and P adhered to soil particles; image 1), split spring N applications and use of the Late Spring Soil Nitrate Test to identify appropriate N plant needs, cover crops to retain extra soil N in the root zone, incorporating longer alternative crop rotations, and incorporating perennials into the landscape to keep sediments and nutrients from entering drainage ways and rivers (a priority along major rivers with fast-flowing cold waters that can transport nutrients farthest downriver; image 2). These efforts will help to increase fertilizer use efficiency, improve on-farm economics, and increase water quality for the 50% of Iowa's 3 million residents that rely on well water.

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Texas: Drought, Fires and Soil and Water Conservation

Dr. Clay Robinson
SWCC Alumnus

Introduction

I was glad for the opportunity the Soil and Water Conservation Club offered me to write about the conditions in Texas this year, and their connection to soil and water conservation. I will provide some background information first, then I will share some current statistics, followed by implications on regional soil and water conservation issues.

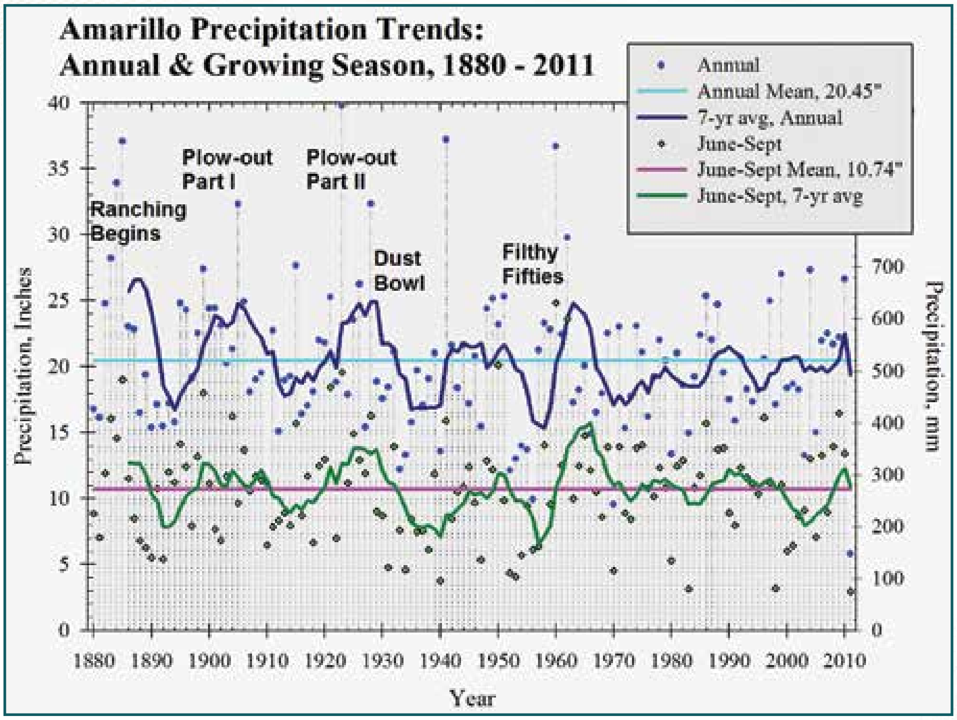
I am a fourth-generation Panhandle native, with a longer heritage in Texas (one great-grand uncle died in the Battle of the Alamo). My wife describes me as a "rabid" Texan. My father's parents and grandparents farmed and ran cattle. I am the first from the Robinson clan to obtain a college degree. They did not understand my pursuit of education; my grandmother once asked, "Why don't you just get a job?" After changing majors five times, I completed a BS in General Agriculture at West Texas State University (now West Texas A&M) in 1984. I worked for a year in triticale research before falling victim to layoffs in the last recession. I went back to school and completed an MS in Plant Science in 1988. As there were still no jobs (20+ flush letters), I took a teaching assistant position in the soils teaching lab at Iowa State University, and became a member of Dr. Richard Cruse's research group. I completed my PhD in 1993, looking at long-term, cropping system effects on soil properties. After two years at Eastern New Mexico University, I returned to West Texas A&M to teach courses in soils and agronomy. I modeled my alter-ego, "Dr. Dirt," after Bill Nye - The Science Guy, in outreach activities to the K-12 audience (DoctorDirt.org). I left as a full professor in May 2011 after 17 years, for a consulting position in the private sector.

A Brief Panhandle History

The High Plains includes the Texas and Oklahoma Panhandles, and parts of New Mexico, southeast Colorado, and southwest Kansas, some of the last areas settled in the United States. Only three rivers crossed the High Plains, and there were only a few springs. Playas provided water for a few months, in some years. With little permanent water, no trees native to the High Plains uplands, and grass as far as the eye could see, there was little incentive for people to settle the region. The Native Americans were nomadic, as were the primary grazers, e.g, bison and antelope.

In the 1870s the bison were killed, almost to extinction, and the Comanches were driven out.. Ranchers brought cattle to the High Plains in the 1880s, forming huge ranches. The ranches were established in a decade or so of above normal rainfall (about 150%). Windmills allowed people to tap the aquifer and Anglo-Europeans were the first to establish permanent homes on the uplands. Later, with favorable, if ill-conceived, government homesteading policies, my great-grandparents joined other farmers, plowing the sod in the early 1900s in another period of favorable rainfall. Political policies during World War I further encouraged plowing the prairie, supported by Powell's (1879) perspective, "The soil is the one indestructible, immutable asset that the nation possesses. It is the one resource that cannot be exhausted, that cannot be used up" (Powell, 1879).

Time proved Powell incorrect. A decade-long drought combined with more than 100 million acres of dryland wheat; fallow cropping systems, lots of tillage, overgrazing, and winds resulted in the Dust Bowl of the 1930s. Irrigation developed concurrently with the development of the natural gas industry following World War II. A more severe, but shorter, drought resulted in the "Filthy Fifties." Soon after the Dust bowl irrigation increased and soil conservation districts were established, enrolling 20 million acres by 1939. One of the Great Plains precipitation rules of thumb originated then, the minimum annual precipitation is approximately half the long-term mean. Some of the land that blew in the 30s had been abandoned and allowed to go back to grass. Irrigated acreage was increasing. Hugh Hammond Bennett was successful in establishing soil conservation districts, enrolling 20 million acres by 1939. All of these factors lessened the environmental and economic impact of the 50s drought.



2011

Good news or bad news? The worst news for farmers, ranchers, and natural resources managers in Texas and some other parts of the South and Southwest, was that there was no good news. Though 2010 was a wet year that produced abundant grass and understory vegetation, the drought began in late September, 2010.

Temperature

- Record heat wave: Texas mean summer temperature beat the previous record by 2.5° F
- Wichita Falls and San Angelo recorded 100 days when the temperature was 100°F or more
- Most cities recorded 20 to 40 more 100+ °F days than the previous record.

Precipitation

- Driest fourteen months (October 2010 - November 2011) in Texas history
- Two recording stations near Midland have received < 1.0” for the year
- West Texas is as dry as the Mojave Desert, receiving less than 25% of normal precipitation
- The Panhandle has received 3” to 5”, about 25% to 33% of normal (16 to 22”) precipitation, about half that of the previous driest year records
- East Texas received about half their normal precipitation, getting the Panhandle norm
- The Drought Monitor (droughtmonitor.unl.edu, 11-22-2011) shows more than 97% of Texas experiencing severe to exceptional drought.
- Given the strength of the La Nina forming again this year, the Texas State Climatologist expects the drought will extend through summer 2012, maybe longer.

Agricultural Impacts

- The heat and lack of rain dried the grass and understory vegetation into a formidable fuel source. The winds set no records, but were persistent.
- In 2006, about 1.67 million acres burned in Texas wildfires, setting a record.
- In 2011 almost 4 million acres have burned in wildfires, along with thousands of miles of fences and hundreds of homes.
- More than half the planted cotton was abandoned before harvest
- Most dryland crops were not planted due to lack of soil moisture or precipitation
- Acreage of corn, wheat, sorghum and other crops were down, as was per acre yield.
- Ranchers bought feed and/or substantially culled herds due to lack of grass for grazing.
- Farm losses in Texas will exceed $5 billion in 2011.

Water Impacts

- Texas water rights laws are based on the rule of capture, and managed through local water districts. The State does not own the water, individuals do. Though the legislature passed a landmark comprehensive water legislation act in 1997, aquifer withdrawals are subject only to local control through groundwater districts.

- There is only one natural lake in Texas. All others are reservoirs constructed to supply water to agriculture, industry, and a thirsty populace. No rain means no runoff. Stream flow and river levels are low. Statewide reservoir storage is at an all time low, less than 60%. Curtails for agricultural water use from reservoirs in 2012 are likely, even in the rice production area along the humid Gulf Coast. Texas aquifers are being depleted, as well, and it will take months to years of above-normal precipitation to recharge the aquifers (Fuchs, 2011).
- Lake Meredith in the Texas Panhandle was built in the 1960s and began delivering water to the 11 member cities (no agriculture use) through 358 miles of aqueduct in 1968. Operated by the Canadian River Municipal Water Authority (CRMWA, 2011), the lake was at 101.9 ft and held 540,000 ac-ft in 1973. Currently, it is at 23.6 ft and holds 22,000 ac-ft, 4% of capacity. Now Ogallala Aquifer well fields are providing water to the half million people once supplied by the reservoir.
- For the first time in the history of the lake, some member cities instituted voluntary water conservation targets.

