

Getting Into
*Soil &
Water*
2016

**Soil & Water
Conservation Club**
at
**IOWA STATE
UNIVERSITY**

**IOWA
WATER
CENTER**

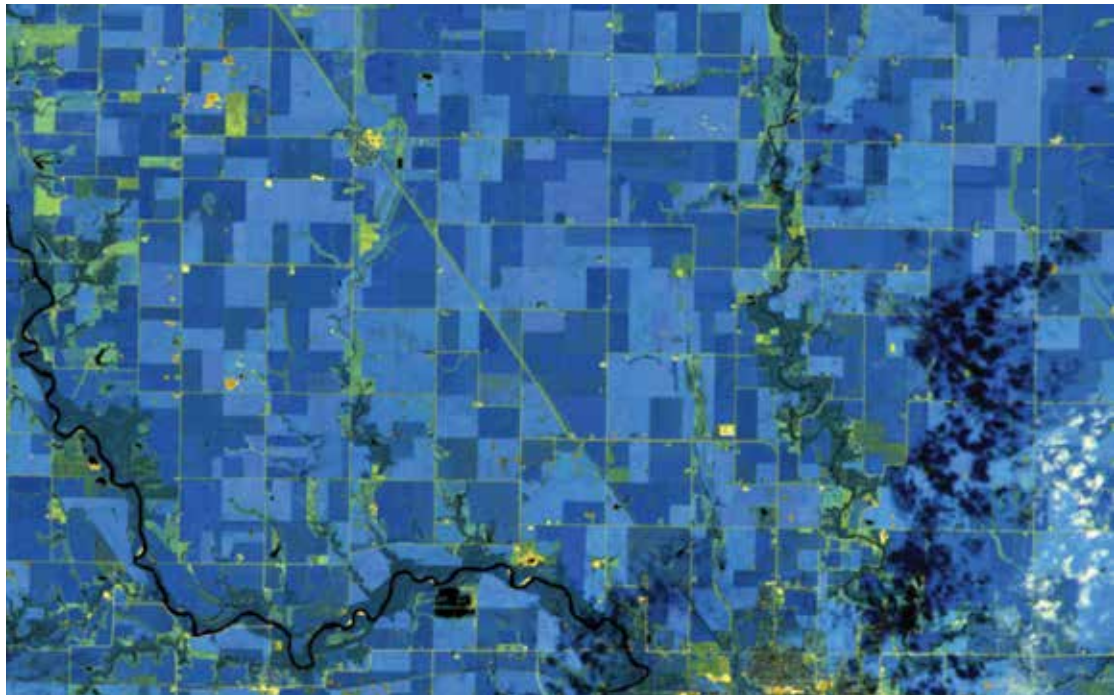
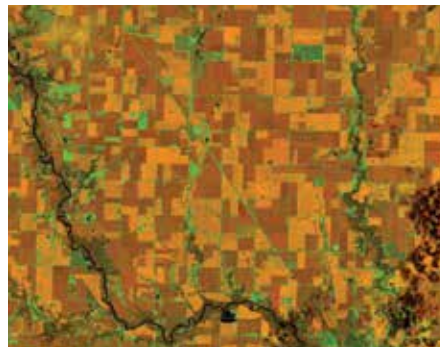
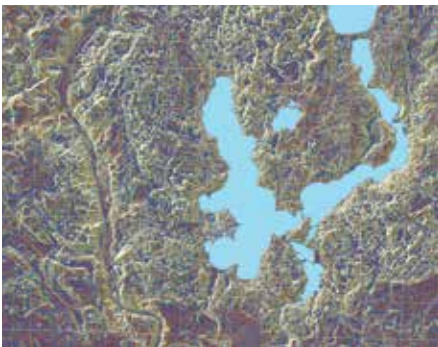


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Cover Art: Landsat satellite imagery (top and bottom) available from the U.S. Geological Survey. LiDAR derived digital elevation model (middle) available from the Iowa Geological and Water Survey, Department of Natural Resources.



Letter from our Editors

WE REMAIN DEDICATED TO SOIL AND WATER CONSERVATION EDUCATION

By Rebecca Clay and Chelsea Runyan, 2016 GISW Editors

Now in its seventh year, the “Getting Into Soil and Water” (GISW) publication remains dedicated to educating a broader audience on soil and water conservation and the preservation of environmental quality. Soil and water affect our lives in hidden and not-so-hidden ways, providing a medium for food production, delivering ecosystem services and sequestering carbon dioxide to mitigate global climate change. As co-editors of the 2016 edition of “Getting Into Soil and Water,” we have had the special opportunity to explore these issues and trends in soil and water, and to create a publication to share our findings with you.

We were moved to lead the GISW publication committee after we each developed interest in soil and water. Rebecca Clay, a senior in agronomy and global resource systems, became interested in soil after realizing the relation between soil quality and food security while volunteering in Kamuli, Uganda. She has since worked on a research project studying Corn Belt farmers’ perspectives on soil health and has worked in food security and soil conservation projects in Ghana, Ecuador and Guatemala. Chelsea Runyan, a senior in psychology, developed an interest in soil and water issues and



Rebecca Clay (left) and Chelsea Runyan (right) are co-editors of the 2016 *Getting Into Soil & Water* publication.

solutions after joining the Iowa State Soil and Water Conservation Club as a junior. Her main interest is in learning and implementing more sustainable practices in day-to-day life and in her surrounding community. Chelsea also served as the club’s secretary in 2015. We come from different backgrounds, but are both committed to educating people about all issues surrounding soil and water and make audiences aware of possible opportunities available to help remediate those issues.

We feel it is necessary to acknowledge the people who made the publication possible and the committee meetings both exciting and thought-provoking. We thank

our club advisors (Dr. Rick Cruse and Dr. Bradley Miller) and the publication committee members (Debbie Aller and Ohene Akuoko) for their dedication to the publication. As a result of our combined efforts, we present to you the 2016 edition of “Getting Into Soil and Water.”

In this issue you’ll find articles ranging in subjects from new apps to teach farming and conservation, to systems-thinking on an Iowa farm and how crop insurance programs impact soil and water. We hope that you’ll find the subjects interesting and might even get involved in soil and water initiatives in your community and beyond.

Rebecca Clay and Chelsea Runyan

Top, left: Iowa State Soil and Water Conservation Club members, L to R: Dr. Rick Cruse (club advisor), Joseph Klingelhutz, Chelsea Runyan, Deborah Aller, Daniel Brummel, Josh McDanel, Jake Ziggafos, Sarah Salmon, Ohene Akuoko, Casey Campbell, Riley Madole, Emma Haven, Rebecca Clay, Jordan Cooper and Dr. Bradley Miller (club advisor).

Top, right: 2016 GISW Publication Committee, L to R: Dr. Rick Cruse, Rebecca Clay, Ohene Akuoko, Deborah Aller, Chelsea Runyan and Dr. Bradley Miller.

Although it took several decades for significant progress to be seen on the land, practices such as contour cropping, terracing and grass waterways were adopted, slowing runoff and reducing soil erosion and sediment export.

Is Iowa's Water Quality Getting Better or Worse?

THE ANSWER DEPENDS ON THE TIME PERIOD ANALYZED

By Keith Schilling, Ph.D., Research Scientist, Iowa Geological Survey, University of Iowa

Media outlets and the public often jump to the conclusion that the latest spill or water quality violation indicates that water quality is getting worse in Iowa, but is it really? If you say that water quality is getting worse, do you mean water quality conditions are worse compared to last year, 10 years ago, 100 years ago or since pre-settlement? Consider the trends in water quality over the last 150 years.

It would be safe to say that Iowa's water quality prior to Euro-American settlement was pristine. Iowa's landscape consisted of tallgrass prairie and savanna at the time; nutrient levels in streams were very low; streams were connected to their floodplains; and the landscape was dominated by infiltration rather than runoff. Compared to the pre-settlement time period, conditions today are unmistakably worse. However, even in this pristine system, it should be known that floods still occurred, streams still eroded their banks (30% of banks in natural meandering streams are severely eroding) and nitrogen was moving through the ecosystem (albeit mainly in the form of organic N).

It did not take long following settlement for water quality conditions to begin to

deteriorate. Over the next 50 years, early settlers turned over the prairie, exposed nutrient rich soils to mineralization, tilled up and down slopes with moldboard plows, drained wetlands and tiled wet areas, straightened streams and generally transformed the landscape to one dominated by runoff processes. As Ding Darling's cartoons (Fig. 1) captured, soil erosion in the early 20th century was a massive problem. In response to more runoff, streams rapidly incised and widened into their floodplains. It was also during this time period that cities were rapidly expanding and contributing to stream degradation with discharge of untreated sewage. Farmers in the 1920's complained that streams were open sewers from cities and that city waste was impacting livestock. Water quality in the early 20th century was considerably worse than today, so the trend since the 1920's represents tremendous improvement.

In the decades that followed, from the 1930's to 1970's, there were many water quality improvements. Cities built wastewater treatment plants and



eliminated the dumping of raw sewage into rivers. Passage of the Clean Water Act in 1972 mandated significant reductions in many discharge pollutants such as ammonia-nitrogen. During the Dust Bowl years, it was recognized that soil conservation practices were

needed, and the Soil Conservation Service was founded. Although it took several decades for significant progress to be seen on the land, practices such as contour cropping, terracing and grass waterways were adopted, slowing runoff and reducing soil erosion and sediment export. Evidence for reduced sediment export is found in the Raccoon River in west-central Iowa. Our research has shown that sediment export was significantly reduced in the watershed despite an increase in river flow and the number of tilled row crop acres (Fig. 2). The general trend in sediment loss since the 1930's has been decidedly downward.

On the other hand, nitrate levels in our rivers are a different story. Limited water quality data from 1906 indicated that nitrate concentrations in several major rivers were less than 1 mg/l



Figure 1

(the EPA drinking water standard is 10 mg/l or 10 parts per million), and we can imagine that pre-settlement concentrations were even lower. We see evidence for this at the Neal Smith National Wildlife Refuge where my research has shown nitrate concentrations draining restored prairie areas are essentially zero. Although prairie soil is very organic rich, it does not leach nitrate because the continuous grass cover sequesters excess water and nutrients throughout a long growing season. Farming with tillage and annual crops breaks the continuous cycle and allows the water to leach nitrate during the spring and fall when there is no crop growth. A convergence of agricultural management changes occurring in mid-20th century, including increased mechanization (removing much of the demand for small grains and perennial rotations) and increasing commercial fertilizer usage, contributed to increasing nitrate levels in Iowa rivers. Average annual concentrations were 3-4 mg/l in the 1950's and increased to 7-8 mg/l in rivers today (Fig.2). During spring, concentrations routinely exceed 10 mg/l in many rivers. The influence of row crop farming on stream nitrate concentrations is profound –our research has shown you can estimate the mean annual nitrate concentrations in Iowa rivers by simply multiplying the percentage of cropped land in its watershed by 0.1. This means that watersheds with 80% row crop can expect to see average annual nitrate concentrations of about 8 mg/l. So trends in nitrate concentrations over the 20th century are definitely upward.

