Sustaining Irrigated Agriculture

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If we are to achieve results never before accomplished, we must expect to employ methods never before attempted.

The National Academy of Engineering ranked the mechanization of agriculture as one of the top 20 engineering achievements of the 20th century. Agricultural and biological engineers can be proud that we contributed significantly to this achievement. But now it’s the 21st century. What new achievement will we claim? Could it be ending hunger?

As you know, we live in the Information Age, and technology is changing what we experience at a rapid pace. With this constant rush of information, seeing beyond short-term goals can be hard, but we need only look to the example of the Sony Walkman to know the folly of not looking ahead. Sony focused its time and money on producing the perfect Walkman, while Apple looked beyond that technology to the iPod. In the long run, the Walkman was a blip on the horizon, and now it’s gone.

The businesses that thrive in the 21st century will be those that are anticipatory, thinking ahead to the next innovation that will make life better. Success will also mean thinking globally. As of October 31, 2011, Earth has seven billion people. Providing food, clothing, shelter, and fuel for everyone will be a global challenge. But agricultural and biological engineers can do it, because we’ve done it before. We represent a profession that serves the world.

The future of agricultural engineering will be in precision agriculture and fascinating new sensor and control systems. The future of biological engineering will involve broad applications, from the micro-scale to the macro-scale, and it’s growing in new dimensions all the time. I challenge you to think beyond the technology that we’re using now, and dream big. And while you’re at it, give back so the world knows what fantastic professionals we are. Remember E – I – O: Expertise, Image, Outreach. Tell the world what we do, and be proud of being an agricultural or biological engineer! In the 20th century, we made the world a better place. Now we’re going to make a difference in the 21st century.

It has been an honor to serve as ASABE President.

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Agriculture must substantially increase productivity over the next 40 years to feed the growing world population. Farmers are also being called on to contribute renewable resources for energy production. Production increases in the past have been partially met by expanding use of irrigation. Irrigated agriculture contributes about 40 percent of the U.S. and global crop value on about 15 percent of the cropped land. In the process, irrigated agriculture uses over 80 percent of the water consumed in many arid and semi-arid areas.

However, irrigation expansion has ceased in many areas of the western United States. There isn’t any more water to divert from rivers, and water is being pumped from groundwater aquifers faster than the natural recharge rates. In fact, in many areas, including the southwest and west coast states and the southern High Plains, which stretch from Texas through western Kansas to eastern Colorado and western Nebraska, the irrigated area is declining.

Declining irrigation is also the result of increased competition for our finite freshwater supplies. Semi-arid irrigated areas like California, Arizona, Nevada, and the front range of Colorado and Utah are desirable places to live, and the new residents expect dependable water supplies. The residents also want to sustain and improve the green river valleys that meander through these regions and that provide recreational opportunities and critical habitat for plants and animals. Increased water use to sustain cities and natural environments will reduce water available to grow crops.

**If we are to meet future food needs ...**

... we must sustain irrigated agriculture and squeeze as much productivity as possible from every drop of water. This is the quest of a group of water management researchers in the High Plains of northern Texas, eastern Colorado, western Kansas, and Nebraska. This area requires irrigation for good crop yields. The snowmelt from the Rockies is not enough in most years, and the massive High Plains Aquifer (often referred to as the Ogallala Aquifer) is being depleted, especially in the south and central portions. Although each region of the High Plains has its own particular problems and oppor-
tunities, the researchers share a common goal—to sustain productive irrigated agriculture. They gather annually to share their research and results at the “Tearing Down the Walls (state borders)” meeting and the Central Plains Irrigation Conference (www.ksre.ksu.edu/irrigate/cpia.htm).

Northern Texas

Scientists at the USDA-ARS Conservation and Production Research Laboratory (CPRL) in the Texas High Plains near Amarillo have been working on maximizing irrigation water productivity for many years. The CPRL is near the southern end of the High Plains Aquifer, where water levels have been declining for many years and deep pumping depths make water expensive to extract. ASABE member Terry Howell and his colleagues at the CPRL Soil and Water Management Research Unit use large weighing lysimeters, essentially large square containers filled with soil and sitting in the ground on large scales, to precisely determine crop water requirements. Lysimeters are the standard for measuring water use on a daily and even hourly basis. With these large tools, the researchers can precisely measure water use and validate other, alternative ways to measure water use, such as instrumentation that measures the atmospheric energy balance at the surface. They recently invited researchers from across the United States to come to their fields and compare their own research and results with the on-site lysimeters. The techniques included instrumentation placed just above the crop canopies and satellite remote sensing imagery. As researchers gain more knowledge and confidence in their ability to measure evapotranspiration, their ability to measure and describe the effects of climatic conditions, water stress, and deficit irrigation also increases.

One of the ways that crops respond to water stress is to close their stomates, which results in reduced water evaporation (evapotranspiration) and increased temperature of the crop canopy. ASABE member Steve Evett and his colleagues are building infrared thermometers that can measure canopy temperatures and indicate the level of water stress. Canopy temperature measurements can be used as a trigger to tell the grower, or the irrigation system directly, when irrigation should be started.

Recognizing the importance of sustaining the High Plains Aquifer as long as possible, the USDA-ARS began the Ogallala Initiative in 2003 with the mission to sustain rural economies through water management technologies. Through this program, the USDA-ARS funds water management projects in Texas and Kansas in a consortium with Kansas State University (KSU), Texas A&M University, Texas Tech University, and West Texas A&M University.

Western Kansas

ASABE member Freddie Lamm, an agricultural engineer at the KSU Colby Research Station and the ARS Central Great Plains Research Station, has been researching the use of subsurface drip irrigation in the High Plains for 23 years. He has shown that the systems can last that long if they are well maintained, and that they are a viable water-saving option for several of the crops grown in the region. With subsurface drip irrigation, the water is precisely placed in the soil root zone and uniformly distributed across the field to help maximize its productivity. Surface evaporation losses are minimized since the crop and soil surface are not wetted. Although the initial cost of drip systems is high, the resulting water conservation, high yields, and long life can combine to make drip systems a good economic choice.

One of the main irrigation limitations in many areas of the central High Plains is that the High Plains Aquifer is not very thick, and growers have already drawn down the water table, so the capacity of their wells has decreased. Center-pivot sprinkler systems that were installed with an adequate water supply 30 years ago may now pump only 50 percent as much water during the peak water-needs period. ASABE
member Norm Klocke, an agricultural engineer at the KSU Research and Extension Center in Garden City, Kansas, and Allen Schlegel, an agronomist at the KSU Southwest Research and Extension Center in Tribune, Kansas, along with Joel Schneekloth, a regional water resource specialist at Colorado State University (CSU), are developing management strategies that will allow growers to maintain productivity with the reduced pumping capacity. Practices include planting two different crops that have varying water needs and schedules under the same center-pivot system. For example, an early-season crop like wheat reaches maturity and has reduced water needs by the time a later-season crop like sunflowers reaches full demand. Through good crop rotations and tillage practices that maximize conservation of both rain and irrigation water, growers can get additional productive years from their wells.