Wasteful Attitudes Toward Water

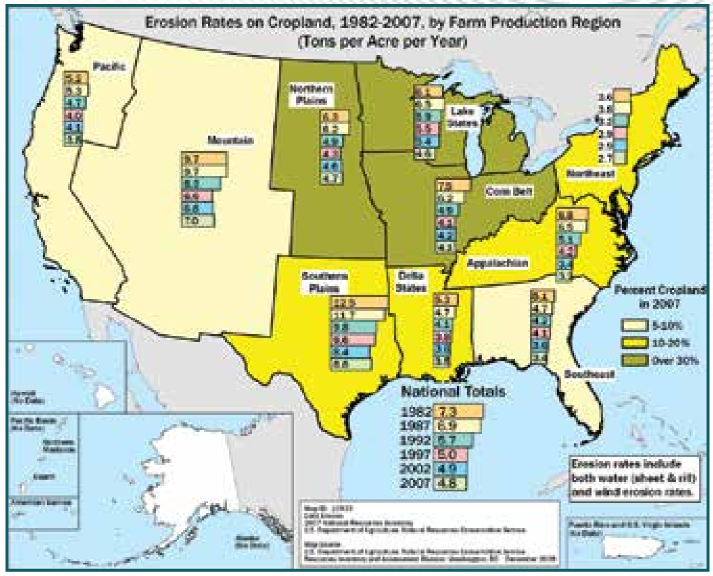
Businesses, schools, homeowners, and universities feel compelled to have trees and green grass all around, planting fescue and bluegrass, cool-season grasses that use two to three times as much water each year as the native, warm-season buffalograss.

For 17 years I told university administrators, including the director of grounds, that West Texas A&M University should be a regional water conservation leader. What they heard was, "You don't want our campus to be pretty." They ignored the beauty of the native plant landscape outside the library, designed by students in one of my classes. The grounds director has improved irrigation application efficiency and reduced water use by half. Now less water runs down the street and ponds in low spots on the lawns and sidewalks, but soils are often still saturated.

Lubbock and Amarillo have shallow, perched groundwater tables due to constant over-watering by homeowners. I have pictures of ice sculptures in lawns watered in February because the homeowner or business did not change the settings on their automated irrigation system.

Attitudes Toward Tillage

This semiarid region must store soil water in a fallow period because growing season precipitation alone is insufficient to produce a dryland crop. Minimizing tillage to keep residues on the soil surface increases infiltration and soil water storage,



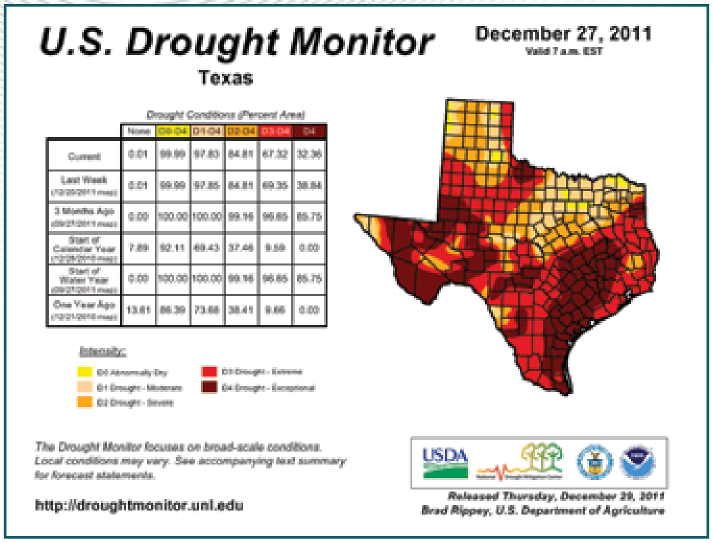
and decreases evaporation during the fallow period.

However, "The Plow that Broke the Plains" (Pare Lorentz, 1936, US Government Short Film) is still in vogue. Many farmers in the region continue to practice clean tillage with disk plows, thinking they are increasing organic matter and creating good mulch. Their goal is to get rid of the "trash." They do not understand they are drying the soil to the depth of tillage and decreasing available water holding capacity as they decrease soil organic matter. Irrigated farmers often burn corn and wheat residue to make plowing easier.

I have been unable to find reliable statistics on residue management practices in the Southern High Plains, but will share some observations. "Trash farmers" are not respected in the small agricultural communities in the region. To be sure, there are some excellent dryland, no-till farmers who "get it." There are some irrigated farmers adopting strip tillage. But the generally accepted notion of limited tillage in the region is tilling in fewer trips, not less-intensive soil disturbance. Even well-meaning farmers who want to practice "minimum tillage" proudly have shown me their new plow that turns a residue-covered surface into dry, bare, brown, powdery, erosion-susceptible topsoil. The prevalence of clean-tillage methods, low-residue crops like cotton, massive crop failures due to the drought, and lands scorched by fire, with 60-mph winds, led to the haboob in Lubbock, October 17, 2011.

From my windshield surveys and conversations with former students, I think the number of producers practicing tillage methods that consistently leave residues on the soil surface is less than half. So, is sustainable crop production on the High Plains possible?

Sustainable, integrated, dryland crop-livestock systems are possible. Research on dryland, no-till wheat-sorghum-fallow



rotations (2 crops in 3 years) at the USDA-ARS-CPRL at Bushland, TX (about 18" annual precipitation) has averaged 40 bu/ac wheat yields with only two crop failures in 30 years of production. The average dryland wheat yield with conventional tillage in that area is less than 20 bu/ac. Long-term, sustainable, dryland crop production becomes more difficult south of Lubbock. The rainfall pattern does not support winter crops in the rotation. The dominant crop, by far, is cotton. The soils are sandier and hold less available water in the root zone. These soils are also more susceptible to wind erosion. Cotton is a low-residue crop that does little to protect the soil from wind erosion.

Irrigated agriculture accounts for 95% of the Ogallala Aquifer water use in the Texas Panhandle and South Plains. The aquifer contains fossil water, with limited, if any, recharge, especially in the north. The current management goal for 2060 is to have 50% of the 2010 aquifer level. That does not account for the large water withdrawals in the first 60 years of irrigation. Many wells that once pumped more than 1000 gpm now pump less than 250 gpm, so a producer needs four to six wells to do what one well once did. Irrigation efficiency improved from about 40% in the early days of flood irrigation to 85% or better with a well-designed pivot. Some are now installing drip systems that have 95% efficiency. But, efficiency is not conservation. Once about half the 10 million acres of Panhandle and South Plains cropland was irrigated. Cropland acres decreased with the Conservation Reserve Program to about 8 million acres in 2010. Due to decreasing water levels and rising energy costs, irrigated acreage is now less than half, and will continue to decline. In some areas, irrigated agriculture lasted only a generation. Though the aquifer water quality has been good, salinity is increasing in many areas as the water table drops, creating more challenges. In some places, there are other fossil water aquifers below the Ogallala, with greater energy costs, and often with poorer water quality. Some producers already are using water from these aquifers. The water management plans call for reducing the rate of withdrawal from the aquifer, not seeking a sustainable use rate. For all these reasons, large-scale, irrigated agriculture in the Texas High Plains and South Plains is not sustainable.

Is Another Dust Bowl On The Horizon?

The Dust Bowl originally referred to the region affected by the worst of the drought and dust events. Now it refers to the worst environmental disaster in United States history. Black Sunday, April 14, 1935, made history as the worst of the worst. But during the height of the Dust Bowl, dusters came 3 to 4 times a week in the peak months, November through March.

In a report to President Roosevelt on the Dust Bowl, Hugh Hammond Bennett et al. (1936) stated, that the basic cause of the present Great Plains situation is an attempt to impose upon the region a system of agriculture to which the Plains are not adapted.

Factors Limiting the Likelihood of Another Dust Bowl

- There are 9 million acres in the Conservation Reserve Program in Colorado, Kansas, New Mexico, Oklahoma, and Texas, concentrated in the areas that were affected most by the Dust Bowl.
- About 1.1 million acres of National Grasslands exist on abandoned homesteads in those same five states.
- Many producers have adopted less intensive tillage practices, from using chisels, large sweep or blade plows, to complete no-till systems, though Colorado extension research showed adoption of better residue management methods decreased with distance from agricultural research stations.
- Soil and Water Conservation Districts, and FSA/NRCS programs encourage soil and water conservation methods.
- Range management practices have improved so overgrazing is less common.
- Irrigated crop production
- Knowledge and technology exist at all levels to be better environmental stewards than we were in the first four decades of the 1900s
- The combination of these factors decreases the contiguous acreage of degraded soil susceptible to wind erosion.

Factors Contributing to a Potential Dust Bowl

- Policies and commodity prices that encourage large-scale conversion of CRP acreage back to cropland. (It happened before: Most of the land planted to permanent grass for the Soil Bank program in the 1950s and 1960s was plowed to produce wheat in the 1970s.)

- Large, confined animal feeding operations (about 7 million cattle, 500,000 dairy cows, and 2 million pigs in the Texas Panhandle alone) create a large demand for locally-produced forage, encouraging irrigated corn production.
- High commodity prices, especially cotton and corn, increase demand for irrigation.
- Reaching the useful life of the aquifer for large-scale, irrigated crop production. What will producers do with acreage that was once irrigated? Converting all that acreage to dryland crop production would increase erosion potential.
- The South Plains will be more susceptible to major wind erosion events than the Panhandle which has more rangeland and grassland. In general the soils in the South Plains are sandier than those in the north. With more irrigated acreage, the south will be more affected by decreasing aquifer levels.
- Long-term drought. Isolated wind erosion events occur every year, but if the drought continues through 2012 and beyond, wind erosion events likely will become more frequent and severe. September-October rains failed this fall, so little dryland wheat was planted. If the May-June rains fail in 2012, few acres of cotton and sorghum will be planted, leaving a lot of fallow ground. If farmers plow for weed control, wind erosion events will worsen.