Finally, what are water quality trends over the last few decades? Despite an increase in monitoring activity, results are pretty

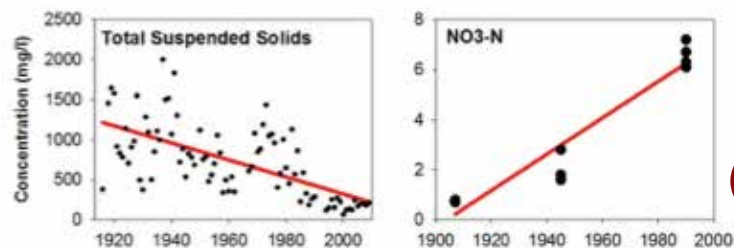


Figure 2

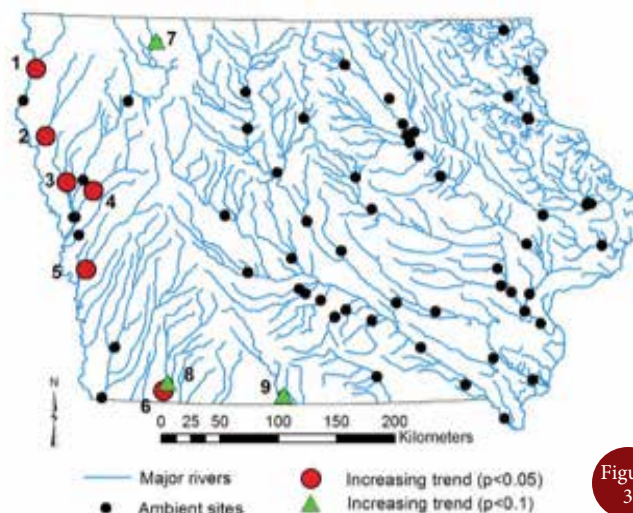


Figure 3

inconclusive. Levels seem to rise and fall with climate variability, higher during wet months or years and lower during dry periods. Care must be taken to decipher trends in water quality over the last decade as weather dominates year-to-year changes. The same monitoring record can show both increasing and decreasing trends depending on the starting and stopping points in the time series. We recently analyzed nitrate concentrations in 46 Iowa streams from 1998 to 2013 and found that 80% of the rivers showed no significant change. The six rivers that did show a change were increasing, and interestingly they were all located in western and southern Iowa (Fig. 3). Phosphorus concentrations are a different story. When we analyzed data from 40 Iowa rivers for the 1998 to 2014 period, concentrations were significantly decreasing at 12 sites and the overall trend was downward at an annual rate of 2.6%. Consistent with long-term sediment trends, declining P concentrations are most likely attributable to decreased erosion.

So, is water quality getting better or worse? The answer depends on the time period analyzed. Water quality conditions are certainly more stable today compared to the past 100 years, but the relative stability of modern water quality can be considered both good news and bad news. The good news is the worst is probably behind us and there are stable benchmarks to judge future progress toward water quality improvements. The bad news is that given the huge changes made in conservation and urban infrastructure over the course of the 20th century, it will probably take a similar massive change and investment in water quality improvements to realize our 21st century water quality goals.

We need not look past the borders of Iowa to find issues related to water pollution, soil degradation and food insecurity. Early education is a critical component to help solve some of these challenges in the state.

Engaging Middle School Students in Environmental Science through an Iowa Lens

PAIR OF LOW-COST ACTIVITIES INTRODUCE IOWA'S KIDS TO CONSERVATION

By Andrea Basche, Kendall Science Fellow at Union of Concerned Scientists

Scientists widely recognize that the environmental challenges of the 21st century exceed those of other times in history, including declining water resources and increasing climate change risks for future generations.¹ Further, a recent analysis of a 119-country survey found that education was most strongly associated with climate change awareness, with the researchers concluding that localized education was a critical component to inspire public action.² We need not look past the borders of Iowa to find issues related to water pollution, soil degradation and food insecurity. Early education is a critical component to help solve some of these challenges in the state.

I was fortunate to participate in a program during my graduate work at Iowa State University that allowed me to pilot environmental science activities with a middle school classroom. During the 2014-2015 school year, I worked alongside Amelia Kissell's 7th graders at Brody Middle School as a fellow with the GK-12 program.³ Through our partnership, as well as collaboration with the 7th grade literature teacher Judith Pauley, we were

able to create innovative activities for our students that immersed them in Iowa's current events. I have outlined below two activities that were implemented at a low cost and focused on Iowa.

Water Pollution in Iowa: Covering All Sides of the Issues

In the fall of 2014, the teaching team facilitated a "roundtable" discussion on water pollution in Iowa. Students researched and role-played one of several stakeholders involved in the public dialogues currently occurring in the state of Iowa. These roles included the Des Moines Water Works, concerned citizens, farmers, the Environmental Protection Agency, non-governmental agency representatives and scientists. Prior to the roundtables, one member from each of the various stakeholder groups was invited to speak to students and answer their questions given their



Andrea Basche

unique perspective on the topic of water pollution in Iowa. During Judith Pauley's literacy classes, all students constructed persuasive essays related to their stakeholder's perspective on water pollution. A final assembly included speeches and questions from approximately 30 7th grade students and was attended by lead officials from the Iowa Department of Natural Resources and the Region 7 Environmental Protection Agency.

Bakken Pipeline Permit: To Approve or Not to Approve

In the spring of 2015, a "performance task" activity was developed for students to explore the proposed Dakota Access Pipeline project. This is a project that if approved would transport crude oil from North Dakota to Illinois and transect the state of Iowa. Students were given a series of documents highlighting the



Fig. 1. There were many more single day classroom activities that excited students and highlighted Iowa. For example, Iowa's rich soils were celebrated with lessons on soil formation as well as a day of getting our hands dirty with establishing prairie plants outside of the school. I found a productive framing of issues helped to remind our students that they are 21st century citizens, responsible for the future of their state and the planet.

environmental impacts of oil development, potential consequences for water and soil quality, job creation, energy security and oil transport safety. Groups of students reviewed the materials and role-played the regulatory body tasked with approving or rejecting the permit for the pipeline. Because the topic is still ongoing in the state, the Iowa Utilities Board, who oversees the pipeline permit, was at that time accepting public comment letters. During literature classes, the students created letters to the agency and approximately 100 letters from these students were filed in the public record.

Opportunities for Engaging a Young Audience in Scientific Exploration

If you are a K-12 teacher interested in hosting scientists in your classroom, or if you are an undergraduate student, graduate student or faculty member with an interest in engaging with a broader audience, I encourage you to seek out or create opportunities. At Iowa State University, Adah Leshem and the pre-college education program with the Center for Biorenewables coordinates and supports many such partnerships. The Teen Science Café Network is an informal, interactive program to promote scientific learning and exploration. Finding a niche to

work with younger students is a chance to share your science, hone communication skills and excite more scientifically curious and engaged citizens.

Adapted from a forthcoming article, co-authored by Adah Leshem and Vince Genareo.

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- ³ <http://www.gk12.iastate.edu>
- ⁴ For more information on lessons and activities, see Amy Kissell's classroom wiki page: <http://mrsamykissell.wikispaces.com>



Systems Thinking on Pinhook Farm

SHARING THE STORY OF TRANSITION TO APPLYING NEW WAY OF APPROACHING ISSUES

By Seth Watkins

Our food system is complex. How I farm and what I raise doesn't just affect me. My decisions affect human health, our environment, our political system and ultimately the very stability of our planet. As the forces of a growing population are placed on agriculture, it is critical that we understand the relationships between all aspects of our food system. Taking a 'systems thinking' approach to problem solving will be a valuable tool in helping us make our farms, our state and ultimately our planet a happy place to live.

Systems thinking is not an easy subject, and thinking about what we're actually doing is not always pleasant. Most of us are linear thinkers. We have been taught to see an obvious and direct relationship between cause and effect. For example, a linear thinking solution to low yield would be to use more fertilizer. A systems thinking approach teaches us that that the relationship between a problem and its cause can be indirect and not always obvious. A systems thinking approach to low yield would be to ask, "Why is my soil not more productive?" This approach would offer solutions that involve understanding complex properties and processes such as soil type and structure, organic matter, carbon to nitrogen

ratios and conservation practices. Asking "why" instead of "how" makes us really think about what we are doing and is the thinking that can lead to long-term sustainable solutions that minimize unintended consequences.

I am grateful to share my story of how I transitioned to applying systems thinking to problem solving on my farm. But I want to disclose that learning about systems thinking is a lifelong endeavor, and I am an amateur at best. The best systems thinking model I know of was developed by Jay Forrester at the MIT Sloan School of Management. I know Forrester has to be a good guy because he grew up on a cattle ranch in the Sand Hills of Nebraska, and he often credits his ranch background with his ability to see interrelationships in complex systems. My favorite short description of systems thinking comes from one of Forrester's students, Mike Goodman: "Systems thinking is all about trying to figure out why something is happening, not what to do about it. It's a system that's 90% diagnosis and 10% treatment, rather



Seth Watkins
Image republished by permission of the Kansas City Star

than the 10:90 ratio used in quick fix responses."² Do not misconstrue this for touchy feely "lets think about this" to avoid working nonsense. This means really looking at what we're doing, then implementing and executing the changes needed to make our operations resilient, profitable and sustainable.

I was not aware of the term systems thinking when I started to implement its principles on my farm. Prior to March 1998 I ran my operation in a linear manner. I calved my cows in February and March because that's what I was told to do. I asked my veterinarian, feed representative, extension personnel and implement companies how to solve problems. They responded to my demands with new vaccines, antibiotics, feed products, university data and bigger more durable equipment to handle the February/March weather in Iowa. Not only did my industry resources find solutions to my problems, they gave me free hats, pocketknives and even the occasional free steak dinner (complete with a white linin tablecloth and two forks at each place setting). They told me this was because

I was feeding the world, and that made me special. I was also taught that some people were concerned about aspects of our food system, but that I should not concern myself because today's consumer didn't understand the complexities of modern agriculture and how critical it was for me to produce. Furthermore, because my work of feeding the world was so important, they even stopped calling me a farmer. I was now recognized as a producer. In industry's eyes, my sole purpose was to produce, and certainly not to be concerned with how my product was used once it left my farm. I've got 9 billion people to feed—how could I possibly question the judgment of industry? Especially when their representatives drive new pickups, wear clean clothes, have college degrees and give me free things?

All the solutions seemed acceptable, except for one thing: seeing a shivering baby calf trying to nurse a muddied udder on a cold March day. This never felt right to me. On March 11, 1998 a severe blizzard stuck. I made it through, but it was something I never wanted the cows, calves, or myself to experience again. Instead of asking *how* I should deal with the problems caused by the blizzard, I asked: *Why* was I working against Mother Nature instead of with her? As I contemplated that question I decided to trust my gut; baby calves aren't supposed to be born in cold rotten weather. Calves are supposed to be born on warm spring days with lush green pastures. From that point forward, I decided my focus would no longer be on production. My focus would be on having clean water, healthy soil and happy cows.

The following summer I executed a significant change to my system. I didn't turn the bulls out till July 4th, meaning our first calves would arrive in mid April. Systems thinker Barry Dunn describes my actions this way, "Only a few high leverage interventions are needed for a large system change."³ With this intervention, something unexpected started to happen. My production increased, my costs decreased and my profits went up. Making a happy cow is actually a wonderful system. It requires



"Society has become so complex that traditional ways and means are not sufficient anymore. Approaches of a holistic or systems nature have to be introduced."