One of the constraints to adoption of deficit irrigation practices is that most farmers depend on federal crop insurance to insure their crops against unplanned catastrophes such as hail or extreme drought. However, the USDA Risk Management Agency (RMA), which manages the Federal Crop Insurance Program, does not know how to establish the potential yield of a crop that is deficit irrigated, so the agency currently insures deficit-irrigated crops at the same rates as lower-yielding dryland crops. ASABE members Norm Klocke and Derrel Martin, ag engineers in Kansas and Nebraska, have been working with the RMA to establish the likely crop yields under different planned deficit-irrigation practices. When farmers know that they can get their crop insured for its intended yield, they will be more willing to try deficit irrigation.

**Eastern Colorado**

Growing populations, energy development, and overuse of water are resulting in declining water supplies for irrigation in eastern Colorado. Cities have been buying irrigated land to acquire the rights to use the water—a tactic called “buy and dry.” Senior water rights holders in the “first in time, first in right” prior appropriation system have been requesting that the upstream well pumpers stop pumping. At the same time, oil and gas exploration companies are leasing any available water for future use in hydraulic fracturing.

CSU and the USDA-ARS are partnering with water districts and private companies to devise ways to sustain the rural agricultural economy in the region. CSU soil scientist Neil Hansen and his colleagues at KSU and the Central Great Plains Research Station at Akron, Colo., have been developing conservation practices for dryland (non-irrigated) agriculture and are applying these practices to limited-irrigation production systems. Reduced tillage and maintenance of surface residues helps collect rainfall, snowfall, and sprinkler water and reduces evaporation losses. Hansen and his colleagues are developing cropping rotations appropriate for ranges of water supplies from dryland to full irrigation. They have shown that an alfalfa grower with inadequate water can use the limited supply in the spring and fall and let the crop go dormant in the heat of summer and still maintain a viable crop.

The USDA-ARS Water Management Research Unit (WMRU) in Fort Collins, Colo., is conducting a detailed study of plant responses to deficit irrigation and how to maximize the “crop per drop,” or more specifically, the dollars per drop. The WMRU researchers are developing water production functions based on crop evapotranspiration to quantify the value of water with different amounts of irrigation. Colorado water law accounts for water in terms of water consumed by the crop rather than irrigation water applied, since water that is not consumed is generally available for others to use.
use downstream. In Colorado, which has interstate compacts with all its neighboring states on both sides of the Rockies, leaving some water for downstream users is critical. ASABE member Walter Bausch is using remote sensing from both the ground and the air to estimate crop stress and determine how much water is actually used by a stressed crop. He is finding that canopy size and temperature are good parameters to help estimate water use.

One of Bausch’s findings is that many crops are very efficient in using the water they receive, so getting more crop per drop with deficit irrigation will require better understanding of how crops respond to water stress. Plant physiologists Dale Shaner and Louise Comas are studying water-stressed plants in detail to see if there are particular irrigation schedules that will help a plant maintain productivity with less water use, and if there are plant characteristics that can be measured to indicate degrees of stress.

Realizing that research from a given field will not apply to all situations, the WMRU is working closely with the USDA-ARS Agricultural Systems Research Unit in Fort Collins to collect field measurements that will validate and improve crop models, such as the Root Zone Water Quality Model, so that these models can predict crop yields under water stress for a wide range of conditions. This is especially important as we face future climate change.

The WMRU is also working closely with a Cooperative Research and Development (CRADA) partner, the Regenesis Management Group, on the Sustainable Water and Innovative Irrigation Management system. Regenesis will incorporate the water productivity research results into decision support systems that will help farmers value their water as a commodity. Water can be used both to produce high value on the farm and for potential income from a city in need of water in times of shortage. The goal is to keep farmers in control of their water supplies. A critical part of the effort is to document water savings to the satisfaction of downstream water users, who are always wary of changes upstream that might affect their water supply. CSU agricultural economist James Prichett is furthering these efforts by surveying farmers to learn how much they feel their water is worth and what types of lease arrangements they might be willing to agree to. All these efforts are designed to sustain productive and economic irrigated agriculture while meeting the water needs of others.

**Western Nebraska**

With recent declines in irrigated area in California and Texas, Nebraska is now the state with the greatest irrigated area. Sitting at the north end of the High Plains Aquifer and on the Platte River drainage, Nebraska, the home of many center-pivot manufacturers, is relatively well supplied with water. However, in the western part of the state, water shortages are critical. In Nebraska, regional Natural Resources Districts monitor and regulate irrigation water use. Declining water levels in the High Plains Aquifer have led to restrictions on pumping, but recognizing that these effects are long term, the Natural Resources Districts often restrict the amount a farmer can pump over a multi-year period. Thus, farmers must decide the value of the water this year for a particular crop mix and precipitation pattern compared to next year—a very complex decision. Derrel Martin, working at the University of Nebraska, and his colleagues have developed the Water Optimizer to help farmers weigh the many options involved in water management decisions. Farmers can input information on their water supply, preferred crops, and production costs, and the Optimizer will help them allocate their limited water supply to gain the best overall returns.

**Investigating the options is the future**

Although the challenges facing irrigated agriculture in the High Plains and in the rest of the western United States are daunting—farmers must produce more with less—failure is not an option if we are to meet the food and fiber needs of the next 40 years. Through many researchers from many institutions working together, our understanding of the options is increasing. Technological breakthroughs, such as new crop varieties that resist water stress, may play a critical role in meeting food needs with limited water resources, but past experience shows that good water and crop management will always be an important part of the solution.

**ASABE member Tom Trout**, research leader, USDA-ARS Water Management Research Unit, Fort Collins, Colo., USA; thomas.trout@ars.usda.gov.
Agricultural watersheds often contain swine, dairy, beef cattle, and poultry operations, with the animal manures from these enterprises applied to local pastures and cropland. Of course, the wildlife in a watershed is also a source of manures. The manures in these watersheds can be sources of fecal bacteria and can contaminate surface waters. Even relatively small concentrations of *Salmonella* and toxigenic *E. coli* 0157:H7 in recreational waters downstream from agricultural watersheds may pose risks to public health because the infective dose of these two pathogens is quite low. The frequency of sickness and mortality caused by these zoonotic pathogens has driven the development of management practices to prevent water contamination. However, these management practices cannot be effectively tested without improved methods of detecting and quantifying pathogens in the environment. For effective conservation practices, we must understand the survival and movement of pathogenic microorganisms across agricultural landscapes. This information is currently incomplete or absent in the scientific literature, and therefore we are not able to accurately predict potential risks to water resources and U.S. food safety.

Health officials test surface waters for fecal indicator bacteria, such as non-pathogenic *E. coli*, because tests for pathogens such as *Salmonella* and *E. coli* 0157:H7 are prohibitively expensive or unavailable. Surface water concentrations of *E. coli* that are greater than an established maximum are considered to be indicative that the water is likely...
contaminated with pathogenic microorganisms. Unfortunately, the association between the pathogens and the indicator bacteria is not strong enough to make definitive statements about the safety, or risk, in any particular case. Practical methods are needed to accurately measure the low, but infective, concentrations and die-off rates of the pathogens themselves.

The rationale behind our work

We have developed a way to quantify very small numbers of zoonotic pathogens in environmental matrices. This development was a combination of previously established methodologies: a method for filtering large volumes of environmental water, standard selective media for pathogen isolation, biochemical tests for presumptive identification, and a molecular method for confirming pathogen identity. Quantification is based on a classical, most probable number (MPN) format. The MPN methodology along with the mature sentinel chamber technology (patented by Michael Jenkins) can be used to compare die-off rates of zoonotic pathogens and fecal indicator bacteria in water and soils.