The High Plains and Southern Plains of the Texas Panhandle continue fighting against Hugh Hammond Bennett's initial assessment: A system of agriculture has been imposed to which the Plains are not adapted; such a system cannot be both permanent and prosperous.

Climate change?

If the climate gets hotter and drier, wind erosion will become more severe.For many reasons, 2011 will go into the books as one of the worst on record: drought, heat, wildfires, crop failures and abandons, along with declining aquifer and reservoir levels. The High Plains and Southern Plains of the Texas Panhandle continue fighting against Hugh Hammond Bennett's initial assessment: A system of agriculture has been imposed to which the Plains are not adapted; such a system cannot be both permanent and prosperous.

I believe ecologically sustainable agricultural systems are possible on the Plains. How? Large-scale irrigation will not be an option, so 30% to 50% or more of the current cropland likely will be returned to permanent grassland and livestock will be integrated into most operations. Furthermore, better residue management practices will be adopted on the remaining cropland. But such systems may not be profitable because future political policies may encourage the transition. This will be especially true if Midwest congressmen and senators, after seeing the insurance payments this year, renew their effort to change the crop insurance program structure to discourage dryland crop production in the Great Plains. We have the technology to avert another Dust Bowl. The question remains, "Do we have the resolve?"

♦♦♦

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Losing Ground

Craig Cox, Andrew Hug and Nils Bruzelius (with the Environmental Working Group)

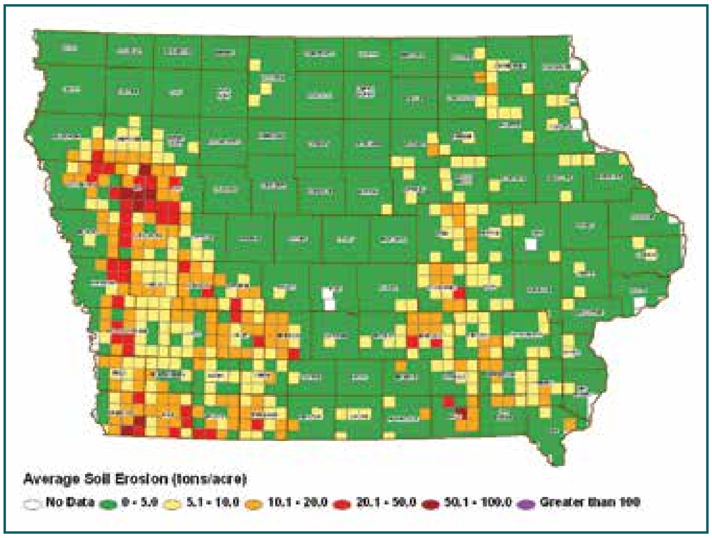

Figure 1. Average soil erosion in Iowa, 2007.

In April 2010, USDA's Natural Resources Conservation Service (NRCS) released data estimating the rate of soil erosion on agricultural land in the United States. On the surface, the data from the 2007 National Resources Inventory (NRI) were reassuring. Erosion in Iowa averaged 5.2 tons per acre per year, only slightly higher than the allegedly "sustainable" rate of five tons per acre per year for most Iowa soils (the amount that can supposedly be lost each year without reducing agricultural productivity).

The Environmental Working Group (EWG) report "Losing Ground" (http://www.ewg.org/losingground/), presented compelling evidence that soil erosion and runoff from cropland is far worse than these estimates suggest. The report, based on estimates produced by the Iowa Daily Erosion Project revealed that in some places in Iowa, recent storms have triggered soil losses that were 12 times greater than the federal government's average for the state according to the Iowa State University (ISU) project. In contrast to the reassuring statewide averages, the researchers' data indicate that farmland in 440 Iowa townships encompassing more than 10 million acres eroded faster in 2007 than the "sustainable" rate. In 220 townships totaling 6 million acres, the rate of soil loss was twice the "sustainable" level (Figure 1).

An aerial survey conducted by EWG in the spring of 2010 indicated that soil erosion and runoff are likely far worse than even the ISU numbers suggest, because researchers' current models do not account for the effect of widespread "ephemeral gullies." The runoff from vulnerable farmland not only washes away soil but also carries with it a potent cargo of fertilizers, pesticides and manure that flows into local creeks and streams and eventually into the Mississippi River. Ultimately it ends up in the Gulf of Mexico, generating the notorious dead zone-a zone of depleted oxygen that suffocates marine life where it forms each year.

Chronically underfunded voluntary conservation programs are failing to blunt the damage caused by the intensification of production on agricultural land. Between 1997 and 2009, the government paid Iowa farmers $2.76 billion to put conservation practices in place. It paid out six times as much ($16.8 billion) in income, production and insurance subsidies that encouraged maximum-intensity planting, not conservation (Figure 2). Across the Corn Belt, the gap was even greater; $7.0 billion for conservation and $51.2 billion for income, production and insurance subsidies.

The $18.9 billion dollars spent to subsidize expansion of the corn ethanol industry, along with misguided federal mandates to produce increasing amounts of ethanol, further increase the pressure to intensify production.

To turn this situation around, the US Department of

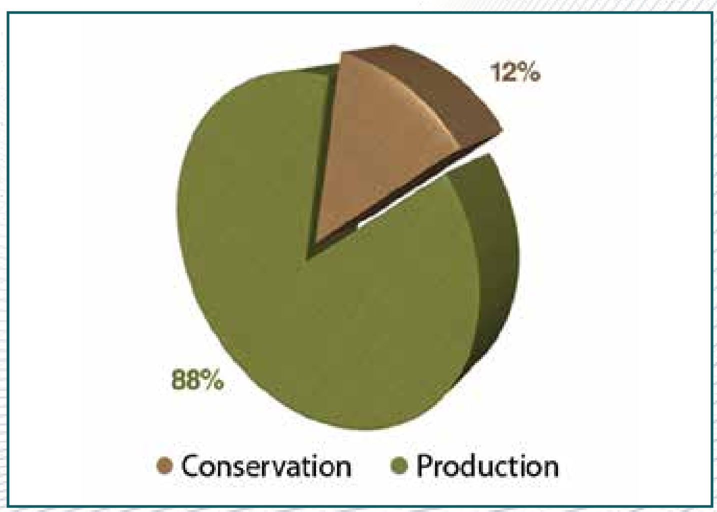

Figure 2. Corn Belt Subsidies, 1997 to 2009.

Gullies like those in these photos scarred most of the fields EWG surveyed in May 2010, visible evidence of serious erosion that is likely far in excess of rates considered "sustainable."

Agriculture (USDA) must step up enforcement of the groundbreaking 1985 farm bill provision, called conservation compliance, which required producers to take action to conserve soil in order to stay eligible for billions in farm subsidies. The USDA must increase its annual inspections to determine whether producers are maintaining the required soil conservation practices and also make full use of its authority to impose graduated penalties on farmers who fail to keep the required practices in place.

In addition, EWG believes that Congress must:

- Reopen and revise all the legacy conservation compliance soil conservation plans approved and applied before July 3, 1996, requiring that they reduce erosion to a truly "sustainable" level and prevent ephemeral gully erosion on highly erodible cropland.
- Require treatment and/or prevention of ephemeral gully erosion on all agricultural land — not just highly erodible land — owned by producers or landlords receiving income, production, insurance or conservation subsidies.
- Require vegetative buffer zones at least 35 feet wide between row crops and all lakes, rivers, and smaller streams.

Between 1997 and 2009, the government paid Iowa farmers $2.76 billion to put conservation practices in place. It paid out six times as much ($16.8 billion) in income, production and insurance subsidies.

- Require all producers participating in existing or new crop and revenue insurance programs to meet conservation compliance standards.
- Ensure that farmers who convert native prairie or rangeland to row crops are not eligible to receive income, production, insurance or conservation subsidies on those acres.
- Adequately fund the USDA technical staff — out of funds provided for programs covered by compliance provisions — needed to plan and implement the required conservation practices and to conduct annual inspections to certify that those practices are in place.

Soil Resilience and Climate Change

Jerry L. Hatfield
Laboratory Director, National Laboratory for Agriculture and the Environment

There is a continual dialog about the food required to feed a population of nine billion people by 2050 and the changing climate and the impacts on food production and food security. In all of this discussion there is little attention given to the fundamental fact that without soil we would produce little food. There is also little notice given to the fact that the land area we will have available to produce this food will continue to decline as the population increases. Another fact which can't be ignored is that our soils continue to be degraded, thereby losing their ability to supply water and nutrients to plants.

The land area we will have available to produce this food will continue to decline as the population increases.

If we examine a very simple concept of water use efficiency as shown on the attached diagram then we observe that the more water transpired by the plant, the higher the grain yield. As we limit water, we limit plant productivity and with the more variable rainfall expected under climate change then we can expect more variation in crop production. Across the Midwest, the primary factor causing yield variation among years is rainfall and within fields is the ability of the soil to supply adequate soil water during the grain-filling period. As an example of this dilemma, when we couple the water use efficiency concept with the desire to produce more corn, a simple extrapolation to achieve 18,900 kg/ha (300 bu/A) of corn from our present levels will require another 200 mm (7.8 inches) of water transpired through the plant. Soil is a water reservoir and the degradation process reduces the ability of the soil to store water because of the loss of organic carbon content and subjects the soil to crusting and erosion leading to less water being infiltrated into the soil. If we have more variable rainfall and a diminished capacity to infiltrate or store soil water then it may be difficult to achieve the yield increases required to adequately feed the world's population.