—Ludwig Von Bertalanffy, (Laszlo, 1972)¹



clean water, which means restraining the cows from ponds and riparian areas. The clean water delivers higher weaning weights and better herd health. The restricted areas become habitats for birds and other wildlife. The birds like to eat the flies that bother the cows. Next, happy cows like diverse forage. They don't like one kind of grass—they like forbs, clovers and multiple species of grass. Clover and forbs don't like broadleaf herbicides, but at \$40 an acre for broadleaf control, neither do I. Guess what else? The clover dilutes my fescue grass and provides better performance for the cows eating it. In addition, since clover is a legume it has reduced my reliance on commercial nitrogen. It also has played a nice role in the antler growth on our southwest Iowa whitetail deer.

What have I done? I've transitioned from a linear cause and effect system that was sustained by cheap crude oil and industry rhetoric to a system that is starting to follow nature's lead. It is a system that is starting

to go beyond sustainable to a system that is actually regenerative. Ultimately, I think the greatest part of systems thinking is that it has given me a renewed sense of purpose. It has helped me remember that I'm not a "producer." I'm a farmer. My job isn't to produce. My job is to care for the land. When I do this properly, the land takes care of us all.

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Soil informatics brings together the latest developments in geographic information science and soil science to provide the best possible spatial information for modelers, policy makers and landowners.

Soil Informatics: Better Maps for Iowa

AS TECHNOLOGY ADVANCES, WE BECOME INCREASIGLY AWARE OF SOIL VARIABILITY

By Bradley Miller, Assistant Professor, Department of Agronomy, Iowa State University

Soil is important, but not all soil is the same. Different soils have different capabilities and vulnerabilities. In large part we have known this for centuries, but as technology advances we've become increasingly aware of the variability of soil. We've since sought to tune our land management practices to that of spatial variation to better accomplish our goals. When the US Soil Survey began at the turn of the 20th century, its maps helped guide farmers in choosing which crops were most suitable for their soil.¹ In the 1940's Soil Survey maps became an important tool for identifying where conservation practices would have the greatest impact in reducing soil erosion.^{2,3} Today, precision agriculture is enabling management practices to be tailored at the sub-field level, while environmental concerns are driving the need to predict interactions occurring as potential contaminants flow through the diverse soil landscape of large watersheds.⁴

Currently, we are using the latest US Soil Survey maps to provide the soil information required for these data intensive endeavors. As impressive and remarkable as those traditional soil maps are, they are not sufficient to provide the

level of detail nor accuracy that precision agriculture and environmental modeling require. Although nearly the entire USA has been mapped for soil, the job is never ending. The average age of current Soil Survey maps in Iowa is 28 years, with the oldest being from 1968. The soil landscape can change considerably over a few decades,^{5,6} but that isn't the largest issue with relying on the current Soil Survey maps. The largest shortcoming of the available Soil Survey maps is that very little modern geographic technology was used to produce them. The amount of fieldwork conducted by the US Soil Survey makes their soil maps among the best in the world, but leveraging modern geographic information and analysis systems would move those maps much closer to meeting the increasing demands for more detailed and accurate soil maps. This is what soil informatics does.

Soil informatics brings together the latest developments in geographic information science and soil science to provide the best



possible spatial information for modelers, policy makers and landowners.

One of the revolutionizing developments that enables modern soil informatics is remote sensing. The first thing to realize about soil mapping is that it is impossible to directly observe the soil at all locations. For one thing, most of the soil

characteristics we need to know are hidden below the surface. Then keep in mind that those soil characteristics can actually change quite a bit within only a few meters. Therefore, we have to spatially predict the characteristics of the soil beyond the limited sampling points. Our best tools for making spatial predictions are relationships between more easily observed above ground features and the soil characteristics we want to know. The existing soil maps used this approach. For the most part, the soil scientists observed what they could in aerial photographs and utilized their experience in the field to make the needed associations between features above ground and what

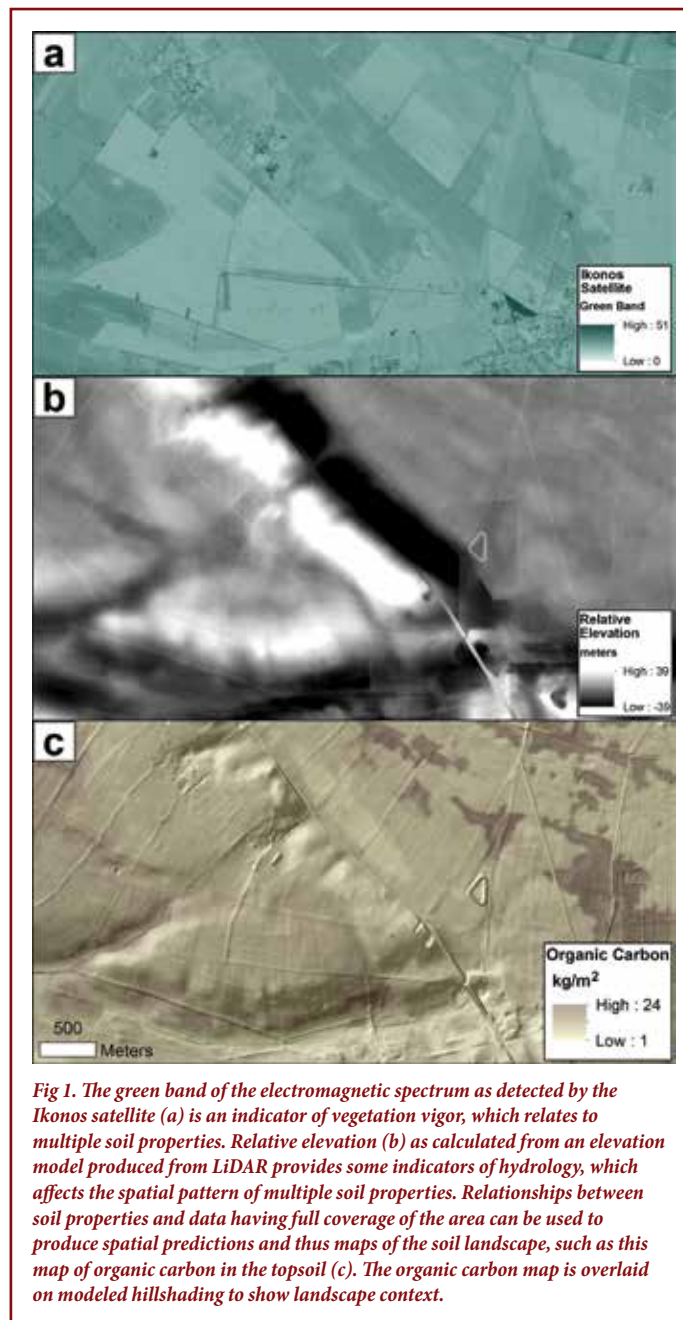
they would expect to find underground. We can now apply this approach much more quantitatively and with more information using the ever increasing amount of data provided by remote sensing technologies.

From satellites orbiting in outer space to small unmanned aerial vehicles (UAVs), there are many sources recording images of the electromagnetic spectrum being reflected from the Earth's surface. The electromagnetic spectrum includes the light we can see as well as bands that we cannot see, such as infrared. Different parts of the spectrum being reflected or not can provide a lot of information about the surface of the soil or the vegetation on the soil, which provides clues about conditions below ground. Another remote sensing product that Iowa is fortunate to have is recent elevation data collected at a high resolution. This elevation map was produced using a technology called LiDAR and has many uses for land management and planning. In the case of soils, we know topography directs water flow and influences local climate. Both of those factors affect soil properties, which means that high quality elevation data can help us predict the spatial distribution of soil properties and model how those properties are likely to change. The amount of information coming from remote sensing is immense, and we still have a lot to sort through and understand.

We have known about and utilized relationships with factors of soil formation to help predict the spatial distribution of soils for the better part of the last century. However, we now can analyze hundreds of potential covariates that relate to concepts of those soil forming factors. For example, relief is a soil forming factor that can now be analyzed in many different ways, such as slope, profile curvature, plan curvature and aspect.

In a way this isn't new, but now instead of thinking about things like aspect in terms of north or south for a general hillslope, we can calculate a specific angle for every location across large areas. The next step is to use sophisticated statistical approaches to help us find patterns in these large data sets. We call this data mining, and when we find useful quantitative relationships between remotely sensed variables and soil properties, we can use them to make better spatial predictions about the soil. The more we do this, the more detailed and accurate our maps become.

Never has the need for soil information been greater and never has there been more opportunity to provide that information. However, there are several obstacles to realizing that potential. The soil landscape is complex with a multitude of interacting processes that have changed over time. In many ways, this makes each location somewhat different because of its unique combinations of processes and history. Nonetheless, this is what makes soil informatics exciting. There are many puzzles to solve, but as we solve them, we will be providing people with better information to optimize land management for sustainable production and environmental quality.



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After harvest, players learn about the risk involved in the farming process – will there be flooding, droughts, tornados, freak accidents, or will it be a good year?

C6 BioFarm: Educating Youth about Conservation and Farming

GAMIFICATION INTRODUCES KIDS TO RISKS AND REWARDS INVOLVED IN FARMING

By Abby Stanek, Graduate Assistant in Agricultural Education and Studies, Iowa State University

The United States knows Iowa for its farming practices, particularly those related to growing corn. However, many of the people in Iowa, as well as across the country, do not know how the corn that is grown is used in the food we eat, the clothes we wear and the fuel we use. C6 BioFarm is changing how Iowans and people across the country understand farming.

C6 BioFarm is an iPad app that youth and adults can download to learn about farming practices. The game and curriculum development is sponsored by Iowa State University Extension and Outreach, CenUSA Bioenergy and Iowa NSF EPSCoR. In the game, players can choose to grow and harvest corn, soybeans or switchgrass. Corn is the most popular crop to plant in Iowa, though planting it year after year decreases the amount of nitrogen in soil, which decreases yield over time. Many farmers plant soybeans every other year to increase nitrogen in soil after corn is planted. Switchgrass is the final crop that can be planted in the game. Switchgrass production is currently being researched at Iowa State. It is a seven-year

crop that grows back year after year, which means that there are minor costs to maintain the crop for years 2-7 while still growing a crop to harvest.

After harvest, players learn about the risk involved in the farming process – will there be flooding, droughts, tornados, freak accidents, or will it be a good year?

These scenarios can lower profitability for the player, much as they do for a real-life farmer. As the player advances through the game, they are constantly faced with decisions, such as whether or not to purchase crop insurance, what to plant and where to plant it and how to use environmentally sensitive land next to rivers and streams. The crop prices and decisions made in the game further affect a farmer's success.

Though it may seem that the C6 BioFarm player is just learning about the risks and rewards involved in farming, players are also learning about conservation practices



Abby Stanek

in the farming process. There are economic benefits for the player for making different decisions that impact soil quality. For example, rotating crops between corn and soybeans increases the amount of nitrogen in the soil, which increases profits over time. There is also a benefit to planting switchgrass on the land next to rivers and streams. If switchgrass is planted in this location, the surrounding area is less susceptible to soil erosion and fast-rising waters.

In the game, C6 BioFarm players address farming from a triple-bottom line perspective. The first aspect is financial – players have to make money in the game to continue, otherwise their farm will go bankrupt and fail. The next aspect is environmental, which helps game players to understand the benefits to soil and water by planting switchgrass on marginal land and rotating their crops. Finally, the social aspect of the triple bottom line helps



Fig. 1. Many students have played the game throughout summer 2015, including at the Iowa State Fair.



Fig. 2. C6 BioFarm players are encouraged to make money every year, but also keep their soil healthy by rotating their crops and planting switchgrass.