Testing the hypothesis

We applied the methodology in a Georgia watershed containing a cow-calf operation, cropland fertilized with poultry litter, and wildlife such as deer, rodents, and a variety of resident and migrating birds. Our objective was to determine the concentrations of *Salmonella* and *E. coli* 0157:H7, and the indicator bacteria *E. coli* and fecal enterococci, and test the hypothesis that ponds in agricultural watersheds can attenuate these fecal bacteria and thus improve downstream water quality. For 31 months, our team sampled a perennial stream at the point where it flows into an impoundment, as well as surface (5 cm) and subsurface (50 cm) water samples from the pond, and the pond’s outflow. We were able to measure very small concentrations of *Salmonella*, ranging between 0.1 and 120 per liter, and concentrations of *E. coli* 0157:H7 ranging between 0.1 and 946 per liter of pond water. In some instances, the concentrations of fecal indicator *E. coli* were below the criterion of water impairment.

We also applied our methods to an on-site experiment that compared die-off rates of a known toxigenic strain of *E. coli* 0157:H7 with strains of indicator *E. coli* and fecal enterococci that had been isolated from cattle feces. In this experiment, pond water was inoculated with *E. coli* 0157:H7 along with *E. coli* and fecal enterococci isolates. The inoculated pond water was then distributed to sentinel chambers, and the chambers were placed in the pond in replicate blocks. These chambers were designed to rapidly equilibrate with the environment of the pond, but they allowed no bacteria to move into, or out of, the chambers. Replicate chambers were removed from the pond at designated times, assayed for bacteria, and die-off rates were determined. The results of these experiments demonstrated that *E. coli* 0157:H7 died off significantly more slowly than either of the indicator bacteria. We also performed tracer studies, which showed that the pond had a long residence time. This increased the die-off rate of the indicator bacteria more than that of the pathogens. This was seen in the disparity between the concentrations of the indicator bacteria and the presence of the pathogens.

Our methods of quantifying *Salmonella* and *E. coli* 0157:H7 have produced results demonstrating greater persistence of pathogens than indicator bacteria in the study watershed. With these methods, very small concentrations can be measured, even when the fecal indicator *E. coli* is below concentrations that would indicate a risk to public health. These methods can also be used to determine die-off rates of pathogens under field conditions.

*Michael Jenkins*, microbiologist and lead scientist, michael.jenkins@ars.usda.gov; *ASABE member Dinku Endale*, agricultural engineer, dinku.endale@ars.usda.gov; and *Dwight Fisher*, research leader (retired), dwightfisher@me.com, USDA-ARS J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, Ga., USA.
Excessive ammonia (NH₃) emissions are becoming an important environmental issue. The generation, dispersion, and deposition of NH₃ can contribute to air pollution, soil and water contamination, and pungent odors. Agricultural activities, especially animal feeding operations (AFOs), are a major source of NH₃ emissions. At an AFO, manure and wastewater contribute to ammonia emissions from the animal housing and from the manure storage and treatment facilities. Additionally, loss of NH₃ to the environment results in the loss of an important nitrogen fertilizer source. Hence, prevention of excessive NH₃ emission from animal manure and wastewater is economical as well as beneficial to the environment.

The latest findings

Our research has shown that an acid-filled, gas-permeable membrane (GPM) system can remove NH₃ gas from liquid manure. After its removal, the captured NH₃ may be used as ammonium sulfate [(NH₄)₂SO₄] fertilizer to partially offset the cost of using commercial nitrogen fertilizer on the farm. We call this process “ammonia mitigation technology for sustainable environment stewardship.”

Different approaches and technologies, including acidic spray scrubbers, biofilters, and chemicals such as acidified clays and sodium hydrogen sulfate, have been examined as methods for decreasing NH₃ emissions from AFOs. However, not all of these methods can mitigate NH₃ in an economically sustainable way because of the high costs of spray scrubbers, the limited useful life of chemicals and other additives, the lack of NH₃ recovery, and the complex operation and management that are often required. In comparison, gas-permeable membranes are simple to set up and easy to operate and manage. Our GPM system uses tubular membranes that can be submerged in liquid manure or suspended in air containing NH₃ gas. A diluted sulfuric acid (H₂SO₄) solution is circulated through the tubular GPM. The membrane has very small pore sizes, so it can repel liquids (due to the surface tension phenomenon) while allowing NH₃ gas to permeate through the membrane. The tubular membrane used in our study was made from expanded polytetrafluoroethylene (ePTFE) with an average pore size of 2.46 microns. To put this in perspective, a typical human hair is about 70 microns in diameter. The GPM material is similar to that of dental floss and has uses in the biomedical field, including blood filtration and synthetic blood vessels.

How the system works

Basically, the GPM system captures NH₃ gas from any NH₃ source and recovers it in the acidic solution. The results are a remediated environment, specifically cleaner air, and diluted (NH₄)₂SO₄ fertilizer. Our laboratory research, conducted in the Department of Biological and Agricultural Engineering at Texas A&M University, showed that the GPM system could remove 50 percent of the total ammoniacal
nitrogen (TAN) from dairy liquid manure contained in different-sized test chambers in about 20 days. Preliminary results showed that about 1 cm² (0.155 in.²) of GPM surface area is needed to extract NH₃ from 3 cm² (0.465 in.²) of liquid manure surface area.

**Looking ahead**

Future laboratory studies will assess the efficacy of using the recovered (NH₄)₂SO₄ to grow crops and livestock feed, which could offset the cost of using commercial fertilizer and possibly offset the cost of using this technology to reduce NH₃ emissions at AFOs. Our long-term goal is to develop a pilot-scale GPM system for installation at an AFO. System optimization can then be based on real-world NH₃ concentrations, ambient temperatures, and pH values. Field studies will also allow us to monitor the GPM system’s ruggedness and reliability in actual use.

ASABE members Saqib Mukhtar, professor and extension specialist, and Amir M. Samani Majd, doctoral student, Department of Biological and Agricultural Engineering, Texas A&M University, College Station, USA; mukhtar@tamu.edu.

**Micrograph of a GPM pore.**

(Above) Lab-scale experiments and (right) demonstration of the GPM system for NH₃ mitigation led by Saqib Mukhtar.
What is biological engineering?  
A discipline?—a reorientation?—the future?

Norman R. Scott

The rush to biological engineering does not take away or resolve what, for many of us, has been the complexities of defining our field for the public. All of us have frequently been asked: “What is agricultural engineering?” Too often, the public perception is that agricultural engineering means farming, or driving a tractor, or some other misconception not even remotely close to the real applications of engineering to the broad areas of agriculture. However, this lack of public understanding can be turned to an advantage when we take the opportunity to inform people about our efforts as engineers to address agriculture and food systems. Just as the physical sciences led to the development of commonly recognized fields of engineering, such as electrical, mechanical, civil, and chemical, the biological sciences have become the foundation for the development of biological engineering.

In an effort to develop a definition for biological engineering that could serve as a common framework for advancing public and scientific understanding of the field, and as president of the Institute of Biological Engineering (IBE) in 2001, I led the effort for adoption of a definition. The definition adopted by the IBE Council (www.ibe.org) is: “Biological engineering is the biology-based engineering discipline that integrates life sciences with engineering in the advancement and application of fundamental concepts of biological systems from molecular to ecosystem levels.”