Soil degradation occurs through physical, chemical, and biological changes. Two agronomic components are always mentioned with soil degradation; increased tillage and residue removal. The physical processes associated with degradation include the loss of soil structure, crusting, compaction, erosion while chemical degradation is linked with nutrient depletion, elemental imbalance, acidification, and salinization, while biological degradation is caused by depletion of soil organic matter and reduction in the diversity and activity of soil microorganisms. Any change in the soil will begin the process of degradation and limit its ability to supply water and nutrients to plants. However, we assume that we can overcome these problems with the addition of nutrients to the soil and supplying water through irrigation. Unfortunately, we consider soil something to be managed around rather than properly managed to increase its capability to supply water, nutrients, and gases (oxygen for root growth) to a growing plant.

In the current climate change discussions, there is a large amount of attention given to the role soil management can play in terms of mitigating climate change. Sequestration of carbon into the soil and reduction of nitrous oxide emissions are often considered to be extremely significant roles for agriculture. However, these discussions often fail to consider the complete linkage in which the practices which decrease CO_2 emissions are the same ones which can reverse soil degradation and ultimately lead to increases in soil water necessary to produce the food needed to meet the population demands. Likewise, the practices associated with N management responsible for reduced nitrous oxide emissions can also lead to improved crop production, higher quality of the product, and reduced water quality impacts.

Soil provides a foundation of efficient agricultural production; however, our current view does not acknowledge the critical role soil has in producing food, feed, and fiber for humankind. Erosion remains a major problem around the world and continues to degrade the soil. To combat this problem we are going to have to come to the realization that soil is a system comprised of biology, chemistry, and physical structures not unlike what we have in our cities. Once we begin to understand the dynamics of this system then we can begin to understand how all of our adaptive strategies cope with climate change will have to incorporate an understanding of the role of soil in supplying water and nutrients. There are large opportunities for soil science to feed the world and provide solutions to climate change. We have to recognize that a key component to the question can be found by looking down at our feet rather than into the stars.

Looking Back and Moving Forward: Soil and Water Conservation in Iowa

Jim Gillespie
Director, Division of Soil Conservation

Iowa passed legislation in 1939 enabling the creation of soil conservation districts and establishment of the State Soil Conservation Committee, forerunner of the Department of Soil Conservation. From 1940 to 1952, 100 soil and water conservation districts (SWCDs) were organized, each led by three Commissioners that volunteered to set policies and priorities to meet local natural resource related needs. The first annual SWCD Commissioner's conference was held in 1947, providing Commissioners an opportunity to learn and share ideas. In 1969, the number of soil conservation district commissioners increased from 3 to 5, and became general elected positions in 1976.

The Department of Soil Conservation was first in the nation to create a soil conservation cost-share program in 1973, which began with $2 million to protect the productivity of the soils. The Department of Soil Conservation became the Division of Soil Conservation (DSC), within the Iowa Department of Agriculture and Land Stewardship in 1986, where it remains today. In 1987, soil conservation districts became soil and water conservation districts. Two years later, in 1989, the Resource Enhancement and Protection program was created to fund water protection practices and projects.

In 2000, the Iowa Water Initiative was enacted to address water quality issues, flood control and protect sensitive areas; in 2005, the Watershed Improvement Review Board was enacted to assist with water quality and flood control projects. An urban conservation program was established in 2007 to help Iowa's towns and cities better manage urban runoff and protect water quality.

Today, the DSC provides financial assistance for implementation of rural and urban conservation practices, funds local watershed improvement projects, supports research in sustainable agriculture and water quality improvement, and funds conservation demonstrations across the state.

Keeping the rain where it falls

Soil and water conservation practices protect soil productivity, improve water quality, reduce flood potentials and enhance

wildlife habitat. In the rural landscape, terraces break up slopes; waterways convey runoff down the hills; grade stabilization structures impound water and release it slowly; wetlands provide for natural filtration; and conservation tillage helps ensure rain is absorbed. All of these practices slow the flow of water off the landscape, which prevents soil erosion and keeps sediment and nutrients out of rivers, lakes and streams. The permanent cover of grasses and trees holds soil in place and builds a healthy soil structure, which allows greater infiltration of rain where it falls. These are essential, natural functions that directly benefit each and every one of us through rich, productive soils and clean water.

Rural or urban, we all live in a watershed and have a duty to protect the natural resources within it.

Recent weather trends show more rain than ever. It is raining earlier in the year, more frequently, and with greater volume, according to Dr. Gene Takle and Dr. Elywnn Taylor from Iowa State University. The increased rainfall has consequences – the storms of 2008 caused over $40 million in damages to conservation practices that were protecting our soil and water. Since then, Iowa has continued to receive storms that breach terraces and erode sloping lands. Conservation practices are a part of the planned system approach to land use and protection. A well-protected landscape is more resilient in heavy rainfall events, lessening the extent of damage through increased capacity to absorb rainfall.

Conservation is everybody's business

Rural or urban, we all live in a watershed and have a duty to protect the natural resources within it. Where towns and cities have traditionally impervious infrastructure that increase runoff and opportunity for flooding, we're now seeing new developments utilize practices such as pervious pavement, bioswales and green roofs. Other areas are actively retrofitting with these practices that increase capture and infiltration of runoff. This shift is encouraging, and a reminder that together, we can make great strides in protecting our soil and water.

Moving forward, we face mounting natural resource challenges. Application of conservation practices on agricultural land must be accelerated; urban conservation services must be increased; and new practices and technical tools must be continually sought.

Soil and water conservation districts will continue to play a pivotal role as we move into the future, working directly with landowners and operators, and leading local watershed projects. There will be greater opportunity to forge new partnerships as we persist in developing a stronger culture of conservation to help Iowans create more sustainable cities, towns and farms. Everyone depends on land for food and fiber; let us do all we can to protect it today, and into the future.

The Division of Soil Conservation is responsible for state leadership in the protection and management of soil, water and mineral resources, assisting soil and water conservation districts and private landowners to meet their agricultural and environmental protection needs.

Pasture Management and Water Quality

James R. Russell
Professor, Department of Animal Science

Pasture and rangeland in the Midwest have been identified as major contributors to sediment, nutrient, and microbial loading of streams, rivers, and lakes. The sources of these pollutants maybe direct deposition of manure into water resources, transport in precipitation runoff from congregation areas near pasture streams, and stream bank erosion. Studies in the literature have shown greater concentrations of sediment, nitrate, phosphorus, and coliform bacteria in water samples collected at sites downstream from a pasture in comparison to upstream sites implying direct effects of grazing cattle. However, these studies have been conducted on pastures grazed at excessive stocking rates for long periods of time. The effects of grazing on water quality of pasture streams can be mitigated through grazing management practices that control the location, timing, intensity, and length of grazing. Thus, when evaluating the effects of grazing cattle on the quality of water in surface water resources, the relationship of cattle distribution to grazing management needs to be considered.

How much time do grazing cows spend near pasture streams? Utilizing GPS collars, we observed that grazing cows spent 1.2 and 10.6% of their time in and within 110 feet of streams in 30-acre smooth bromegrass pastures. However, when we conducted similar tests on pastures at 5 different farms in the Rathbun Lake watershed, we observed considerable variation in the response of the probability of cattle being within 100 feet of a pasture stream or pond to the ambient temperature

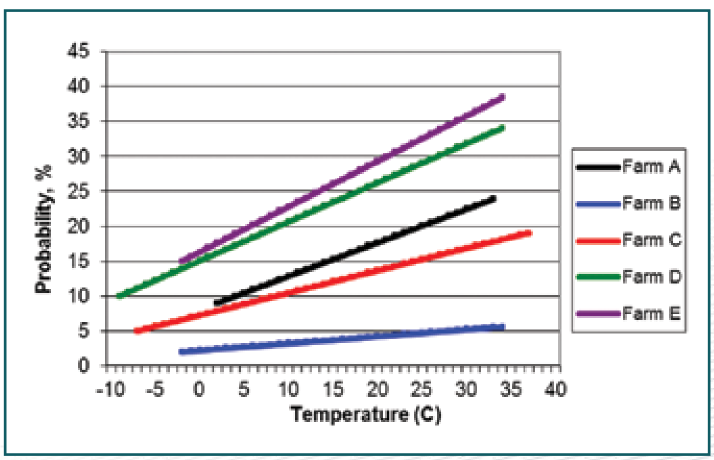

Figure 1.Probability of cattle being within 100 feet of a pasture stream or pond at different ambient temperatures in 5 pastures in the Rathbun Lake watershed (Bear, 2011).

Figure 2. Stabilized stream crossing

(Figure 1). While the roles of botanical composition of the pasture forage and shade distribution were evaluated, the major factor affecting the proportion of time that cattle were near a stream or pond was the size of the pasture. Thus, the greatest risk of pollution of surface water resources from grazing cattle will occur in small narrow pastures. When concentrated near pasture streams, shade may also attract congregation of cattle in riparian areas.

The proportion of time that cattle are in or near pasture streams can be reduced through grazing management. Restricting stream access by grazing cattle to a riparian paddock in a rotational grazing system that was grazed to a height no shorter than 4 inches or longer than 4 days reduced the proportion of time that cattle were in and within 110 ft of a pasture stream by 95 and 68%, respectively. Restricting stream access by grazing cattle to stabilized crossings reduced the proportion of time that cattle were in and within 110 ft of a pasture stream by 86 and 80%, respectively (Figure 2). More restrictive methods of preventing access to pasture streams such restriction to stabilized crossings are most important in small pastures (Figure 3).