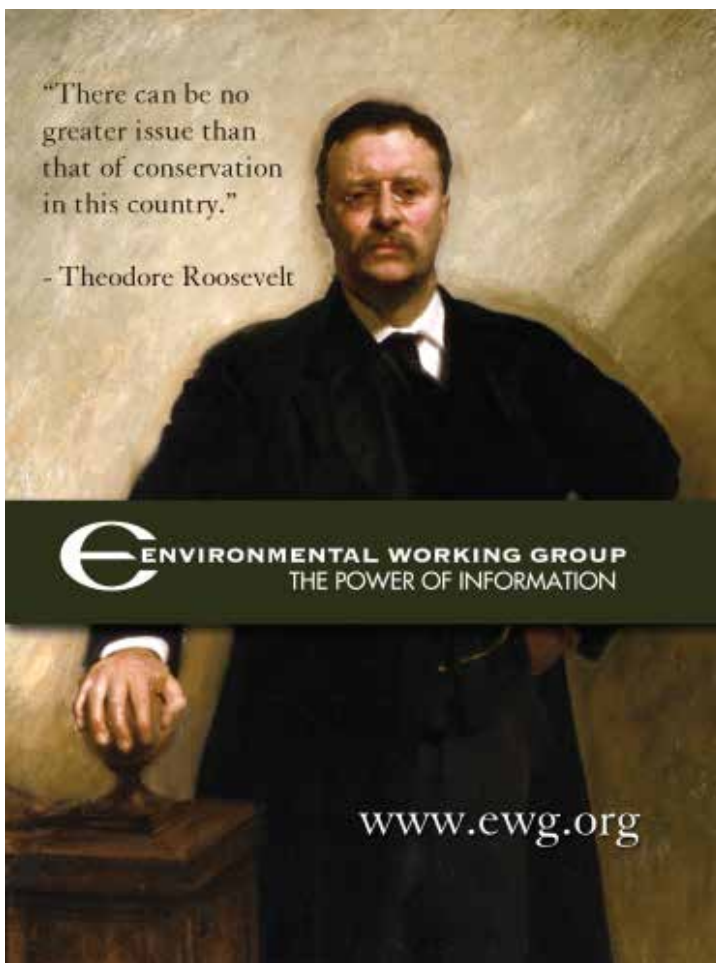
players to realize that their decisions impact their family, area, state, country and world.

The Bratney Company 4-H Robotics Challenge also educated youth about soil conservation with the help of C6 as mascot and sponsor at the 2015 Iowa State Fair. At the event, the robotics teams built machines that spread biochar across a mock field, with extra points given if a solution utilized a smaller carbon footprint by not using battery power. Biochar is a soil amendment that increases carbon and nutrient retention when added to soil. Youth also built and programmed NXT LEGO robots that performed different tasks around the farm.

In addition to the iPad game, there is an accompanying curriculum for educators, which includes lesson plans and activities, career videos and an iBook. The topics of these lessons include carbon and renewable energy, agriculture production and environmental impacts, biomass conversion, STEM careers and the triple bottom line. The goal of the curriculum is that educators will use the information from the lessons and activities and apply it to what students are doing while playing the iPad game.

Since beginning beta testing in May 2015, C6 BioFarm has educated 2,173 youth and adults with information about conservation practices and farm management. There has been an overwhelming response that youth are learning and enjoying playing the game.

In the future, C6 BioFarm plans to continue to develop curriculum for classrooms and add more features to the game. The game is now available for download on iPads – master it now so you are ready for the additional features!



Overall, it is important to remember that soil management is about managing pores and as Bossio and colleagues stated “every land use decision is a water use decision.”

How Does Soil Organic Matter Really Impact Plant Available Water?

A CRITICAL COMPONENT IN AGRICULTURAL PRODUCTIVITY

By Deborah Aller, Graduate Assistant, Department of Agronomy, Iowa State University

In 2012 one of the worst droughts in decades hit the state of Iowa. The lack of rainfall left crops vulnerable to water stress, soil to erosion and limited overall production capacity. It was during this time that farmers recognized the role organic matter plays in enhancing soil moisture. Even though organic matter has long been acknowledged as an important component of the soil matrix (it is the reason we add manure and compost, leave crop residues on the soil surface and/or plant cover crops), many misperceptions exist about the role organic matter has on influencing soil water and specifically plant available water. It was not until 1994 that soil organic matter (SOM) was recognized as having a significant effect on plant available water.¹ The main question that exists is: does SOM directly and/or indirectly increase plant available water?

Soil organic matter, the organic fraction of soil, results from the decomposition of plant and animal residues. It is critical to all chemical, physical and biological activities in soil which impact ecosystem and agricultural productivity. SOM

is dynamic in nature, is differentiated by its composition and rate of decomposition and varies in abundance and distribution in soils. Levels of SOM are heavily dependent on temperature, moisture and management regimes.

Plant available water (PAW), also known as available water content/capacity, is defined as the water held between field capacity and permanent wilting point of a soil. A soil is considered to be at field capacity when all pores have drained freely by gravity. When sufficient amounts of water can no longer be taken up by a plant to sustain turgor the soil has reached permanent wilting point. Between field capacity and permanent wilting point, as soil water content decreases and the water transitions from being held in pores to being tightly retained on particle surfaces as water films, the energy required to extract this water increases.



Deborah Aller

The classical definition of PAW, more frequently than not, does not hold true under real field conditions. Many physical, chemical, biological and environmental factors are at play influencing how much water is actually taken up by a plant. The relative proportions of sand, silt and clay (soil texture) and aggregate formation (soil structure) have a direct

influence on available water content. SOM influences structure by altering the arrangement of and/or interactions between soil particles. SOM directly affects soil porosity and aggregation, which inherently changes bulk density, pore size distribution and hence overall soil structure. SOM is dominantly hydrophilic (water loving) in nature, which influences the surface adsorption affinities of solid particles and impacts water retention.² More specifically, organic matter increases the rate at which water is held in the soil at field capacity more rapidly than at



Fig. 1. A handful of organic matter: SOM is a valuable resource important for building and maintaining the health of your soil (Photo courtesy of NRCS)

permanent wilting, resulting in a net increase in the water held within the plant available range.³

Some forms of SOM, depending on composition and rate of breakdown help maintain pore structure over time, allowing for greater and sustained soil water content improvements. For example, biochar, a soil amendment that is more resistant to breakdown than other forms of SOM, increases total porosity, enabling more water to be physically retained in the soil, and this change is greatest towards the field capacity end of the PAW region.^{4,5} Furthermore, SOM has a greater impact on improving PAW in medium and coarse-textured soils than finer-textured soils. This results from SOM decreasing the number of macropores and increasing the number of smaller pores in soils that have a lower clay content, providing a greater variety of pore sizes including those which hold plant available water.

Overall, it is important to remember that soil management is about managing pores and as Bossio and colleagues stated “every land use decision is a water use decision.”⁶ Any management choice influences all aspects of the soil matrix either directly or indirectly. Soil organic matter cannot be isolated as having solely direct or indirect effects on plant available water. In reality SOM affects how much water plants can access both directly and indirectly. It is the complex interplay of soil properties, environmental conditions and management systems that leave no well-defined

answer. Regardless of how SOM impacts available water content, the evidence clearly supports that SOM is important for the maintenance of good soil structure, water retention and optimum plant growth and development.

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Approximately 18,000 randomly selected hillslopes in Iowa are used to estimate and report Iowa's statewide average soil loss value. The same hillslopes are used each time an estimate is made.

Soil Erosion Defined

IOWA'S LANDSCAPE IS LIKELY TO CONTINUE DEGRADING WITHOUT SIGNIFICANT CHANGES

By Rick Cruse, Club Advisor and Professor, Department of Agronomy, Iowa State University

"Iowa soils are a miracle from God."

This quote expresses the appreciation of an Iowa State University international graduate student when discussing soil health. Most Iowans underappreciate the incredible production potential of our soil. Unfortunately our miraculous soils are leaving our hillslopes (Fig. 1) and are concurrently credited for millions of dollars in off-site damage.

Based on USDA estimated soil loss from sheet and rill erosion, we are losing about one pound of soil for every pound of corn grain that is produced in our state. We erode about three pounds of soil for every pound of soybeans produced. This has had, and continues to have, serious negative impacts on crop production.

The topsoil in the Midwest is typically the most fertile and most productive part of the soil profile. Topsoil normally contains a greater concentration of nutrients, more organic matter, more soil organisms and better soil structure than other soil profile layers. It is also the most vulnerable part of the soil profile for degradation. Degradation, damage of the soil such that it negatively impacts crop production and other functions, is typically caused in the

Midwest by compaction, excess tillage, loss of soil organic matter and/or erosion.

Erosion worldwide is recognized as the greatest cause of soil degradation and arguably is the greatest soil degradation agent in Iowa as well.

Averaged across Iowa, we are eroding soil from hillslopes about 10 times faster than it is forming. An average Iowa hillslope was losing about 5.8 tons of soil per acre per year in 2012,¹ and research suggests about 0.5 tons of soil per acre forms annually.² Recent information generated by the Daily Erosion Project (<http://www.dailyerosion.org>) suggests some areas of Iowa are experiencing sheet and rill erosion rates approaching, or exceeding, 50 tons per acre annually—100 times faster than the soil renewal rate.

How do we get these erosion rates, and do they accurately reflect soil loss from farm fields?

Models that have been widely tested against field measurements are the



accepted tool for estimating soil erosion worldwide as well as that occurring on Iowa farmland. A version of the Universal Soil Loss Equation, RUSLE2, is probably the most widely used of those models. The current National Resources Inventory uses that model to estimate the weight of soil that is transported in runoff water from randomly selected hillslopes.

The National Resources Inventory, NRI, is a USDA-NRCS program established over 30 years ago that periodically evaluates the condition of this country's soil resources. One NRI component estimates and reports average sheet and rill erosion rates for each state.

Approximately 18,000 randomly selected hillslopes in Iowa are used to estimate and report Iowa's statewide average soil loss value. The same hillslopes are used each time an estimate is made.

Because estimates are made on the same hillslope within given fields, the periodic estimates capture the effect of changing soil and crop management practices that



Fig. 1. Soil erosion typically observed in Iowa during the spring prior to planting and crop canopy development.

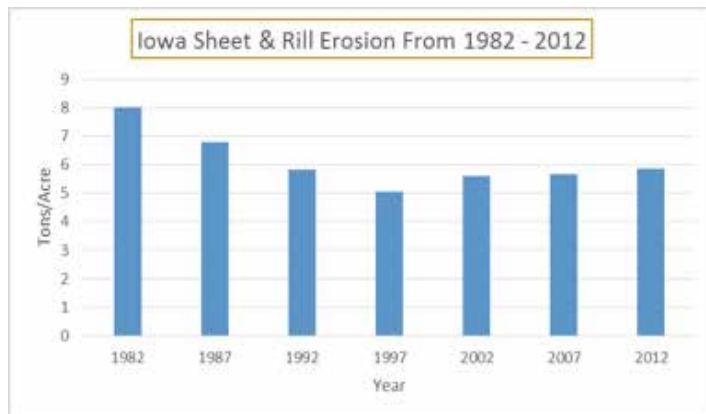


Fig. 2. Trends in Iowa sheet and rill erosion for 1982 – 2012.

impact soil erosion. Long term rainfall characteristics are used to make soil erosion estimates; this excludes year to year rainfall variability. Estimates were made in 1982, 1987, 1992, 1997, 2002, 2007 and 2012.