While no definition can reach a unanimous acceptance, this definition can and should be used widely to develop a reasonable understanding of biological engineering and lead to a broad acceptance. Of course, a definition alone will not create comprehensive acceptance and usage, but broad adoption of this definition by academic departments, industry, and individuals can establish biological engineering as a recognized engineering field, based on integration of fundamental concepts from the biological and physical sciences.

Building on this definition of biological engineering (BE), and based on my own career, I suggest that BE covers a spectrum, from the systems level to the molecular level (fig. 1). In fact, the distribution of research and teaching in BE can be characterized as a normal distribution: from large-
scale systems such as sustainable communities and anaerobic digestion at one extreme—to the organism level in the center of the curve—to the molecular level, such as nanobiotechnology, at the other extreme. This distribution analogy could represent a research career in BE, and it also communicates the wide scope of BE. In my own career, for example, my engagement at the nanotechnology level is more as an advocate for developing research programs than in laboratory studies. Like many biological engineers, the main focus of my research falls in the central portion of the curve, which represents research with whole organisms.

A researcher’s place along the spectrum—that is, the $x$-axis—should be regarded as somewhat arbitrary, as well as the value of the $y$-axis, which is loosely correlated to the number of projects and the time invested in them. Without going into detail on specific projects, some of the fundamental interactions of biological and engineering elements within animal systems in my research have included:

- The physiological response of dairy cows to controlled electric currents to elicit the effects and behavior of animals in response to stray voltages in dairy systems.
- Development of wireless animal identification systems with the inclusion of physiological responses to identify time of estrus in dairy cows.
- In-depth analyses of teat milk flow from dairy cows relative to the biomechanics of tissue deformation, pathogenic transport mechanisms (mastitis infections), and machine milking.
- Studies of thermoregulation in poultry using gradient-layer thermoelectric calorimetry to assess heat production and heat loss while simultaneously characterizing the influence of the hypothalamus and biogenic amines in maintaining body temperature.
- Assessment of a fuel cell using animal manure as the substrate for electricity generation.

The progress of academic engineering departments in adopting “biological” (in some form) in their organizational titles did not necessarily translate into real changes in their curricula, at least at first, but this transformation has been occurring steadily over the past decade. Such a transformation occurred in the Department of Biological and Environmental Engineering at Cornell University, and the new curriculum is shown in figure 2. This example should not be seen as an absolute curriculum but rather as an example of the type of program that can create a solid foundation for BE research and teaching. Call it the “DNA” of biological engineering.

**DNA of Biological Engineering**

**Curriculum:** [semester hours in ( )]

**Core Sciences (46)**
- Mathematics (16)
- Physics (8)
- Chemistry (7)

**Biological Sciences (15)**
- Introductory with lab (8)
- Biochemistry
- Cellular biology or genetics or molecular biology

**Core Engineering (13)**
- Computer programming
- Engineering Distribution
  - Probability and statistics
  - Mechanics of Solids

**Core biological engineering courses (14)**
- Principles of biological engineering
- Bio-kinetics and thermodynamics
- Biological and environmental transport processes (heat and mass)
- Biofluids

**Biological engineering electives (9)**
- Biomedical engineering
- Bioprocess engineering
- Bioenvironmental engineering

**Major-approved engineering electives (15)**

**Liberal studies (24)**

**Approved electives (6)**

Total — 127 semester hours

**Figure 2. The “DNA” of biological engineering.**

Environmental Engineering at Cornell University, and the new curriculum is shown in figure 2. This example should not be seen as an absolute curriculum but rather as an example of the type of program that can create a solid foundation for BE research and teaching. Call it the “DNA” of biological engineering.

**ASABE member Norman Scott,** professor, Department of Biological and Environmental Engineering, Cornell University, Ithaca, N.Y., USA; rs5@cornell.edu.

What does biological engineering include?

**Abdel Ghaly**

Biological engineering is a science-based, application-independent engineering discipline that is aligned with the foundation of biology and possesses the principles of engineering. It is capable of integrating discoveries from various disciplines to design solutions for problems in biological systems (fig. 3). The purposes are: (1) to produce food, feed, fiber, fuels, and chemicals from biomaterials; (2) to protect the environment and human health; and (3) to conserve and replenish natural resources. The overall goal is to achieve economically and environmentally sustainable development through the application of bioprocesses and biotechnologies in all facets of life. Biological engineering is therefore different from the application-focused discipline of agricultural engineering, which is defined more narrowly as the practice of science and engineering as applied to agriculture.

As Norm Scott noted, the roots of BE go back to the founding of ASAE in 1907, and discussion about BE has con-
continued since then. These discussions resulted in the establishment of several BE undergraduate programs in the United States and in Canada, such as at Guelph University in 1975. There are now several technical societies and institutes that are partially or totally devoted to BE in North America. For example, the Canadian Medical and Biological Engineering Society was established in 1965, followed by the American Institute of Medical and Biological Engineers in 1991. The Institute of Biological Engineering was established in 1995 in the United States, followed by the Canadian Society for Biological Engineering in 2004. And of course, as Norm mentioned, ASAE added “biological” to its name and became ASABE in 2005.

While BE education is now available at most universities, biological engineers need to do a self-assessment to avoid identity problems and remain a relevant and vibrant group within ASABE. They should ask themselves the following questions:

• Who are biological engineers?
• What are the responsibilities of biological engineers to the Society?
• Can biological engineers adapt to changes?
• Are biological engineers able to take advantage of new opportunities?

Is there a future for BE? Not surprisingly, we believe that there are outstanding opportunities for BE to reach the status of any other engineering discipline, including the well-established engineering fields. BE can emerge as a separate and distinct discipline, but only if there is agreement about what it should contain and if it is given time to develop. Critical to this development are:

• Adoption of a widely used and consistent definition of BE.
• Continued emphasis on BE as a science-based engineering discipline.
• Academic curricula that integrate life sciences with engineering for biological systems from the molecular level to the ecosystem levels (the “DNA” of BE).
• Increased interactions and enhanced development of an understanding of BE in the industrial and public sectors.

ASABE member Abdel Ghaly, professor, Department of Process Engineering and Applied Science, Dalhousie University, Halifax, Nova Scotia, Canada; Abdel.Ghaly@da1.ca.

Biological engineering: What it means to me

Arthur T. Johnson

I have been involved with biological engineering for almost my entire professional life, and I have been totally committed to its definition, promotion, and dissemination. Here are some thoughts that come to mind when BE is discussed. These are, of necessity, only briefly presented.

History of Biological Engineering

Although the history of BE goes back well before 1965, Pat Hassler changed the name of the North Carolina State University program to Biological and Agricultural Engineering in 1965, and Bill Fox and Jim Anderson followed at Mississippi State in 1967. Along with Rensselaer Polytechnic Institute, these were the first accredited BE programs. There were many in ASABE who championed BE and pushed for a common definition. Beyond ASABE, my own BE efforts were concentrated in The Alliance for Engineering in Medicine and Biology, The American Institute for Medical and Biological Engineering, and the American Society for Engineering Education.
Attributes of Biological Engineers

They are generalists. They have an appreciation for interrelationships and interconnections, they approach BE problems from a systems perspective, and they use analogical thinking.