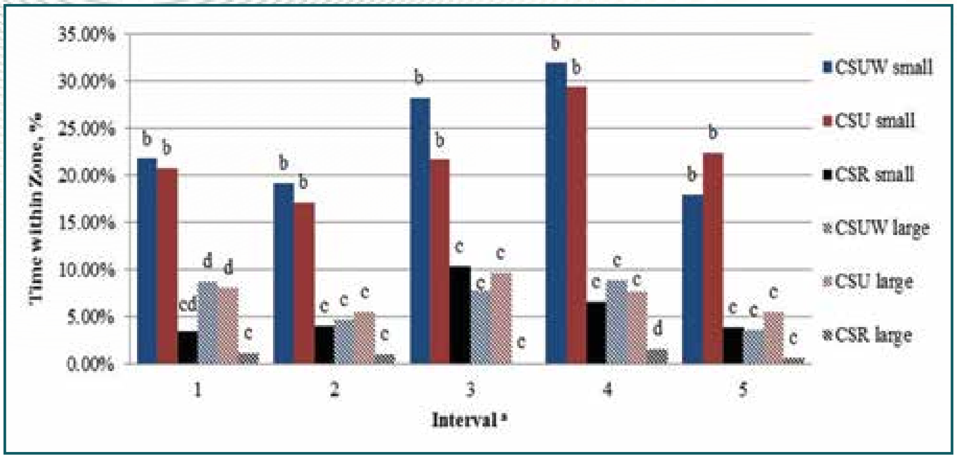

Figure 3. The effects of off-stream water (W) or restricting stream access to stabilized crossings (R) in small (10 acre) or large (30 acre) pastures grazed by continuous stocking (CS)(Bisinger et al., 2011).

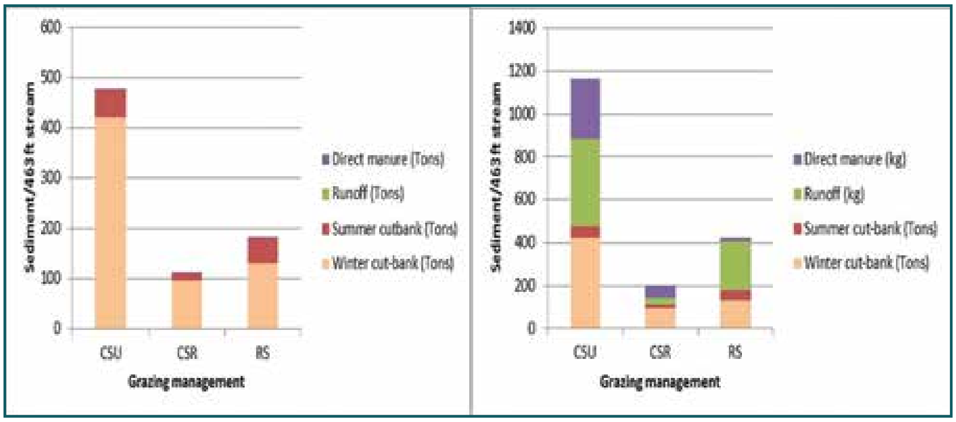

Figure 4. Contributions of direct manure deposition, precipitation runoff and cutbank erosion on sediment loading of streams in pastures with different grazing management practices (Schwarte et al., 2011).

The role of grazing cattle in pollution of surface water resources

When comparing direct manure deposition, transport in precipitation runoff, and cut bank erosion as sources of pollutants in pasture streams, it was found that cut bank erosion, particularly during winter, contributed 99 and 95% of the sediment (Figure 4) and phosphorus-loading in the streams, respectively. However, stream bank erosion has been related to neither grazing management nor stocking rate in our studies. Thus, environmental factors such as stream flow and freeze-thaw activity have greater effects on sediment and phosphorus loading of pasture streams than grazing management (Figure 5). Similarly, because the concentrations of total coliform bacteria in 1,254 water samples collected at upstream and downstream sites on 13 pasture streams in the Rathbun Lake watershed were unrelated to pasture stocking rate,it seems that other sources of coliforms like other domesticated or wild animals or septic tanks may be as important in affecting bacterial loading as grazing cattle.

However, when grazing is not properly managed, grazing cattle may contribute to sediment, nutrient, and microbial loading of pasture streams. Grazing by continuous stocking at high stocking rates will increase the risks of non-point source pollution by reducing vegetative cover and increasing manure accumulation in and near pasture streams. Thus, the presence of bovine enterovirus, a non-pathogenic bacteria used as a marker for cattle feces in water, was observed in water samples collected from streams in pastures in which cattle had been present for up to 6 days prior to the sampling.

To summarize, while sediment and phosphorus loading are largely the result of hydrologic factors, risks of nonpoint pollution of pasture streams may be reduced by site-specific implementation of grazing management practices that maintain adequate vegetative cover by reducing congregation of grazing cattle near pasture streams.

Environmental Benefits of Organic Farming

Kathleen Delate
Professor, ISU Organic Ag Program, Departments of Agronomy and Horticulture

What is Organic Agriculture?

Organic agriculture is the oldest form of agriculture on earth. Farming without the use of petroleum-based fertilizers and pesticides was the primary option for farmers until after World War II. The war brought with it technologies useful to agriculture, including ammonium nitrate, originally used for munitions, finding a ready market as a fertilizer, and organophosphate nerve gas next utilized in insecticides. Technical advances resulted in significant benefits, while negative environmental and social consequences led many to examine organic farming techniques. Organic agriculture seeks to use technical advances that consistently yield benefits, such as improved soil fertility and conservation practices, while avoiding those leading to negative impacts on society and the environment, such as water pollution and pesticide–resistant insects and weeds. Interactions between crops, animals, insects, soil, and water are key. For example, implementation of an organic soil nutrient plan may include crop rotations, cover crops, and compost to maintain or enhance soil fertility. In lieu of prohibited synthetic pesticides, biological, cultural, and physical methods limit pest expansion. Genetically-modified organisms (GMOs), or transgenic crops, such as herbicide-resistant plants, are prohibited.

As defined by the International Codex Alimentarius Commission, "Organic agriculture is a holistic production management system that avoids use of synthetic fertilizers, pesticides and genetically modified organisms, minimizes pollution of air, soil and water, and optimizes the health and productivity of interdependent communities of plants, animals and people." The 1990 Organic Food Production Act (OFPA) and 7 CFR Section 205 codified certified organic practices in the U.S. within the USDA-National Organic Program (NOP). In 2002, U.S. organic standards went into effect, creating a uniform set of regulations aiding market growth. A 36–month transition period is required between the last conventional practice, such as the application of a non-NOP-compliant pesticide and harvest of a certified organic crop. In 2008, 4.3 million acres of land were under organic production in the U.S., with 106,000 organic acres in Iowa. In 2010, U.S. organic industry sales were $29 billion, and $55 billion worldwide. Iowa is a leader in organic agriculture in the U.S. because of the high number of organic farmers (520) and processors (32), and the nationally recognized organic research and extension program at ISU.

Effects on Soil and Water Quality

Protection and enhancement of soil organic matter is critical for maintaining soil quality in sustainable agricultural systems. Recognizing the importance of soil organisms in mineralizing nitrogen for plant use, Sir Albert Howard (1873-1947), one of the pioneers of organic agriculture, formulated "The Law of Return," acknowledging the need to recycle organic waste materials, such as manure and leaves, on agricultural fields to replenish soil organic matter (Heckman, 2006). Because a longer crop rotation is required in organic farming, and the same crop cannot be produced in consecutive years on the same field, a typical four– to six–year organic rotation in Iowa includes a legume (alfalfa, clover, or vetch) and small grain (oat, wheat, or barley), in addition to corn and soybeans. Legumes supply nitrogen while small grains supply nutrients, particularly carbon, and aid in weed management.

Research at the Long-Term Agroecological Research Experiment (LTAR) experiment in Greenfield, Iowa, has shown that organic crops are competitive with conventional crops, even during transition (Delate and Cambardella, 2004). Averaged over 13 years, yields of organic corn and soybean have been equivalent to or slightly greater than conventional crops in a corn-soybean rotation. The 12-year average for alfalfa and oats, and an 8-year average for winter wheat, also show no significant difference between organic yields and the Adair County average. Soil analyses show total nitrogen increasing by 33 percent in the organic plots, with higher concentrations of carbon, potassium, phosphorous, magnesium and calcium, suggesting organic farming fosters greater efficiency in nutrient use and has higher potential for sequestrating carbon. Craig Chase, Extension Farm Management Specialist, calculated organic returns to management, and found, on average, organic systems return roughly $200 per acre more than conventional crops.

While research on water quality differences between organic and conventional systems is just underway in Iowa, mechanisms for an improved capacity for greater water and soil nutrient retention in organic fields may center around enhanced soil organic matter content. Recent data from a 12–year study in Michigan (Snapp et al., 2010) showed organic fields with half the annual nitrate leaching than conventional fields. NO3-N concentrations and subsurface drainage discharge also were reduced by 50% and 41%, respectively, under extended-rotation systems in Minnesota (Oquist et al., 2007).

Organic agriculture presents a unique opportunity for Iowans to take advantage of the growing market demand for organic products. More and more farmers are interested in both the profitability and the environmental benefits that organic systems can yield .