Figure 2 gives the NRI estimated annual sheet and rill soil erosion for Iowa from 1982 to 2012. Note that erosion rates dropped dramatically (nearly halved) from 1982 to about 1997, after which erosion rates have gradually increased.

Multiple factors have likely contributed to the soil conservation improvement observed prior to 1997, including cross compliance in the 1985 Food Security Act, Conservation Reserve Program (CRP) of the 1985 Food Security Act and improved herbicides allowing farmers to produce row crops with less tillage. Following 1997, gradual increases are likely attributed to higher grain prices leading to reduced CRP acres.

Lack of progress in reducing soil erosion rates after 1997 is a serious concern, especially since our sheet and rill erosion rates remain at rates 10 times greater than estimated soil renewal rates. And these soil erosion rates do not include soil lost in ephemeral gullies such as those seen in Fig. 1. Major advances have been made in machinery, crop genetics, herbicides and other management inputs without advances in our ability to conserve our soil resources.

These observations and soil erosion estimates based on quite rigorous NRI protocol suggest Iowa's landscape, currently dominated by row crop agriculture, is likely to continue degrading unless significant changes are made.

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“The Alliance also agreed to define sustainability not as a specific target, but as a process of continuous improvement over time.”

Sustainable Agriculture: Applying Science Based Metrics to Achieve Continuous Improvement

ASSESSING SUSTAINABILITY AS A CONTINUUM

By Allison Thompson, Director of Science and Research, Field to Market

Future farmers in the major grain belts of the United States will be working to supply food to a world population 50% larger than today. They will be contending with challenges such as more variable weather patterns, depleted water supplies, eroded soils and increased demands for clean water by downstream communities and ecosystems. Today’s farmers are working to prepare for the challenges of the future by measuring and monitoring their lands’ sustainability.

Long-term sustainable agriculture is a system which meets the needs of the present while improving the ability of future generations to meet their own needs. Over the past decade, a diverse group has come together to form Field to Market: The Alliance for Sustainable Agriculture, a multi-stakeholder initiative working to unite the agricultural supply chain in defining, measuring and advancing the sustainability of US food, fiber and fuel production.

Field to Market members include many major US companies and organizations who consider the future of agriculture and reducing negative environmental outcomes from crop production to be crucial to their

own operations as well as for the public good. Said groups include food and beverage manufacturers; retail stores that sell food and fiber products sourced from US lands; agribusiness companies that supply crop inputs and equipment to farmers; national and state level grower associations who represent farmers; conservation and environmental organizations; and universities and government organizations. Collectively, these groups represent a complete supply chain for commodity crops such as corn, soybeans, wheat, rice, potatoes and cotton.

Representatives from these diverse organizations began meeting in 2007 to discuss a common framework for understanding and advancing sustainable agriculture. They agreed on a set of core principles, committed to a science-based process that focuses on environmental outcomes of farm operations and commits to working with individual producers on the right solutions for their land. The



Allison Thompson



Alliance also agreed to define sustainability not as a specific target, but as a process of continuous improvement over time. In 2009, they launched the first version of the online tool, the Fieldprint® Calculator, designed based on these principles for all members to use as a common framework.

As of the end of 2015, Field to Market has grown to include more than 85 member organizations, who are engaged in about 50 Fieldprint® projects that connect farmers to the supply chain and measure their sustainability performance on eight metrics:

1. Land Use
2. Energy Use
3. Greenhouse Gas Emissions
4. Soil Carbon
5. Soil Conservation
6. Irrigation Water Use
7. Water Quality
8. Biodiversity (piloting)

Farmers work with their crop advisors or university extension agents to enter their field data into the Calculator and interpret their score. As projects accrue five consecutive years of data entry they will have established benchmarks for the current level of sustainability based on these metrics. In future years, they will work towards achieving and measuring continuous improvement against this benchmark (Figure 1).

Since Field to Market’s metrics were first established, science has continued to advance our understanding of how specific agricultural practices influence these sustainability outcomes. Thus, they are regularly reviewed and, as necessary, revised based on new scientific understanding. Metric revision follows a structured process that is coordinated by a working group of elected representatives from Field to Market, and are subject to validation and an independent peer-review process.

Field to Market also works with similar efforts on improving agricultural sustainability in order to align and collaborate to improve the collective message. For example, Field to Market has been participating in the Soil Renaissance since 2013, a foundation-led effort to bring together communities to work towards raising awareness of and improving soil health on

agricultural lands. By working with the experts who are advancing a research agenda for understanding soil health, Field to Market can convey the importance of this work to the Alliance and work to make progress on both the science and implementation of practices to improve soil health. Through collaboration, the message and reach of sustainable agriculture efforts can be amplified, and collectively improve the productivity, efficiency and environmental outcomes of our farmland.

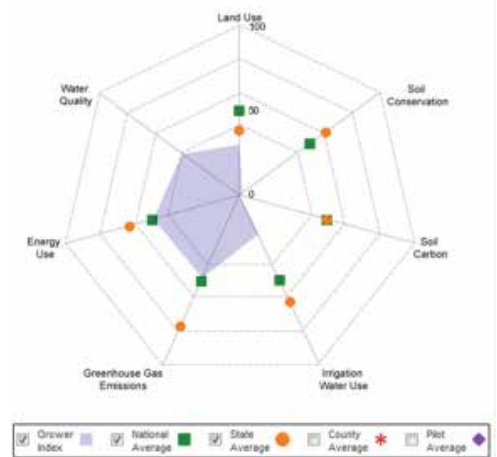


Fig. 1. Schematic of Field to Market’s sustainability measurement tool.



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The environmental consequences of the crop insurance program are even worse than the high costs that the program generates.

Environmental Impacts of the Federal Crop Insurance Program

PROGRAM CAN BE COSTLY FOR TAXPAYERS AND ENVIRONMENT

By Anne Weir, Senior Analyst, Economics, Environmental Working Group

The federal crop insurance program was originally created to protect farmers from extreme weather events. Farmers pay a premium to the federal government and in return they receive an insurance policy that pays out if anything happens to their crop during the growing season. In theory this seems like a great idea; who doesn't want to protect farmers from hail, flooding and tornadoes? However, in practice the crop insurance program is incredibly costly for the government and the environment.

On average, farmers only pay 38 percent of the full cost of the premium to buy a crop insurance policy. That means that taxpayers foot a huge bill in premium subsidies, around \$6.5 billion a year on average over the last five years. Also, most farmers don't buy policies that insure only their crop yields, instead they buy more expensive policies that guarantee a certain amount of revenue per acre. These most popular policies payout if the price of the crop drops, yield declines, or some combination of the two. The popularity of these types of policies again increases the cost of the program.

The environmental consequences of the crop insurance program are even worse than the high costs that the program generates. Crop insurance encourages farmers to cultivate high-risk and marginal land. Farming this environmentally sensitive land leads to soil erosion, nutrient loss, water pollution and loss of biodiversity.

Insuring there is a generous guaranteed business income encourages landowners to expand drainage, enlarge their operations and/or make other business decisions they might not make without that income guarantee.

The 'prevented planting' component of the crop insurance program is particularly egregious. It costs billions of taxpayer dollars while encouraging growers to plow up wildlife-sustaining wetlands in the Prairie Pothole Region of North and South Dakota. The prevented planting program



Anne Weir

compensates farmers when extreme weather or other factors make it impossible to plant their crops. The problem with this program in the Prairie Pothole Region is that it encourages farmers to plow up seasonal wetlands that are normally wet in the spring. So, farmers often plow up wetlands in the fall when they are dry, and then attempt to plant

in the spring. In most years they cannot plant because the wetlands are flooded, but producers get a payment that more than covers the money they "lost" trying to plant. Taxpayers are sent the bill and wetlands are degraded.

More than 50 percent of North America's breeding waterfowl depend on the wetlands in the Prairie Pothole Region, and 40 bird species make their home in these wetlands. Plowing up the wetlands greatly decreases habitat, and correspondingly biodiversity. Repeated plowing of wetlands also shrinks the size

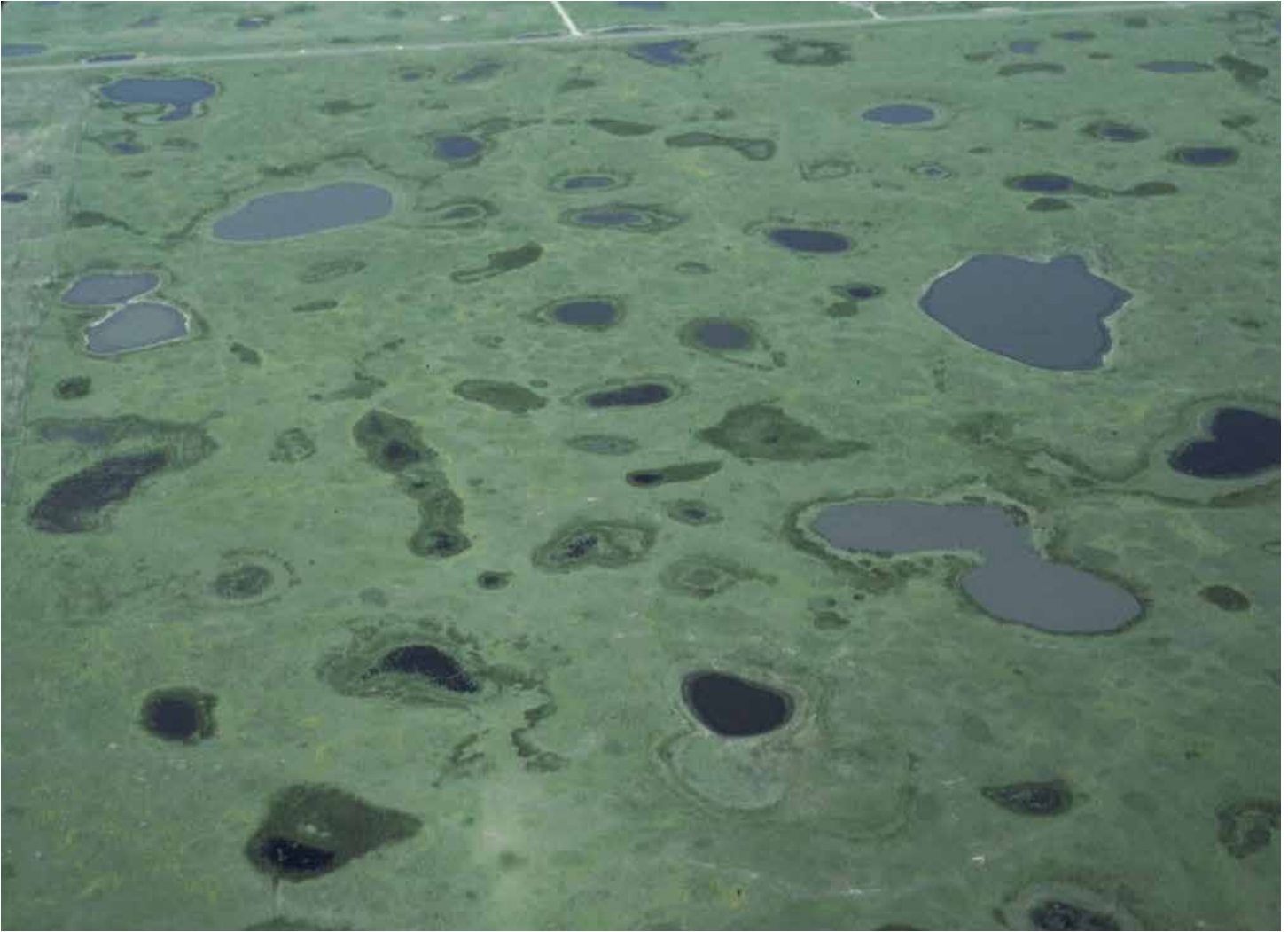


Fig. 1. This is an aerial view of seasonal wetlands in the Prairie Pothole Region. The prevented planting crop insurance provision is reducing the number of ecologically-important wetlands located in this region.

and depth of the wetlands, and leads to soil erosion. And as the wetlands decrease in size and capacity, they become less likely to prevent floods in surrounding areas.