They are enthusiastic. They appreciate the wonders revealed about the ways of living things, they see themselves as positive contributors to humankind and the state of the world, and they are, consequently, highly motivated.

They are creative. They work with biological tendencies rather than against them, they do not need to subdue or dominate other living things, and they use imagination to extend natural tendencies.

They are skilled. Hands-on experience enhances understanding, and personal involvement begets inspiration and improvement for BE systems. Biological engineers have confidence in their abilities. It is therefore important for BE students to have meaningful laboratory experiences as part of their education.

They are science-based. This means that their interests and knowledge base encompass all possible applications (fig. 4). Their interests are not tied to any particular industry, and advances in one specialty apply to all. This breadth of BE is one of the hardest attributes to embrace, and it stands as an obstacle to full development of BE as a separate discipline. No matter what the foundational disciplines are for those moving in to BE, their concept of BE is colored by their specific backgrounds.

They know biological principles. In fact, to be effective as a biological engineer, this knowledge is essential. These biological principles include, but are not limited to:

- Competition for resources.
- Reproduction. (This principle is amazing in itself; what other chemicals are compelled to reproduce at the expense of all other chemicals in the world?)
- Selection of the most likely to reproduce.
- Information legacies.
- Influence of physical, chemical, and biological environments.
- Likelihood of unintended consequences.
- Redundancies.
- Exceptions to the rule is the rule.

They are thoroughly familiar with the fundamental research in biology. Web searching is used to find details, not general information. Googling is not effective if you don’t know where to start.

They have a common knowledge base, and they conform to the IBE definition of BE given earlier.

Finally, biological engineers are visionaries. They ask questions, such as:

- What is possible?
- How would this problem be solved biologically (bioinspiration)?
- Is there a biological solution to a similar problem (biomimetics)?
- What are the limits?
- How can I work with biological principles, not against them?

Basic Textbooks

When agricultural engineering was just emerging as a discipline, it was much more isolated than BE is now. There was no explicit fundamental agreement about common educational objectives or foundational knowledge. However, agricultural engineering had the Ferguson series of textbooks, which served the purpose of forming disciplinary cohesive-ness. Those textbooks became the basis for agricultural engineering as a separate discipline. BE needs the same thing.

With that in mind, I have written three textbooks that could lead the way toward an academic infrastructure for BE. The last two are probably more relevant than the first:

**Biomechanics and Exercise Physiology: Quantitative Modeling** contains the means to predict physiological and ergonomic responses to work and exercise, as would be needed in a BE design.

**Biological Process Engineering: An Analogical Approach to Fluid Flow, Heat Transfer, and Mass Transfer Applied to Biological Systems** uses analogs to demonstrate the concepts behind transport processes, and it presents design equations and tables of values meant to assist with BE designs.

**Biology for Engineers** (with significant addenda at www.bioe.umd.edu/~artjohns/books/biology-for-engineers/1stEd-Addenda.pdf) is the most fundamental of the three, and it presents biology as engineers should know the science (fig. 5). It is broad and comprehensive, emphasizing how biological systems actually function, so that biological engineers know what to expect when working with living things.

**ASABE member Arthur Johnson**, professor, Department of Bioengineering, University of Maryland, College Park, USA; artjohns@umd.edu.

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**Figure 5.** Seeing through the “microscope” as well as the “big picture” is the job of biological engineers.
Here in the year 2035, the typical U.S. horticultural farm is far more different from its 2010 version than today’s field crop farm is from its 2010 version. Horticultural production has had to change more than crop farming because its water and labor issues were more pressing. Although there remains a great diversity in U.S. horticultural farms, some general trends have been observed.

**It’s all about the water**

Horticultural crops, such as fruits and vegetables, continue to be concentrated in the “fruitful rim” of the Pacific, Gulf, and southern Atlantic coast states. A big challenge in these states has been water availability, especially as climate change has increased evapotranspiration and changed weather patterns. As populations and industry expanded, the dominance of agriculture in freshwater consumption was questioned. Strict water allotments are now enforced, and they were the subject of much political and legal activity. As a result, irrigation systems have continued their long-term trend toward precise control and application with minimal losses. The combination of wireless sensor networks, high-resolution remote sensing, and geospatial databases allows water needs to be pinpointed. Wireless control, often down to the individual emitter, allows those water needs to be exactly met where sufficient water is available.

The water issue, combined with increasing temperatures due to climate change, has caused some agronomic crops, such as cotton, peanuts, and rice, to move farther inland. To some extent, they have been replaced by additional horticultural crops, including new fruits and vegetables. Just as consumption of healthy items such as broccoli and blueberries increased in the previous 25 years, our more adventurous palates have encouraged increased production and consumption of mangoes, bitter gourds, and other tropical horticultural products in the southern United States.

**Mechanization on the march**

Overall, our national tendency continues to be that we export low-value bulk commodities, such as corn, wheat, and soybeans, and import higher-value products, such as fresh tomatoes, table grapes, and fruit juices. Although some imports, such as coffee and cacao, are due to climatic reasons, many imports into the land-rich United States are due to our history of high domestic production costs. However, the U.S. horticultural production industry has grown significantly since 2010 due to a reduction of labor costs with increased mechanization and automation. Harvest labor is no longer half the cost of production, as it once was for many crops.

At first, this mechanization was a response to concerns about labor availability. Despite increased availability of visas, the majority of horticultural workers remained undocumented aliens. Concern with this situation led to research and development of mechanization for “specialty crops” in general, which includes horticultural crops.
For example, in tree fruit production, the automated platform allowed farm workers to be more efficient. Just by leaning, as in the old Segway, the worker can steer the platform anywhere in the tree canopy or to the next tree. Eventually, the workers themselves were removed in favor of robotic pruners and thinners. Machines were developed that combined the gentleness of robotic harvesters with the productivity of mass harvesters through arrays of actuated picking mechanisms. Of course, their commercial success was greatly aided by growing trees in narrow, high-density rows with planar fruit placement.

The harvesting of vine, bush, and row crops was similarly mechanized. This was made possible by the continued development of lower-cost and faster sensors, computers, and especially actuators. The machines were able to continuously adjust to the plants and products, and thereby avoid damaging them.

It is hard to believe that consumers once did not know where their food came from. Today, each piece of fruit and every vegetable has a passive RFID installed when it is harvested, and it is individually tracked from field to fork. The feedback from automated sensors throughout the distribution system provides continual refinement of the management practices in the food chain.

Still bugs in the system

Unfortunately, the ubiquity of pests remains a problem. The interconnected global economy, as well as climate change, have brought new pests and changed the relative importance of previously known pests. Horticultural production systems have had to adapt to changing pest pressures. In addition, the shorter periods of cool temperatures have resulted in a more constant baseline pest pressure.

The huge variety of horticultural crops means that chemical pesticides cannot be developed economically for many individual types of fruits and vegetables. However, the reduced costs of genetic engineering have allowed pest-defeating and pesticide-tolerant genes to be inserted into some fruits and vegetables. Plant vigor and tolerance have also been improved by robotic grafting machines that use high-pressure water-jets to cut the rootstock and scion, while cast-in-place sleeves join the cuttings into transplants tailored for particular situations. The use of such transplants has now spread from greenhouses to open fields and has become the dominant production method for tomatoes, melons, peppers, and other crops.