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Unintended Impacts on Soils From Long-Term Farming in Iowa

C. Lee Burras
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Introduction

Iowa has wonderful soils that are producing amazing yields and selling for record prices. Their productivity reflects highly upon their natural formation and our management. Many people think our soils will always remain amazingly productive. There are certainly reasons to think this is possible. But there are also reasons why our soils can eventually fail even when using the most sophisticated and technologically advanced farming practices. If that failure occurs it will likely indicate our inability to fully appreciate the limits of soil formation and, especially, soil regeneration. The goal of this paper is to give three very brief examples of unintended impacts that have occurred in our soils due to long-term cultivation and human use.

Unintended Impacts of Long-Term Farming

> "….about 31% (of Iowa)....has been seriously eroded and 50 to 75% of the original fertile surface soil has been washed away….." "Along with the (soil) loss there has been…loss…. (of) about 247 tons of nitrogen, 82 tons of phosphorus and 2,046 tons of potassium for every 160 acres……..On the basis of (the 1936) price of commercial fertilizers….this… amounts to approximately $2,975/acre." (p. 3). R.H. Walker and P.E. Brown. 1936. Soil Erosion in Iowa. Iowa State College Ag. Exp. Sta. and USDA-SCS Special Report No. 2, Ames.

Successful farming uses soils in order to grow plants and animals beneficial to humans while simultaneously maintaining or even enhancing the soil. A key component has been crop rotations that include deep rooted perennial crops such as alfalfa to maintain soil humus and stabilize the soil profile. Modern cropping has moved to continuous row cropping by relying on fertilizers, pest control and improved equipment. However, eliminating deep-rooted plants means soil profiles must change – and typically do so in ways we poorly recognize. Three of these unintended changes are (a) reduction in soil porosity, (b) redistribution of soil across fields, and (c) changes in soil classification.

Porosity is a critical soil property. It controls water infiltration, storage and drainage. It influences root growth and proliferation as well as the depth to which oxygen gets to roots and carbon dioxide escapes from the root zone. Porosity is also quite fragile, reflecting the balance between soil degradation and regeneration. In a well functioning natural soil, pores will account for one-half or more of the A horizon volume, with a mix of macro-, meso- and micropores being present. In a heavily cropped field, pore volume can drop by 10% or more due to compaction, erosion, loss of organic matter and other changes. It is useful to note that a 10% reduction in soil porosity equates to more than 30,000 gallons per acre-foot. Perhaps more importantly, the macro- and mesopores are lost with long-term row cropping (see Figure 2). This significantly

Figure 1. A soil profile from near Solon in Johnson County, Iowa. (Stronghurst series, fine-silty, mixed, superactive mesic Aeric Ochraqualf)

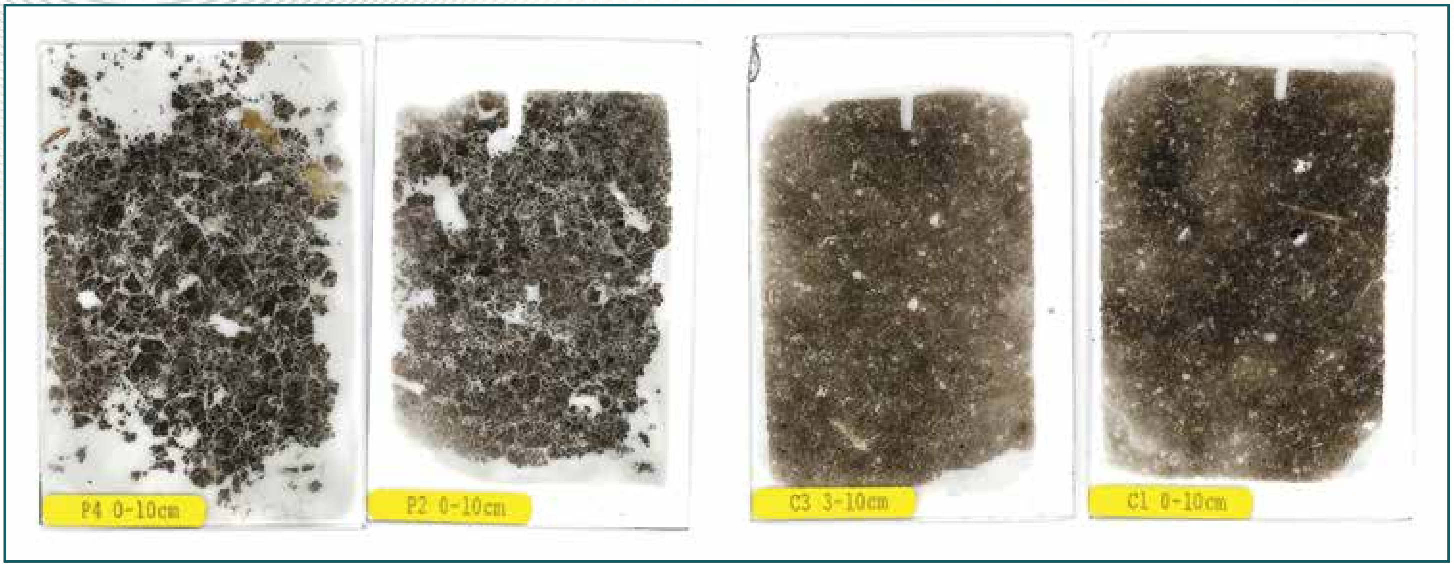

Figure 2. Thin sections from the top four inches (10 cm) of soil in Doolittle Prairie, Story County, Iowa and an adjacent cropped field. The two thin sections on the left are from Doolittle Prairie.

reduces infiltration and drainage as well as gas exchange.

One of the best indicators of whether or not a soil is at risk is simply the soil staying in place. Discussing soil movement generally means considering soil erosion, especially wind and water erosion. However, for this paper I am more interested in field scale product of soil movement, not the process of erosion. Simply stated, the 20th century was a time of incredible soil redistribution in Iowa. Across Iowa there are literally thousands of locations where there is 20 inches or more of soil on one side of the fence than the other (Figure 3). Typically the upslope side of the fence has a soil that is accumulating A horizon while the downslope side of the fence has largely lost its entire A horizon. This "stair stepping" at fences was largely if not entirely unintended. It stems from deposition from sheet and rill erosion. It stems from tillage induced soil movement. Regardless it indicates a break in soil regeneration processes, which indicates soils at risk of further degradation.

Figure 3. Example of two fencerows acting as sediment traps (upslope) and beginning point of erosion (downslope). There is a four foot "step" across the fencerow near the tree in the center of the photograph. There is only a three foot "step" between fields near the front of the photograph. Doolittle Prairie.

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The change in soil porosity and soil distribution across fields means soil processes and horizonation have changed and continue to change in Iowa. That is occurring in response to less soil regeneration than was occurring when perennial vegetation was prevalent in Iowa. In turn this is changing the very classification of the soils across Iowa. This was best documented by, Jessica Veenstra, who re-examined about 80 soils that had been extensively described and classified between 1943 and 1963. She found soil properties have been changed to 60 inches depth, resulting in 60% of these soils having changed Soil Taxonomic classification. These changes were especially prevalent in intensively cropped locations. (See Veenstra, J.J. 2010. Fifty Years of Agricultural Soil Change in Iowa. Unpubl. PhD Dissertation, Iowa State University Library).

Conclusion

The soils of Iowa are amazingly productive. But the more they are used for cropping – or any other human use – the more they are changed from what they were originally. The magnitude and direction of change in these soils is proportional to the extent to which land use practices differ from natural soil formation and regeneration processes.

A Legacy of Past Soil Erosion

Mark D. Tomer

Figure 1. Young Corn *by Grant Wood (1891-1942). 24" x 30", 1931, oil on masonite, Cedar Rapids Museum of Art. This painting illustrates the exposure of soils to erosion during the early years of row-crop agriculture in Iowa. Used by permission.*

If there is a single truth about history, it's that there is no escaping it. This is as true for us as it is for our landscapes and rivers, which are products of both the ancient and the recent past. We are learning today that natural systems can respond very slowly to changes that occurred in the past. This is particularly true of rivers, which are still responding today to events that accompanied the settlement of Iowa.

Consider the changes that Iowa has seen in the past 200 years. Iowa's first European settlers saw the full bounty of Iowa's prairie soils and could not perceive the long-term risks of farming as they practiced it then. One of those long term impacts results from the amount of soil erosion that occurred during the early decades of agriculture in Iowa. That eroded soil was deposited along local stream valleys, and continues to impact Iowa's rivers today.

Many Iowans are proud of the important role this state played in the history of agricultural conservation in the U.S. Iowa is the birthplace of Aldo Leopold, and the nation's first Conservation District. But what did Iowa agriculture look like before the need to conserve soil was recognized? One place to find what pre-conservation agriculture in Iowa looked like is in Grant Wood's paintings. Wood was meticulous about depicting the way of life and patterns of human habitation in Iowa back around 1930. In his painting 'Young Corn' (Figure 1), consider the field of corn in the foreground. There are widely spaced corn plants, so wide there would have been a fraction of the crop residue found in today's corn fields. Also, we see the planting rows going straight down slope, right to the edge of the stream. The wide, sparsely planted rows of corn oriented with the slope certainly contrasts what Iowa agriculture looks like today. From this painting, you can get some idea of how the first several generations of farming here exposed Iowa's soil to erosion. Certainly, there were more acres in hay and pasture back when animals powered agriculture, but the land in annual crops (16.4 million acres in 1919 compared to 23 million acres today) had little or no protection from erosion. Some artists were affected by erosion and the Dust Bowl; try a web image search of the southern plains artist Alexandre Hogue to find examples.

With the Dust Bowl of the 1930s, we recognized the impacts of soil erosion, and took the first steps to control it. We can all be proud of Iowa's legacy of conservation and our efforts to protect and sustain our soils. But with the increasing intensity of storms observed in the last few years, there is also a need to renew and strengthen our commitment to conservation so that severe soil loss can become a thing of the past.