The prevented planting program is also costly for taxpayers. Between 2000 and 2013, 195 counties in the Prairie Pothole Region received \$4.9 billion in prevented planting insurance payouts for fields that were too wet to plant. Sixty-five counties have been given a payment every year for 14 years in a row, and these counties made up 69 percent of the \$4.9 billion in payments.

The federal crop insurance program and specifically the prevented planting component are costly for taxpayers and the environment. Crop insurance could and should be a safety net that steps in when farmers suffer a potentially crippling loss. But the crop insurance program we have today has strayed far from what most people would consider a safety net. Reforming crop insurance legislation

could go a long way towards saving taxpayers money while reducing environmental harm.

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Precision Conservation: Why We Must Engage the Private Sector

RETAILERS AND FARMERS SHOULD COME TOGETHER IN REGARDS TO CONSERVATION

By Tom Buman, Founder and CEO of Agren

Fifty years! Yes, that's right. At the current rate it will take 50 years to design and install all the grassed waterways needed in Iowa and this timetable is being generous. The 50 years doesn't even account for maintenance, repair and replacement of these grassed waterways after their normal 10-15 year lifespan.

This is not acceptable, especially when you consider all conservation practices like ponds, wetlands, water & sediment control basins, terraces, no-till and cover crops are on this same timetable. Please note, this is not a criticism of the conservation agencies. Between the county, state and federal conservation agencies there is not enough technical staff to handle the workload; and—surprise—there is little hope this staffing shortage will significantly improve any time soon, if ever.

A planning meeting to develop the Iowa Raccoon River Watershed Water Quality Master Plan was held in 2010. A key finding from the meeting was the recognition that perhaps the most limiting factor to getting adequate application of conservation practices in the watershed is a lack of sufficient conservation planning services. So, if we can't count on additional

government services, what is the answer?

Since the beginning of time, or at least since I started my conservation career in 1982, the talk has always been, "let's get the private sector involved in conservation planning." It is hard to argue with this logic. Certainly farmers could use the help.

So why not get ag retailers involved in conservation planning? Conservation planning by ag retailers could capitalize on the trust and long-standing relationships farmers already have with them, both as suppliers and as consultants. In many cases, retail agronomists and independent crop consultants know nearly as much about the landscape, soils and productivity of a customer's individual fields as the farmer himself knows; and they have existing relationships with the farmer. It is plausible to consider that conservation planning could be facilitated by retail agronomists and/or independent crop consultants as they conduct their regular business with



farmers.

However, before the private sector can be successful with conservation, appropriate conservation planning tools and precision conservation technologies must be accessible to private technical service providers. These tools must be easy to use and understand. Alternatively, new conservation planning tools and technologies need to have outputs appropriate for use by third-party service providers as they

work with farmers. The concept of using emerging technologies to efficiently plan conservation practices is critical to expanding the network of conservation planners into the private sector.

The bottom line is we just can't wait fifty years. We must find a way to increase conservation planning assistance now. Enabling the private sector with precision conservation tools is one way we can do it.

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Rural, urban and suburban Iowans agree on the grand vision of abundant crops, healthy soils and clean water for the state, but are challenged by how to attain it.

Getting into Soil and Water Virtually with PEWI

PEWI IS A FUN, FREE AND INTERACTIVE ONLINE WATERSHED TOOL

By Lisa A. Schulte, Carrie Chennault, Nancy Grudens-Schuck, John Tyndall and Robert Valek

Now more than ever soil and water conservation are top priorities for Iowans. Soil loss through erosion has been a persistent problem, made more challenging by new weather patterns, like extreme rains. Water quality problems are not new, but have become more salient with municipal drinking water warnings and beach closure, and now a federal lawsuit¹. Rural, urban and suburban Iowans agree on the grand vision of abundant crops, healthy soils and clean water for the state, but are challenged by how to attain it. We need practical ways of achieving soil and water conservation alongside farm production goals. Yet, trying new things is risky, and conflict stymies creativity.

To help overcome this hurdle, we've created an online watershed game that allows users to play with agricultural land management options in a risk-free space. The tool is called PEWI—short for People in Ecosystems/Watershed Integration—and is available for free at <http://www.nrem.iastate.edu/pewi>. PEWI addresses soil health in terms of erosion control and soil carbon sequestration, and water quality in terms of nitrogen and phosphorus contamination, and sediment loads. PEWI asks users to

balance conservation goals with crop yield by interactively designing land use within a 6,000 acre virtual watershed (Fig. 1), allowing users to simulate real-world land-management options including:

- Conventional corn and soybean production systems that till the soil;
- Conservation corn and soybean production systems that use no-till planting; cover crops, terracing, grassed waterways and vegetative buffers along streams;
- Horticultural uses, such as fruits and vegetables;
- Forage crops, such as hay and alfalfa;
- Bioenergy crops, including herbaceous and woody crops;
- Pasture, including continuously and rotationally grazed; and
- Prairie, forest and wetland native land uses.

PEWI is not a specific real-world watershed, but we used scientific data from the undulating Des Moines Lobe and hilly Southern Iowa Drift Plain landforms. Just like in the real world, users have to react to weather: PEWI randomly draws from seven potential precipitation levels representing average, drought and extremely wet conditions in Iowa. Users



Fig. 1. PEWI user interface with explanation of interactive controls and feedback mechanisms.

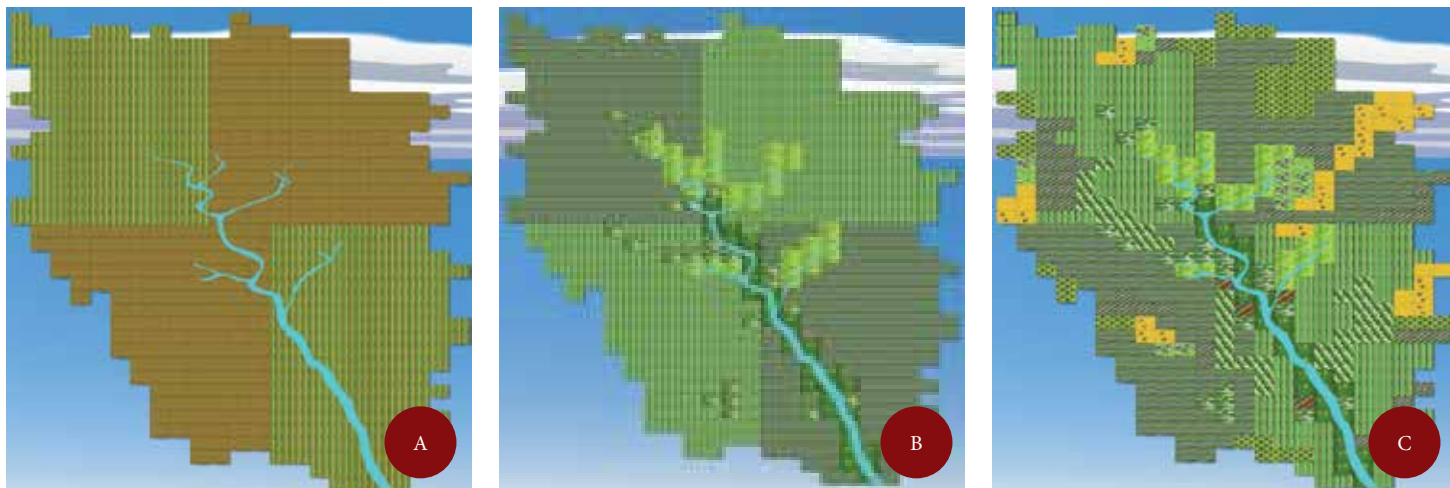


Fig. 2. Three land-use scenarios constructed in PEWI: (A) traditional corn and soybean production, (B) conservation corn and soybean production with strategic wetland restoration and stream buffers, and (C) conservation and alternative crops with strategic wetland restoration and stream buffers.

create three years of land-use scenarios, during which they assess their soil, water, yield and habitat outcomes that are generated instantly, as the user makes changes.

PEWI is fun! We've used PEWI in a variety of settings from middle school to college classrooms, as well as with adults. Every age group finds something to like and learn from PEWI. For example, some people create their dream landscape, where they would like to live. Others try to gain sufficient income from crops and livestock, while staying within acceptable ranges for pollutants (Fig. 2). One participant put prairie everywhere—just to see what would happen.

PEWI is educational! PEWI helps users first define problems and opportunities associated with agricultural land use, and then implement actions to work toward specific goals or justify actions taken. While PEWI invites users to simply play and discover on their own, we have also developed companion educational exercises freely downloadable at our website.

PEWI is scientific! We developed PEWI's algorithms—the rules and mathematical equations by which the agronomic and environmental outcomes are determined—based on the best available science, incorporating knowledge from peer-reviewed scientific literature. If you are interested in the science behind PEWI, you can work with an interactive graphic to understand the relationships among factors used to produce environmental outcomes, http://carriec.github.io/pewi/presentations/science_review/tree, or download and review all the base equations at: <https://www.nrem.iastate.edu/pewi/Chennault-2014-MSThesis>.

PEWI is still in development! We continue to develop PEWI based on feedback from users. We welcome others to help us with this journey by providing ideas, learning exercises, or code. PEWI's code is fully open source through GitHub, allowing anyone, yourself included, to collaborate and help expand PEWI's features: <https://github.com/nrem/pewi>.

PEWI is a fun, free and interactive online watershed tool that helps users test out agricultural and strategic conservation land-use options risk free. We hope it will help Iowans learn how we can have our corn and beans while enjoying healthy soils and clean water, too!

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1 Des Moines Register, 11 March 2015, Water Works votes to sue 3 Iowa counties over nitrates.

The image is a promotional graphic for "Water Rocks!". At the top, it says "water rocks! INSPIRING YOUTH TO APPRECIATE OUR WATER RESOURCES". Below this are six Polaroid-style photos arranged in a 2x3 grid, each with a caption underneath. The photos show children and adults engaged in various water-related activities. The captions are: "FREE CLASSROOM AND COMMUNITY VISITS", "PLAY 'ROCK YOUR WATERSHED'", "WATCH 70+ AWARD-WINNING VIDEOS", "INTERNSHIPS FOR HIGH SCHOOL AND COLLEGE STUDENTS", "ATTEND A WATER ROCKS! SUMMIT", and "GO GEOCACHING!". At the bottom, the website "WWW.WATERROCKS.ORG" is listed, along with a logo that says "I love water rocks!".

By regulating microbial and enzyme activities, soil pH may affect the availability of several nutrients.

Why is Soil pH Important?