Weeds are now dealt with by advanced cultivating machines that distinguish weeds from crops by spectral reflectance, shape, and leaf texture. Herbicide is only applied where weeds are actually located. When herbicides cannot be used, intrarow weeder use computer-controlled waterjets to cut weeds very close to the crop. Insect and disease control remain problematic, but at least now such problems can be quickly detected with remote sensing.

Integrated fine-tuned production

Today’s horticultural farm relies heavily on computerized models of plant growth, pest effects, and market trends. The goal is to deliver the right amount of the right quality fruit or vegetables at the right time to the market. Some things never change. All production operations are fine-tuned to meet the market demand. All the inputs are dynamically manipulated to ensure that production is the right size, the right maturity, and the right quality despite the disturbances of weather and pests. In the face of serious economic and environmental challenges, these farms have been a great success. And that success has only been possible through the efforts of the agricultural and biological engineers who developed the precision irrigation systems, the mechanization and automation systems, the computerized models, and the other technologies that allow efficient, economical production with minimal environmental impact, even in a changing climate.

ASABE Fellow John K. Schuellier, professor of mechanical and aerospace engineering, and agricultural and biological engineering, University of Florida, Gainesville, USA, schuejk@ufl.edu.
People tend to have a rather anthropocentric view of time based on their personal experiences. One distortion caused by this anthropocentric view of the world is that modern, i.e., industrial, agriculture has been around long enough to feel like it is the only way agriculture has ever been done. However, at just a century old, industrial agriculture represents only 1 percent of the 10,000-year history of agriculture and only 0.05 percent of the 200,000-year history of Homo sapiens. Industrial agriculture is therefore still a novelty, a hypothesis still under investigation, and one that is increasingly being questioned (see, for example, the International Assessment of Agricultural Knowledge, Science, and Technology for Development: www.agassessment.org). If our anthropocentric view of the world is not the best way to understand the past or the present, then it is unlikely to be a good guide to the future. For that, we need the perspective of science.

One of the achievements of science is the shattering of our narrow perspective with mind-bending discoveries, such as that time had a beginning 13.7 billion years ago, as well as describing the formation of the earth, the emergence of multicellular life, and the ongoing process of evolution. So what is a scientifically informed view of the future of farming?

The millennium scale

First, we need to determine time scales. The future of agriculture is intrinsically linked to the ongoing survival of humans as a species because there is no conceivable human-made substitute for photosynthesis, nor is there a practical replacement for the 48 million square kilometers (18,500,000 square miles) of farmland on the planet. Human civilization will therefore continue to depend, utterly, on agriculture.

The average life of a species is a 1,000,000 years, which means that we need to plan for another 800,000 years. A million years is where evolutionary time merges into geological time, so while 800,000 years is a stark figure to illustrate what is ahead of us, trying to plan that far ahead is nonsense.
cal. Instead, we need to take it one step at a time. I suggest that the size of those steps should be one millennium, i.e., 1,000 years. This nice round figure is derived from several sources. A main source is David Montgomery’s 2008 book *Dirt: The Erosion of Civilizations*, the main thesis of which is that most civilizations have a maximum duration of about 1,000 years because this is how long it takes them to destroy their soils. A much earlier source is Franklin King’s *Farmers of Forty Centuries, Or Permanent Agriculture in China, Korea, and Japan*, which documents the very few farming systems that persisted for longer than a millennium.

The test period of agricultural sustainability is 1,000 years because the processes that undermine farming, such as soil loss, move so slowly that it takes this much time for them to have permanent effects. Conversely, if an agricultural system can persist for 1,000 years, then its impact on the planet is likely to be smaller than the corresponding natural processes that support farming, such as soil formation. Therefore, such agricultural systems can be considered permanent. A thousand years may seem like a long time to think ahead, especially when climate change models only cover the next century and a week is a long time in politics. However, unless we think on a millennium time scale and act accordingly, then history, as the aphorism says, will repeat itself, and what history tells us is that every previous civilization has become extinct upon depleting its most basic resource: the soil.

Much of western thought is still trapped in a Cartesian duality that views people and commerce as separate from the natural world. However, this assumption is the opposite of what science tells us, i.e., that all of humanity and our economic systems are utterly dependent on the planet’s natural systems, all the way down to the oxygen that we breathe but don’t pay for. Therefore, to determine if our agricultural system can exist permanently, i.e., for a millennium, it is essential to understand how the planet’s systems work and how dependent agriculture is on them. Unfortunately, many of the technologies of industrial agriculture do not work with natural systems; too often, they work against natural systems. They are an example of that Cartesian world view: agriculture, like any other human activity, is considered separate from the natural world and is therefore managed like any other industry. For example, the two most important technologies that support industrial agriculture are fertilizers and pesticides.

**The future of fertilizers**

Pre-industrial farming systems had to recycle all the chemical elements of life (nutrients) in organic form in the immediate area. Otherwise, yields plummeted, and people died because they had no other sources of nutrients. In comparison, industrial agriculture, by importing lithospheric nutrients from fossil sources such as guano and mining (e.g., rock phosphate), allows nutrients to be exported in farm production without being returned to the land. In addition, these fossil reserves of nutrients are both finite and very small compared to their current rates of extraction. As with petroleum, their production will eventually peak. Phosphorous production is forecasted to peak in about 70 years, and potassium in about 400 years. Even if these forecasts are moved out by a century, or more, they are still well short of our millennium measure of permanence.

At the other end of the fertilization process, most of the mined nutrients, after passing through farmland and produce, are lost to the oceans, either directly from the land or indirectly through sewer systems, to freshwater, and then to the oceans. Once in the oceans, there is no practical means of recovering these nutrients in the same quantities at which they are being lost. And there are no substitutes for these elements in agriculture. It is impossible to substitute one element or compound for another without completely rewriting biology. Therefore, as fossil nutrient supplies begin to decline, agriculture will begin a downward spiral—unless all the lithospheric nutrients removed from farms are recycled back to farms, as was done in pre-industrial agriculture.

The obvious solution is to start recycling the lithospheric nutrients now, before current reserves reach their forecasted peak, and use fossil reserves as top-ups until leaks from the nutrient cycles are reduced to geological rates. However, while conceptually simple, there are immense political and economic impediments preventing this development.

Nitrogen is a special case because it is an atmospheric nutrient (di-nitrogen, or N2), but nitrogen is only available to life in lithospheric, reactive (Nr) forms, such as ammonium and nitrates, which only a few species of microbes can create from di-nitrogen. N cannot therefore be made from “thin air” in nature, but nitrogen fertilizers are currently made from fossil fuels, mostly natural gas (methane), which means that current nitrogen fertilizers are fossil fertilizers. There is a non-fossil alternative, i.e., using renewable energy for electrolysis of water to produce hydrogen to power the Haber-Bosch process to make N fertilizers, but the cost of this process is several times that of fossil fuels. Economics is a moveable feast, but if renewable N fertilizers cost several times more than fossil N fertilizers, then something in farm financials will have to give before fossil N can be replaced. Food prices will have to increase, or there will be a conversion to biologically fixed N, which has its own costs. In addition, because nitrogen fertilizers are made from fossil fuels, their price moves in lockstep with the price of oil, which is on a long-term upward trend.