At the same time, we should be aware of what happened to the many millions of tons of soil that were eroded from Iowa cropland in those early days of pre-conservation agriculture, and their continuing impacts on conservation issues today. The fact is, most of that sediment did not move very far and can still be found along the valleys of our rivers and streams. Take a look at the stream bank shown in Figure 2. The casual observer might conclude that downcutting by the stream has created this high bank that is clearly subject to stream erosion. However, the bank is mostly composed of sediments washed off nearby fields during the first 100 years of farming in this watershed. At this location, the valley has accumulated sediment, and the stream channel's elevation remains close to where it has been for a long time. Note the stream bank would only be two or three feet high were it not for the accumulated historical sediment.

Along our rivers, this phenomenon linking historically accumulated sediment with current stream conditions turns out to be more the rule than the exception (Figure 2). This legacy from the early years of agriculture has three major implications for water quality and river management today.

First, we often find that sediment loads in streams are more due to stream bank erosion than field erosion. We need to continue to improve efforts to reduce soil erosion, but we should not always expect successful erosion control will result in an immediate and obvious benefit of reduced sediment loads in streams, because sediment from soils eroded long ago is still entering our rivers and streams.

Second, the historically accumulated sediment occupies a volume of low-lying floodplain area, which would have originally been available for storage of floodwater. The loss of this storage volume available for floodwaters worsens flooding today, because floodwater that could originally be stored on the flood plain near the channel must now occupy areas higher on the flood plain, or be routed more quickly downstream.

Third and finally, we are seeking ways to 'reconnect' our rivers and floodplains, but should recognize the challenge typically results from build-up of recent sediment on the floodplain when we plan how to restore that connection. When we restore our rivers, stabilize their banks, and address flooding concerns we are usually dealing, at least in part, with a legacy from erosion that occurred one hundred years ago. This legacy of erosion impacts conservation issues today, and is a reminder that future generations count on us now to control soil erosion as best we can.

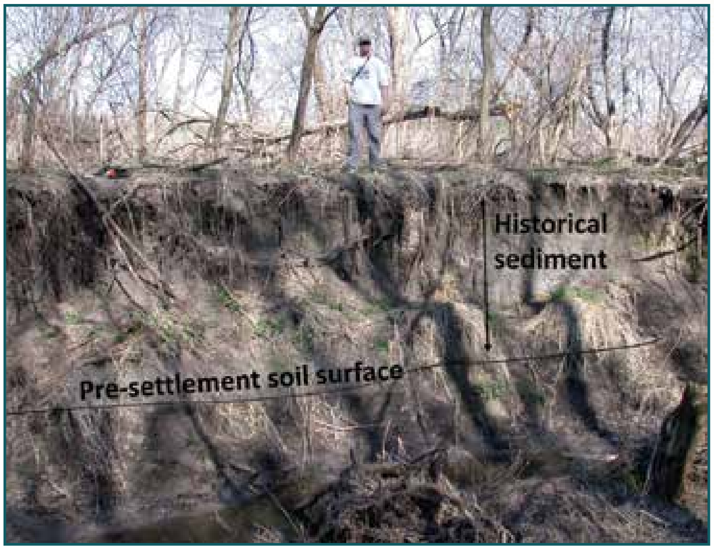

Figure 2. A stream bank in central Iowa. Most of the height of this bank is composed of sediments that were eroded from nearby fields between about 1830 and 1940. This stream bank would only be 2-3 feet high if it were not for soil erosion that occurred during the early years of agriculture in this watershed. Photograph by Keith Schilling, Iowa DNR.

Study of Historical Sediment in an Iowa Watershed

The Des Moines Lobe in north-central Iowa is not regarded as prone to soil erosion, due to this region's relatively flat landscape and extensive tile drainage. However, there was an indication, based on a regional analysis, that sediment loads from one watershed on the Des Moines Lobe, the South Fork of the Iowa River, were unexpectedly large. A study was conducted to determine if historical sediment could be influencing sediment loads in this watershed. Based on evaluation of soil cores collected along transects crossing the South Fork River valley, sediment that accumulated since settlement averaged 2.6 feet thick and was found on average a distance of 260 feet from the river channel. This sediment was estimated as equivalent to 70 tons per acre of soil eroded from the uplands across this 158,000 acre watershed, although erosion prone slopes near the river valley probably contributed a large share of that sediment. The volume of sediment reduced the capacity of the floodplain to store floodwater by an estimated 4123 acre-feet of water, considering pore space of the sediment, enough to displace 0.4 inches of runoff during major flood events. In addition, channel straightening of the South Fork and its tributary Tipton Creek were documented, and have reduced channel length and hastened routing of water downstream to the Iowa River. Historical soil erosion has impacts on river conditions today; these impacts can include large sediment loads from bank erosion, exacerbated flooding, and disconnection of rivers from their floodplains. Source: Yan et al., 2010.

Further reading:

Leece, S.A. 1997. Spatial patterns of historical overbank sedimentation and floodplain evolution, Blue River, Wisconsin. Geomorphology. 18:265-277.

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Walter, R.C., and D.J. Merritts. 2008. Natural streams and the legacy of water-powered mills. Science. 319:299-304.

Yan, B., M.D. Tomer, and D.E. James. 2010. Historical channel movement and sediment accretion along the South Fork of the Iowa River. Journal of Soil & Water Conservation. 65:1-8.

Life in the Soil: Who Cares?

Tom Loynachan
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We all should care! Without life in the soil, there is no life above soil. Yes, the soil is composed of many, many living, breathing organisms. Just how many depends on the soil but numbers can be staggering in our fertile, high organic-matter soils of the Midwest. It is often said that a handful of soil contains more living organisms than people on planet Earth. The only reason this can be true is because most are so small we must use a microscope to see them. In a sphere the size of the period at the end of this sentence (approximately 500 µm in diameter), about 125 million bacteria would fit into the volume of the sphere. That's approximately 1/3 of the US human population!

So if they are so small, how can they have an impact? It is because of their numbers and distribution. They are everywhere in nature and are active in decomposition of plant residues and animal wastes, recycling carbon, providing nutrients to plants (including nitrogen through biological fixation), forming soil structure to provide air and water for plants, and maintaining a sustainable environment in the soil.

Based on genetic evidence, we are finding there are many soil microbes that we can't culture in the laboratory. Without culturing them, it is difficult to determine what they do. Estimates of the number of microbial species range from 10,000 to 100,000 per gram of soil. Clearly there is much yet to be learned about soil microbes.

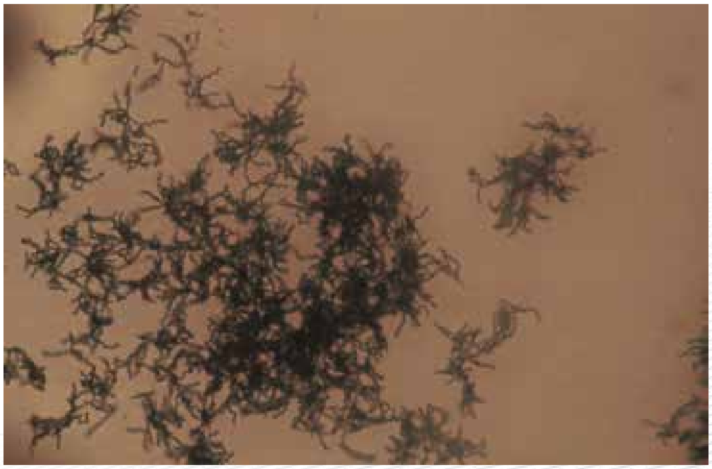


Figure 1. Freshly turned soil gets its 'earthy' odor from soil actinomycetes shown here (500x magnification, image credit T. Loynachan).

Figure 2. Life in the soil can be cruel. Here a nematode-trapping fungus has captured its lunch, a nematode. The darker loop structures entangle the nematode and the fungus will penetrate the nematode within about 24 hours to digest it (1000x magnification, image credit T. Loynachan).

Carbon and Nutrient Cycling

Organic matter from plants and animals fuels the soil food web (Fig. 3). Producing organisms use sunlight and carbon dioxide in the atmosphere to form plant tissue. As the tissue falls to the soil, a whole series of events occur in a food web. The smaller organisms decompose the waste materials and do two things: 1) release carbon dioxide back to the atmosphere, and 2) incorporate a portion of the carbon into their biomass (living tissue). This biomass serves as a food source for higher-level predators, and the process is repeated. Some larger organisms such as earthworms and higher animals directly consume the plant materials but their wastes and, yes, eventually their bodies are returned to the soil. The soil is the biological 'incinerator' that converts all these materials back to starting components. The carbon is recycled back to carbon dioxide in the atmosphere and the minerals are released in such form that they can be reused for new plant growth. In a burial service: "ashes to ashes, dust to dust" is often said, and this appropriately describes the activity of soil microorganisms in recycling.

Soil Humus

A small portion of the decomposing plant and animal residues is converted into soil humus. Soil humus appears not to

Table 1. Although conditions vary widely, expected populations[a] of smaller soil organisms per gram of healthy Midwest soil are huge.

Organism	Size	Numbers per gram[b]
Bacteria	0.2 - 2 µm	100,000,000
Actinomycetes	0.2 - 2 µm x filamentous	1,000,000
Fungi	5 - 15 µm x filamentous	100,000
Algae	10 - 40 µm	10,000
Protozoa	20 - 200 µm	1,000
Nematodes	200 - 1000 µm	100
Other invertebrates	> 200 µm	1

a) For comparison, a square yard of soil 6 inches deep may contain 30-300 earthworms.
b) Remember, there are 454 grams in a pound (a pound of soil is the approximate amount in a full pint jar).