IMPACTS OF NITROGEN ON SOIL pH

By Natalia Rogovska, Assistant Scientist, Department of Agronomy, Iowa State University

Soil pH is a measure of the acidity or alkalinity of a soil; it represents hydrogen ion (H^+) concentration in the soil solution. Soil pH is one of the most important indicators of soil quality as it affects an array of physical, chemical and microbiological properties of soil. It is important to understand that there is no ideal pH level; the optimum pH depends on the crop grown and can range from acidic (pH 5 - 5.5), to neutral, and slightly alkaline (pH 7-7.5). Soil pH can affect plant growth directly and indirectly.

Root membrane permeability and ion transport across the root membrane are negatively affected by excess H^+ . Indirectly, soil pH affects plant growth through altering nutrient availability, which may result in nutrient deficiencies or toxicities. In strongly acidic soils (high concentration of H^+), aluminum (Al) and manganese (Mn) toxicities are usually more important than H^+ toxicity for limiting plant growth. Conversely, plant availability of Iron (Fe), Mn and other micronutrients decreases with an increase in soil pH (lower concentration of H^+). One micronutrient that is exception to this trend is Molybdenum.¹

Another important aspect of soil pH is its potential effect on plant pathogens.

Many pathogens survive across a wide range of soil acidity; however, some show an optimal pH range for growth and/or reproduction. The magnitude of plant growth reduction from plant pathogens varies among different varieties, levels of infestation, field topography, climate, management practices and both physical and chemical soil properties.²

Soil pH can also influence plant growth by affecting soil microbial activity. In general, microbial growth and viability are greater in high pH soils than low pH soils, and the activity of many soil enzymes increases with increasing pH. By regulating microbial and enzyme activities, soil pH may affect the availability of several nutrients.

Soil Acidification and Nitrogen

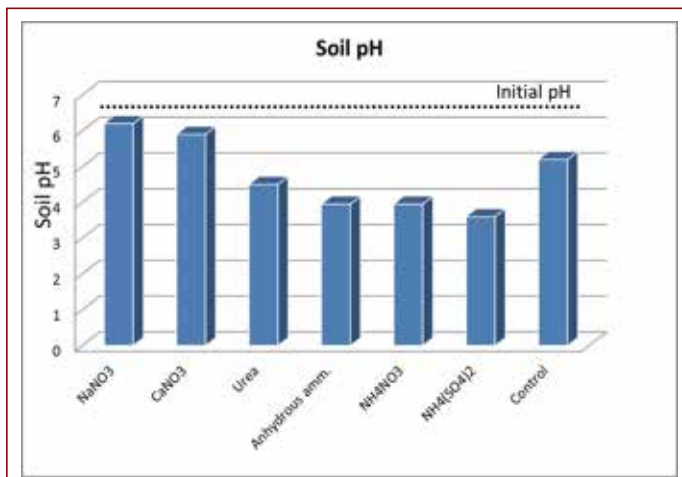
Agricultural soils acidify with time as basic cations are removed or leached from the soil and H^+ ions are produced due to oxidation processes occurring in the soil.



For example, decomposition of soil organic matter is considered to lower soil pH through the release of H^+ ions that were associated with organic anions or by nitrification- the conversion of ammonia to nitrite and then nitrate. Application of certain synthetic nitrogen fertilizers can also increase acidity due to release of H^+ ions during nitrification.

The form of nitrogen (N) applied and its fate in the soil-plant system is probably the major driver of soil pH change within agricultural systems, as the form of nitrogen and its transformation affect the amount of acidity formed. The conversion of N from one form to the other involves the production or consumption of acidic H^+ ions, and the uptake of urea, ammonium or nitrate by plants will also affect soil acidity.³ For example, urea and anhydrous ammonia produce one H^+ per unit of ammonia N where ammonium salt produces two H^+ . Nitrate (NO_3) can be then leached with a loss of basic cation as $Ca(NO_3)_2$, denitrified or taken up by plants.

If nitrate is taken up by plants, the net



Nitrification causes the soil to become more acidic by releasing two hydrogen ions to the soil solution for each nitrate ion produced:

$$\text{NH}_4^+ + 2\text{O}_2 \rightarrow 2\text{H}^+ + \text{NO}_3^- + \text{H}_2\text{O}$$

Fig. 1. Changes in soil pH after nine years of continuous application of nitrogen fertilizer in different forms at a rate of 150 kg/ha. Adopted from Khonje et al., 1989.

acidification per molecule of ammonium is halved compared to the scenario when nitrate is leached. This is due to the consumption of one H⁺ ion (or release of OH⁻) for each molecule of nitrate taken up - this is often observed as pH increases in the rhizosphere (the area immediately around plant roots). If nitrate is denitrified (converted to nitrogen gas), it consumes three times more H⁺ than was produced during nitrification. The denitrification reactions which consume H⁺, are essentially the reverse of those for nitrification in which H⁺ are produced. Therefore, the net acidity in the soil from ammonia N sources largely depends on the relative magnitude of these two processes. Addition of nitrate fertilizers such as calcium nitrate and sodium nitrate cause little change or sometimes increase soil pH (Fig. 1).

In a closed system where there is no net gain or loss of nitrogen, there is no net generation of H⁺. This happens because H⁺ released by nitrification is consumed by denitrification and plant uptake of nitrate-nitrogen that later is returned back to the soil in the form of organic N in residues. The incomplete cycling of N in agricultural soils is the main cause of acidification. Application of agricultural lime can readily neutralize acidity produced by nitrogen fertilization.



Fig. 2. Many Iowa high pH soils have carbonates (natural lime) in them. A quick test for presence of carbonates can be done by pouring some acid on the soil. Soils that contain carbonates will bubble and fizz as it comes to contact with acid. Soil on the left does not contain carbonates; soil on the right contains 32% carbonates by weight.

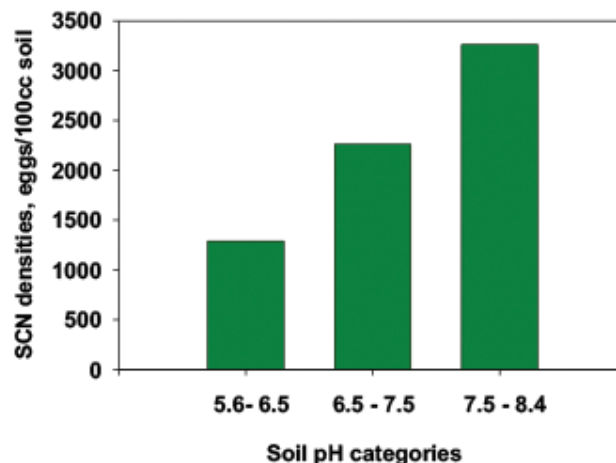


Fig 3. Plant pathogens thrive better at specific soil pH. This graph shows that soybean cyst nematodes prefer high pH soils.

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The future is bright for our youth to engage in this work; we need an army of qualified persons to realize our potential.

Building a Sustainable Water Future

MATURING THE WATERSHED APPROACH IN THE 21ST CENTURY

By Roger Wolf, Director of Environmental Programs and Services, Iowa Soybean Association

Who is Iowa Soybean Association (ISA)?

The ISA commodity association develops policies and programs to help farmers expand profit opportunities while promoting environmentally sensitive production. Economic resources come from the Soybean Checkoff and outside sources. The Association is governed by an elected volunteer board of 21 farmers. Approximately 40,000 Iowa farmers plant 10 million acres of soybeans annually, producing over 550 million bushels. We strive to improve the competitiveness of Iowa soybean farmers.

The ISA Research Programs work with thousands of farmers, with farms located in watersheds across Iowa. We have 25 dedicated staff specialists in four emphasis areas including: Contract Research Coordination, On Farm Network, Environmental Programs & Services and Data Analytics. Since 2001, the ISA has invested over \$40 million in the On Farm Network and Environmental Program. About one third of these funds are from the Iowa Soybean Checkoff and are leveraged with state, federal and private grants. The primary goal of the work that I manage is to advance natural resource conservation practices and environmental quality.

In 2015, we were involved in 32 project

initiatives across Iowa. These efforts support farmers directly and address priority resource concerns including nutrient loss reduction, water and soil quality, habitat and overall sustainability. Much of this work is targeted to local watershed areas. We help groups of farmers in organized watersheds develop comprehensive, local plans. These plans set downstream outcome goals and then create implementation strategies and new opportunities for collaborators and partners to assist.

Why does ISA do this?

ISA's mission is to "expand opportunities and deliver results." Coupled with this, we believe collaboration and partnerships lead to better outcomes. We believe that managing the soil, water and nutrients differently will allow us [farmers] to be more productive and will lead to a more resilient agriculture; that managing habitat strategically will provide multi-objective services; and that we can and should work together and collaborate with urban interests. We believe that through applying science and technology and using a participatory process of measuring, monitoring and mapping, that



Roger Wolf

we mature and develop our ability to manage a higher performing system.

Why the Watershed Approach?

The watershed approach presents us an opportunity to build a sustainable water future. Anyone who has actively engaged or monitored the effort to understand and improve

water quality in the United States during the past several decades could reasonably conclude we have arrived to a "watershed moment" for the watershed approach.

For at least the past decade, innovators in the public and private sectors have championed a watershed approach — broadly collaborative, locally led, framed by the principles of adaptive management, voluntary and sustained over time — to address the complex and varied water quality concerns due to nonpoint source pollution.

Together, leaders and stakeholders have learned that nonpoint source pollution cannot be addressed effectively with the generic, top-down, command-and-control approach used to reduce point source pollution for the past 40+ years. Furthermore, bringing the point source



community into the watershed management purview presents opportunities and synergy that may deliver multiple benefits to the broader community.

Likewise, greater collaboration is occurring at national, state and local levels. Today, stakeholders who sometimes are at odds with one another—state and federal agencies, farm groups, urban interests, industrial point source dischargers, drinking and waste water utilities, plus conservation and environmental nonprofits—align on the principles of the watershed management approach to improve water quality.

The idea of governing on the basis of hydrologic units is not new. In 1889 John Wesley Powell delivered this idea to the Montana Constitutional Convention:¹ “... each drainage basin in the arid land must ultimately become the practical unit of organization, and it would be wise to adopt a county system which would be convenient with drainage basins.”

Powell recognized the need to address water quantity concerns, by pulling together all stakeholders and resources in the watershed drainage area. This logic can be extended to water quality concerns.

Powell’s advice was ignored, and today leaders must find a way to work around governance structures that intersect watersheds and fail to engage all the stakeholders needed to achieve measurable water quality improvement. Despite these challenges, leaders have created alternative, project-specific governance structures that engage key stakeholders; obtain and manage resources; and coordinate planning, implementation, evaluation and reporting tailored to local conditions and issues.

In conclusion I believe Iowa has a unique opportunity to lead the next generation of agriculture production and natural resource management. There is unprecedented interest in moving forward on this. The future is bright for our youth to engage in this work; we need an army of qualified persons to realize our potential. I look forward to building a sustainable water future by maturing the watershed approach in the 21st century.