Nitrogen is also the most footloose of nutrients, having multiple forms with multiple effects, which means that it is now a major planetary pollutant, with widespread impacts on “human health, ecosystem health, biodiversity, and climate,” according to the European Nitrogen Assessment. So even if N fertilizers were somehow manufactured renewably, their downstream impacts would still be sufficiently severe to jus-
tify curtailing their use, as has already been done in the European Union under the Nitrates Directive. Ultimately, the current patterns of nitrogen fertilizer use in industrial agriculture will have to change, due to both increasing costs and societal constraints.

In short, the current approach to fertilization in agriculture cannot persist in the long term. Eventually, humanity will be forced to work within the biogeochemical cycles, as it generally did before the advent of industrial agriculture, by recycling all biological residues and relying much more on biologically fixed nitrogen, such as by using legumes.

**The problem with pesticides**

Pesticides (in the broadest sense, including herbicides) were hailed as miraculous when they first appeared, and to some extent they still are. Selective systemic herbicides kill weeds but not the crop, something no other technology can achieve, at least with such ease, low cost, and reliability. However, pesticides are now losing the battle against evolution as resistance to pesticides is spreading. This would not be such a problem if there were sufficient replacement pesticides in reserve. But there are few such replacements, and not for lack of effort. The profitability of agrochemical companies, at least before the advent of transgenics, depended on finding and patenting new chemicals, and billions of dollars have been spent on research. In the wake of that progress, new pesticides are simply no longer waiting to be discovered. As Anne Thompson, head of development and registration at Dow AgroSciences, said at the “The Future of Weed Research” workshop in the U.K. in 2008, “Please tell the farmers there is no cavalry coming over the hill.”

In addition to the slowing R&D, societies are starting to re-evaluate the real costs of pesticide use and are increasingly moving from an ethical position of risk management, i.e., assuming a pesticide is safe unless demonstrated otherwise, to an ethical position of precaution. The assumption is that a pesticide is unsafe unless demonstrated otherwise, which shifts the burden of proof from the general public to the manufacturers and users of pesticides.

Pesticides are therefore facing a triple whammy of evolved resistance, few replacements, and increasing societal intolerance. The extrapolation of this trend is that the number of effective and legal pesticides will continue to decline. In other words, we are at the start of the “post-pesticide” era, and we need to consider what that will mean. Fortunately, we have alternatives to chemical pesticides in the form of physical, biological, and ecological pest management techniques, such as interrow hoeing, biological control of insects, and crop rotations. Few of these techniques are as easy to use as pesticides, and they often require wholesale changes to farm systems, such as converting from monocultures to mixed cropping. This changeover is going to take quite a bit of work.

**The real future of farming**

Yes, industrial agriculture has achieved amazing feats, dramatically increasing yields and feeding billions of people, but today’s farming systems are built on a temporary foundation. The technologies behind the amazing achievements only work in the short term (centuries), not the long term (millennia), and therefore cannot be the future of farming. These technologies, and the high yields they produce, ultimately depend on finite supplies of fossil resources, so they can only be a stop-gap measure while we develop systems that are actually sustainable. For many, this is not news. The unsustainability of industrial agriculture was understood from the very beginning. Wise heads, such as Franklin King, pointed this out one hundred years ago, when industrial agriculture was still in its infancy.

So, given that humanity wishes to endure for the long term, and as agriculture is our only source of food, then agriculture must change from its current reductionist philosophy to a more holistic philosophy, while making wise use of the new knowledge created by science.

**... agriculture must change from its current reductionist philosophy to a more holistic philosophy, while making wise use of the new knowledge created by science.**

Charles Merfield, head of the BHU Future Farming Centre, Canterbury, New Zealand; charles.merfield@bhu.org.nz.
The American Society of Agricultural and Biological Engineers (ASABE) and the International Code Council (ICC) announced their intention to jointly develop a new ANSI standard, designated “ASABE/ICC Landscape Irrigation Sprinkler and Emitter Standard,” that will establish requirements for landscape sprinklers and emitters. The new standard will address design, performance, and uniform testing and assessment methods for these devices. Both organizations recognize the impact that requirements and testing methods for irrigation products will have on product performance, durability, and system design. Ultimately, this will enhance the performance of the entire irrigation system and lead to greater water conservation.

“ASABE and its members bring a long history of proven technical expertise and knowledge to the development of this new turf grass and landscape irrigation products standard,” said John Terry, chair of ICC’s Codes and Standards Council. “The effort is intended to complement and support the landscape irrigation provisions found in ICC’s 2012 International Green Construction Code, as well as numerous state and local codes and regulations.”

“Both ICC and ASABE are known for their technical integrity and are committed to setting an example to the industry and our respective memberships to reduce the impact that water waste has on the environment and our economy. We are both perfectly positioned to make a difference, especially as a team effort,” explained Darrin Drollinger, executive director of ASABE.

The standard is nearing release for public comment, providing an opportunity for any interested stakeholder to provide formal, written input on the draft document. Further, the meeting of the full Landscape Irrigation Emission Device Standard Committee was held on May 30 and 31 in Chicago. A formal meeting announcement can be found on the committee’s website at www.iccsafe.org/IS-IEDC. Interested parties are also welcome to participate in any or all of the three task groups for sprinklers, microirrigation devices, or definitions/labeling, as shown on the website. To participate in any of these activities, contact Shawn Martin at ICC. The ASABE staff contact for this project is Travis Tsunemori. These activities are all open to the public.

The American Society of Agricultural and Biological Engineers is a scientific and educational organization dedicated to the advancement of engineering applicable to agricultural, food, and biological systems. Founded in 1907 and headquartered in St. Joseph, Mich., ASABE comprises 9,000 members from more than 100 countries. ASABE members serve in industry, academia, and public service and are uniquely qualified to develop efficient and environmentally sensitive methods of producing food, fiber, timber, and renewable energy sources for an ever-increasing world population.

The International Code Council is a member-focused association dedicated to helping the building safety community and construction industry provide safe and sustainable construction through the development of codes and standards used in the design, build and compliance process. Most U.S. communities and many global markets choose the International Codes.
Soil erosion modeling: It’s getting better all the time

In Brief: ARS is about to release an updated Universal Soil Loss Equation that incorporates more intricate combinations of observation- and process-based science to produce the most accurate soil erosion estimates yet.

About 50 years ago, scientists at the USDA devised the Universal Soil Loss Equation (USLE), a formula that farmers could use to estimate losses from soil erosion. USDA scientists will soon release an updated version that integrates models generated by current computer technology, an updated soils database, and new findings about erosion processes.

The original USLE used five factors to estimate the tons of soil lost per acre per year from the impact of raindrops and the flow of runoff water across fields disturbed by plowing and tilling. The formula has become the basis for estimating soil erosion wherever land is disturbed by farming or other human activities.

Every conservation plan written by the USDA Natural Resources Conservation Service has been based on soil erosion calculations derived from USLE or its successors, the Revised Universal Soil Loss Equation (RUSLE) and version 2 (RUSLE2). Now research leader Seth Dabney, at the USDA-ARS Watershed Physical Processes Research Unit in Oxford, Mississippi, is putting the finishing touches on an update of RUSLE2, which uses more intricate combinations of observation-based and process-based science to produce soil erosion estimates.

New formulas have been added that can generate simulations of pasture plant lifecycles, which in turn can be used to estimate the effects that livestock and their different grazing patterns have on soil erosion. The revised equations can also produce estimates of how much plant residue can be removed from crop and pasture lands for ethanol production without exposing the soil to excessive erosion.