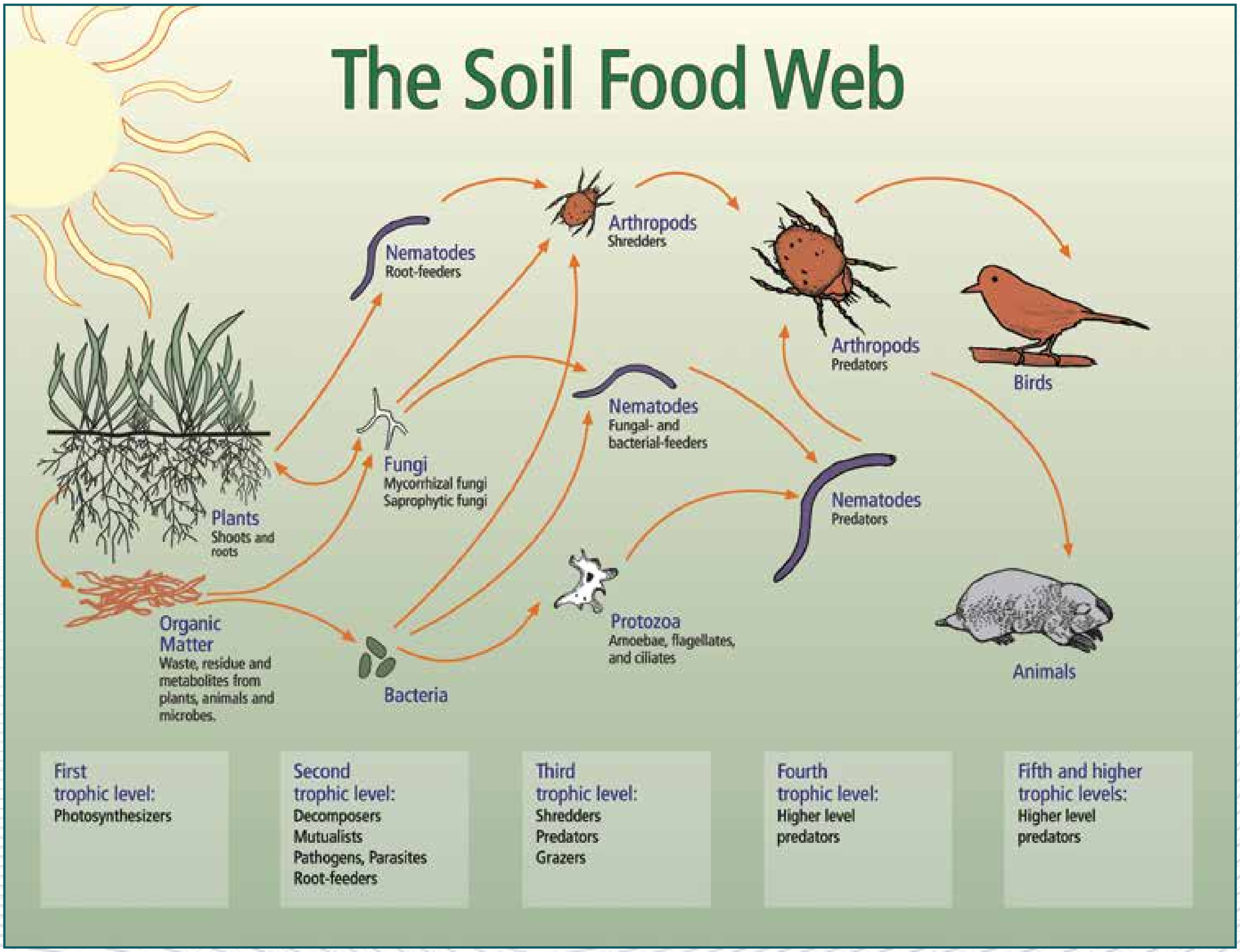


Figure 3. Soil serves as a biological incinerator where organics are cycled through a food web. With each cycle, carbon dioxide is released back into the environment and a portion of the carbon in converted into new tissue that serves as food for a higher-level predator. Most of the carbon is eventually released to the atmosphere but some will end up as soil humus (image credit the Natural Resources Conservation Service, USDA).

Figure 4. Fungi produce miles of hyphae in an acre of soil. Here are the fruiting structures of the soil fungus Penicillium (1000x magnification, image credit T. Loynachan).

be just plant and animal components that fail to decompose. The process of humus formation is complex and results in an organic material that remains after prolonged microbial decomposition. Microbes are thought to synthesize end products that polymerize to form the amorphous humic structures. Research shows that some of these compounds are stable for hundreds of years. As the organic matter becomes oxidized, it turns dark brown to black. Humus provides nutrient-holding capacity and stores moisture, both of which are needed for plant growth.

Soil Structure

Soil structure is the grouping together of sand, silt, and clay particles. It is important for the soil-water-air relationships required for plant growth. Two processes are involved in structure formation. First, there must be forces that join the particles together (such as root pressure, freeze/thaw or wet/dry cycles, etc.) and then the particles must be 'glued' to bind together. One of the important glues is soil humus. Another glue is fungal hyphae (strands) that surround soil particles binding them together. It is estimated that 10-to-100 meters of fungal hyphae can occur per gram of soil.

Nutrient Availability

Microbes impact nutrient availability for plant growth in three main ways:

a) they release the nutrients contained in plant and animal tissue as the tissue decomposes,
b) they increase phosphorus and other immobile nutrient availabilities in the soil through mycorrhizae, and
c) they provide nitrogen through nitrogen fixation.

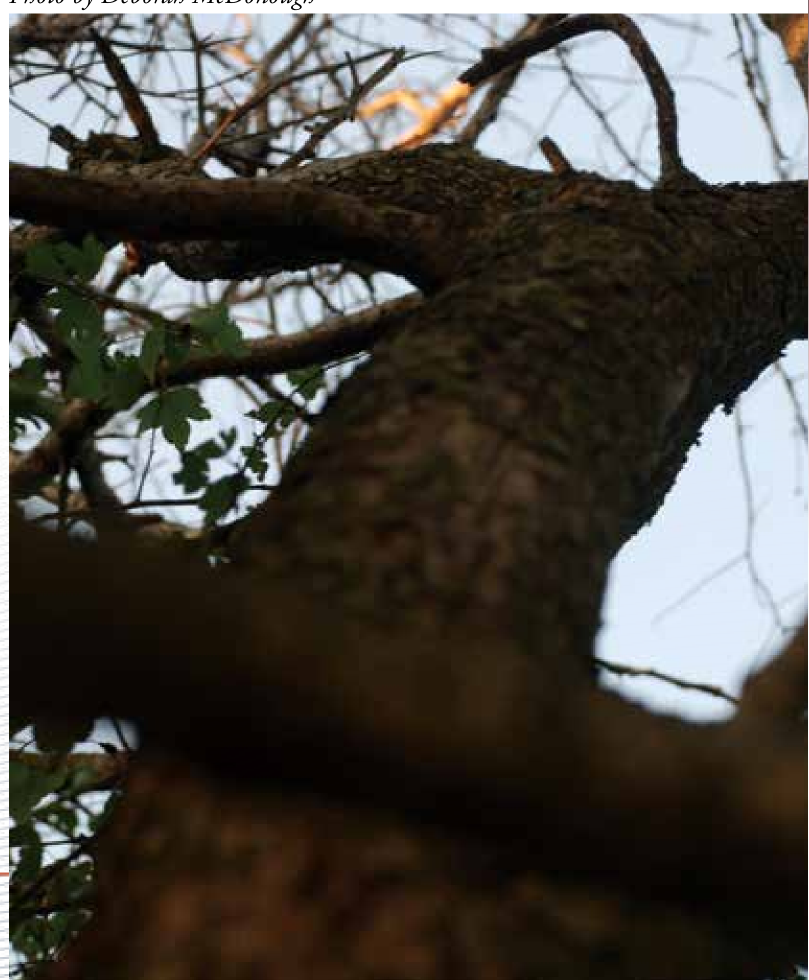
Mycorrhizae are symbiotic associations between fungi and higher plants that extend the soil volume through which plant roots can take up nutrients and water. Phosphorus is particularly important because it is immobile in the soil. The fungus increases the absorptive area of the plant roots.

Nitrogen is the most deficient nutrient for plant growth in many soils of the world. The cereals (corn, wheat, rice, and barley) are very responsive to nitrogen fertilization. Prior to human-made fertilizers, bacteria were the main source of nitrogen for plant growth. They can take nitrogen gas from the atmosphere and make it into a form available to plants. Some plants such as legumes develop special structures called nodules to house the bacteria. The plant feeds the bacteria and the bacteria provide nitrogen to the plant. Thus with mycorrhizae and nitrogen fixation, there are microbial methods of providing or enhancing the availability of two of the three primary macronutrients commonly used in fertilizers. Long term we need to better understand these natural, biological systems to maximize food production while minimizing environment impact.

So, the next time you walk across a field, watch your step. Life itself above ground is sustained by the living organisms below ground.

To see soil organisms on the move, visit:
http://www.agron.iastate.edu/~loynachan/mov/

Photo by Deborah McDonough



keeper
of the land

Soils are the base for civilizations past and present. We rely on soils for producing food, to filter and store our water, and to contain our wastes.

Agronomists help to conserve this precious natural resource for future generations and a healthier Earth. Their understanding of soils is essential to develop agricultural and natural resource sustainability and protect environmental quality.

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