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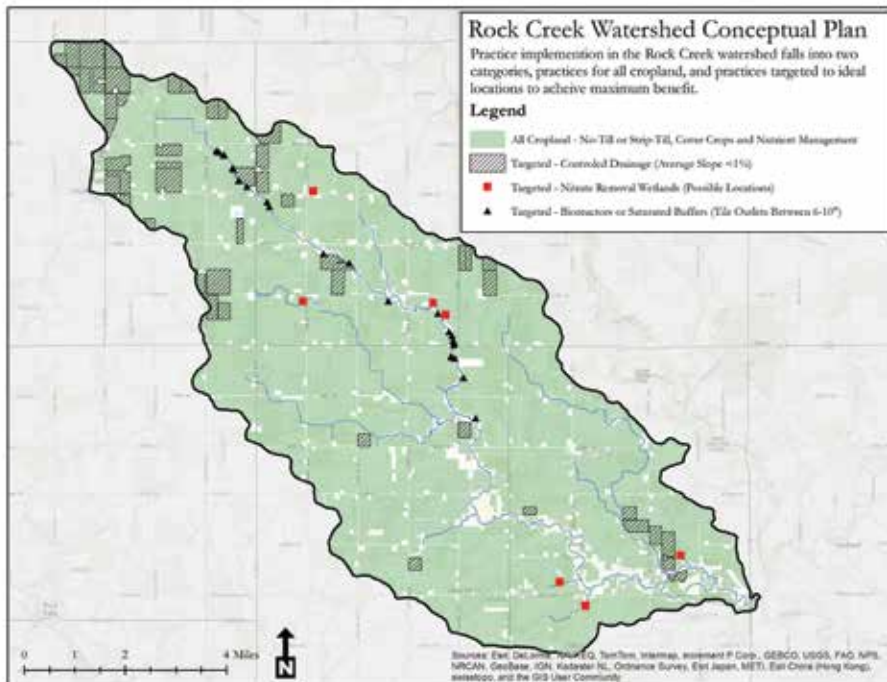


Fig.1. ISA worked with farmers to develop the Rock Creek Watershed plan, which includes implementing buffers, cover crops, saturated buffers and bioreactors (Map courtesy of Adam Kiel, ISA).

Fig.2. Stream and buffers in the Rock Creek Watershed (Photo courtesy of Joseph Murphy, ISA).

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“We can sit down, and rather than having an explicit conservation conversation with land managers, we can have a make more money conversation with land managers.”

Conservation Has a Place in Agronomic Business Planning

FOCUSING ONLY ON REVENUE LIMITS ABILITY TO DEAL WITH VARIABILITY

By Ali Luety, Writer at AgSolver

Between 3 and 15 percent of land being row cropped are consistently not profitable. Those unprofitable zones often leave farmers with a negative return on investment. However, agronomic business plans have not acknowledged these zones in the past. Why?

In the past and still today, farmers have often focused strictly on revenue. Revenue-focused agronomic planning limits our ability to deal with variability within fields.

Instead, the primary goal is to increase field average yields in order to increase profitability.

AgSolver started with a vision. That vision involved changing agronomic business plans from revenue based to return-on-investment (ROI) based. By transitioning to ROI-based agronomic planning, the land manager accounts for subfield variability when determining how to deploy their working capital. Subfield zones that don't turn inputs into

commodities efficiently can be repurposed to make the farmer more money.

David Muth's experiences working with environmental performance and integrated landscapes for bioenergy systems sparked his interest in utilizing our vast public data resources.

He and his colleagues then integrated public data with private precision data, such as machine generated, to discover subfield variability.

“We looked back at this and clearly saw how we were spending our money in fields and this disconnect between business planning at a field and an enterprise level and business performance at a subfield level,” Muth, SVP at AgSolver, said. “Once we saw enough acres, processed enough data, and understood how this was impacting our performance, we started to build a bank of case studies where we



Ali Luety

could look at individual fields and full operating systems. We concluded we're just not spending our money in a way that makes sense.”

To address the opportunity that Muth saw, AgSolver created applications such as Profit Zone Manager™.

The application integrates public data resources and

the farmer's personal budget and field information to generate a reasonable crop budget and cash flow set up for an operation or field. Zones within fields are identified where the ROI and business performance are lacking. Then, land managers receive assistance to investigate what Muth calls a “lower cost revenue source” within each zone.

In many cases, lower cost revenue sources are conservation programs administered by USDA NRCS or FSA. They can include

forage markets and recreation markets, but are usually conservation-oriented.

“That’s the synergy between business performance and environmental performance, and that’s how we find these places where conservation practices can be applied to our fields based on a business imperative,” Muth said. “You have to find that nexus where the business outcome meets the conservation outcome.”

Nearly every farmer probably agrees that conservation is important; however, there hasn’t been much economic incentive to implement conservation practices.

For example, say a farmer is offered \$600/acre by a lender to grow corn. The farmer’s actual costs are closer to \$750/acre. The farmer must allocate that working capital across the acres that gives her or him the best return on investment.

“We can sit down and rather than having an explicit conservation conversation with land managers, we can have a make more money conversation with land managers,” Muth said. “And part of that make more money conversation in a large percentage of our fields involves conservation activities coming into the mix.”

Conservation is becoming an increasingly hot topic as fundamental market conditions right now are forcing land managers to become more prescriptive and careful about allocation of dollars across the production system.

What’s more, the Des Moines Waterworks lawsuit, the EPA Waters of the U.S., and other regulatory engines put pressure on the performance of our agriculture system from an environmental standpoint.

By creating a partnership between a conservation and business plan, AgSolver has a very unique position in the marketplace. Farmers now have a business imperative to make sure they are leveraging land resources that are the best at turning their inputs into commodities.

AgSolver looks toward the future with big plans in mind. Partnerships with Pheasants Forever, Heartland Cooperative and USDA NRCS allow land managers to understand their business performance.

AgSolver can provide partners with access to conservation resources to get the actual practices on the ground.

Farmers can make more money while putting conservation methods into practice. That’s the ultimate message that Muth loves to share with the AgSolver customers. Interested in learning more? Visit AgSolver website at <http://agsolver.com>.

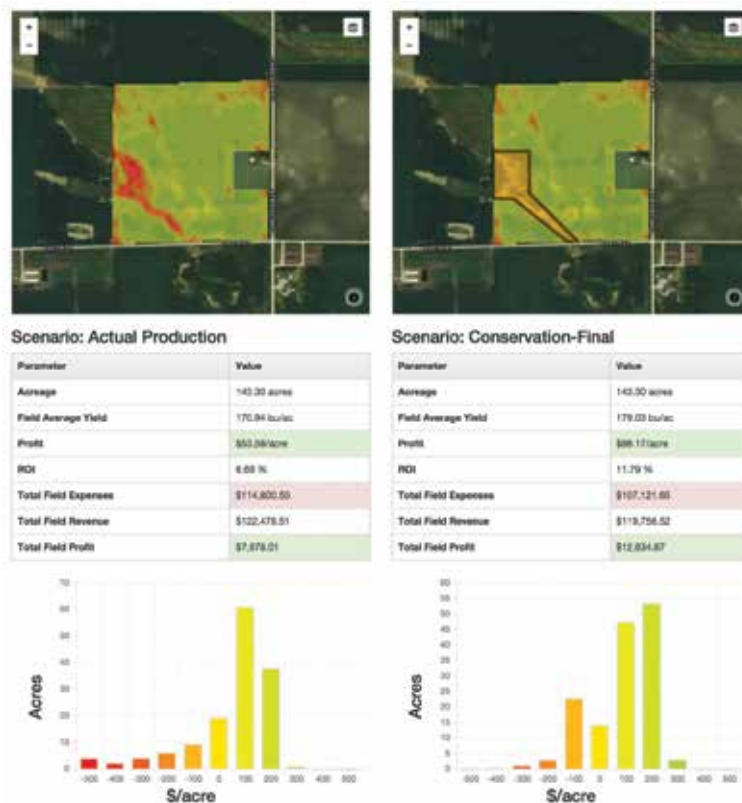



Fig. 1. Moving non-profitable acres into pollinator habitat to improve financial performance.



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In a nutshell, the raw information UAS are able to gather (visual and otherwise) can enable farmers to use irrigation and other resources more precisely, easing demands on other fronts.

The Role of Unmanned Aircraft Systems for Evaluation and Monitoring

DRONES MONITOR FIELDS AND IDENTIFY WHERE RESOURCES ARE NEEDED

By Andrew Manu, Professor, Department of Agronomy, Iowa State University

During the past ten years, the field of unmanned aircraft systems (UAS) has expanded considerably. The integration of positional, navigational and imaging technologies coupled with the ability to mount these on UAS has opened possibilities for a variety of applications. These uses include urban mapping, monitoring and mapping of habitats and natural resources, wildlife management, and assessing the extent and effects of natural disasters such as floods and fire. Although UAS are yet to be employed extensively for environmental and agricultural purposes, their declining cost and ease of use are likely to make them indispensable tools in these two domains.

UAS show great potential for practical applications in tropical agriculture, not only as a research tool, but also as a technology that can provide cost-effective, up-to-the-minute data. Such data are critical for agricultural specialists and development planners, especially those that minister to the needs of rural areas. The technology can enable the active engagement of farming communities in

monitoring their fields on a regular basis and help identify where water resources and inputs are needed. UAS also offer a complementary opportunity to obtain real time information about the expanse and coverage of farms and other land uses, crop density and growth (e.g., where crops are thriving and where they are not).

The data they capture will be most useful to support sustainable agricultural productivity. In a nutshell, the raw information UAS are able to gather (visual and otherwise) can enable farmers to use irrigation and other resources more precisely, easing demands on other fronts.

The African agricultural landscape is populated by smallholder farmers whose typical average parcel size is less than 2 ha. However, these smallholder farmers contribute more than 90% of Africa's food



production. Unfortunately due to environmental and socioeconomic conditions characteristic of the tropics, these smallholder farmers are vulnerable to climatic shocks, declining ground and surface water resources, market volatility, soil erosion and soil fertility decline. These significantly impact African agricultural development, and effective measures and strategies

need to be developed and adopted to address these constraints.

Remote sensing technologies have been used as monitoring and evaluation tools in natural resources and agriculture. Over the last decade, these technologies have been used to identify and map cropping systems and intensities of smallholder farmers. As examples, scientists have evaluated the use of satellite information data such as MODIS images and higher resolution SPOT and LANDSAT to map cultivated areas on the landscape. The

LANDSAT threshold method, the MODIS Enhanced Vegetation Index time series, among others, were used delineate crop fields in Mali and Senegal in West Africa and in two regions in India. While these studies provided some insight into the cropping patterns and associations over large spatial and temporal scales, the application of these methodologies in the typical African agroecosystems can have some significant challenges.

First of all, the typical farm size of smallholder farmers is usually smaller than the spatial resolution of the satellite data obtained from MODIS or LANDSAT. This makes it difficult to extrapolate results in any meaningful way in the fragmented agricultural landscapes of the tropics. Secondly, data obtained from these sources are normally not in sync with cultural practices of farmers as well as the growth patterns and stages of crops.

The emerging UAS technology can be used to overcome these challenges and develop a system that can best be used to assess and monitor cropping systems in the tropics. In addition to the low cost of acquisition, maintenance and relatively low operational cost of UAS compared to previously discussed technologies, UAS flown at relatively low altitudes produce ultra-high resolution (sub-decimeter) images which are needed to quantify plant cover, composition and structure at multiple spatial scales.

They provide the flexibility in sequential image acquisition programming to sync with farm operations and with different growth stages of crops. What is encouraging is that a number of image processing and orthorectification challenges have been resolved, and it is now up to researchers and other practitioners to take advantage of this emerging technology to study cropping systems with the aim of boosting productivity, reducing poverty and promoting sustainable livelihoods in the developing world.

Photos

Fig. 1. A unmanned aircraft vehicle (UAV) takes off from an Iowa corn field (Photo by David Samson).

Fig. 2. UAVS can take aerial images of agricultural land to determine where to allocate inputs. This is an image of Iowa cropland, taken by a UAV (Photo by David Samson).





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