RUSLE2’s revised database contains information on climate and soil properties that affect erosion for the entire United States. The database also includes detailed descriptions of management systems that are organized nationally into 75 crop management zones. RUSLE2 can now also be used to predict runoff amounts and to develop a representative runoff event sequence that can be linked with a process-based channel erosion model.

For more information, contact Ann Perry, USDA Public Affairs Specialist, ann.perry@ars.usda.gov. More information about RUSLE2 can be found at www.ars.usda.gov/Research/docs.htm?docid=5971.

Ephemeral gullies, like the one above in a central Iowa field, often cause much erosion on farms. These gullies seem to disappear after tillage but then reappear during rain events. Photo by Lynn Betts, courtesy of USDA-ARS.
Bristol scientists produce world’s first magnetic soap

**In Brief:** A University of Bristol team has dissolved iron in liquid surfactant to create a soap that can be controlled by magnets. The discovery could be used to create cleaning products that can be removed after application, such as in the recovery of oil spills at sea.

Scientists at the University of Bristol, U.K., have developed a soap, composed of iron-rich salts dissolved in water, that responds to a magnetic field when placed in solution. The soap’s magnetic properties result from tiny iron-rich clumps within the watery solution. The generation of this property in a fully functional soap could calm concerns over the use of soaps in oil-spill cleanups and revolutionize industrial cleaning products.

Scientists have long been searching for a way to control soaps (or surfactants as they are known in industry) in solution, in particular to increase soaps’ ability to dissolve oils in water and then remove them from a system. The team at the University of Bristol previously worked on soaps sensitive to light, carbon dioxide, or changes in pH, temperature, or pressure. Their latest breakthrough is the world’s first soap sensitive to a magnetic field.

Ionic liquid surfactants, composed mostly of water with some transitional metal complexes (heavy metals, like iron, bound to halides, such as bromine or chlorine) have been suggested as potentially controllable by magnets for some time, but it had always been assumed that their metallic centers were too isolated within the solution, preventing the long-range interactions required to be magnetically active.

The team at Bristol, led by Professor Julian Eastoe, produced the magnetic soap by dissolving iron in a range of inert surfactant materials composed of chloride and bromide ions, similar to those found in everyday mouthwash or fabric conditioner. The addition of iron creates metallic centers within the soap particles.

To test the soap’s properties, the team introduced a permanent magnet into a test tube that contained the new soap beneath a less dense organic solution. When the magnet was introduced, the iron-rich soap overcame both gravity and surface tension to levitate through the organic solvent and reach the source of the magnetic energy, proving the soap’s magnetic properties.

Once the surfactant was developed and shown to be magnetic, Professor Eastoe’s team took it to the Institut Laue-Langevin (ILL) in Grenoble, France, a leading center for neutron science and home to the world’s most intense neutron sources in the world, feeding beams of neutrons to a suite of 40 high-performance instruments that are constantly upgraded.

This research also used facilities provided though the University of Bristol’s industry collaboration, the Krüss Surface Science Centre (KSSC). Krüss GmbH is a German manufacturer of instrumentation for surface science analysis. This facility is hosted in the School of Chemistry at the University of Bristol and provides access to state-of-the-art equipment as well as training and support for researchers in the university (www.kruss.de/en/home.html).

For more information, contact Hannah Johnson, Public Relations Office, Communications Division, University of Bristol, U.K., hannah.johnson@bristol.ac.uk.

Dr. Isabelle Grillo, head of the chemistry laboratories at ILL said: “The particles of surfactant in solution are too small to see using light but are easily revealed by neutron scattering, which we use to investigate the structure and behavior of all types of materials at the atomic and molecular scale.”

The potential applications of magnetic surfactants are huge. Their responsiveness to external stimuli allows a range of properties, such as their electrical conductivity, melting point, the size and shape of aggregates, and water solubility, to be altered with a simple magnetic on and off switch. Traditionally, these factors, which are key to the effective application of soaps in a variety of industrial settings, could only be controlled by adding an electric charge or changing the pH, temperature, or pressure of the system, all changes that irreversibly alter the system and cost money to remediate.

The soap’s magnetic properties also makes it easier to collect and remove from a system once it has done its job, suggesting further applications in environmental cleanup and water treatment. Scientific experiments that require precise control of liquid droplets could also be made easier with the addition of this surfactant and a magnetic field.

As Professor Eastoe said, “Most magnets are metals, so from a purely scientific point of view, these ionic liquid surfactants are highly unusual, making them a particularly interesting discovery. From a commercial point of view, although these exact liquids aren’t yet ready to appear in any household product, by proving that magnetic soaps can be developed, future work can reproduce the same phenomena in more commercially viable liquids for a range of applications, from water treatment to industrial cleaning products.”

Peter Dowding, an industrial chemist not involved in the research, added: “Any system that acts only when responding to an outside stimulus that has no effect on the system’s composition is a major breakthrough, because you can create products that only work when they are needed. Also, the ability to remove the surfactant after it has been added widens the potential applications to environmentally sensitive areas like oil spill cleanups, where concerns have been raised in the past.”

The Institut Laue-Langevin (ILL) is an international research center based in Grenoble, France. ILL operates one of the most intense neutron sources in the world, feeding beams of neutrons to a suite of 40 high-performance instruments that are constantly upgraded.

The research was supported by the EPSRC-funded ecoClean national center for PhD training and was part of the University of Bristol’s £3.5 million upgrade of the surface science research at the University of Bristol. For more information, contact Dr. Isabelle Grillo, Head of Chemistry, Chemistry Laboratories, Institute of Physical Chemistry, Université de Grenoble, 38041 Grenoble, France.
Floating robots use GPS-enabled smartphones to track water flow

In Brief: A fleet of 100 floating robots took a trip down the Sacramento River in a field test organized by engineers at the University of California, Berkeley. The smartphone-equipped floating robots demonstrated the next generation of water monitoring technology, promising to transform the way government agencies monitor one of the state’s most precious resources.

The Floating Sensor Network project, led by associate professor Alexandre Bayen, a researcher at the Center for Information Technology Research in the Interest of Society (CITRIS), offers a network of mobile sensors that can be deployed rapidly to provide real-time, high-resolution data in hard-to-map waterways. One area that stands to benefit from this technology is the Sacramento-San Joaquin River delta, with its complex network of channels that direct drinking water to two-thirds of California’s population and irrigation water for 1.2 million ha (3 million acres) of agriculture.

A high volume of sensors moving through the water can shed light on processes that are influenced by how water moves, such as the spread of pollutants, the migration of salmon, or how saltwater and freshwater mix in the delta’s ecosystem, the researchers said. The field test gave researchers a picture of how water moves through a junction in the river with a resolution never before achieved.

“We are putting water online,” said Bayen, who holds joint appointments in UC Berkeley’s department of electrical engineering and computer sciences and department of civil and environmental engineering. “Monitoring the state’s water supply is critical for the general public, water researchers, and government agencies, which now rely on costly fixed water sensor stations that don’t always generate sufficient data for modeling and prediction. The mobile probes we are using could potentially expand coverage in the delta—on demand—to hundreds of miles of natural and manmade channels that are currently under-monitored, and help agencies responsible for managing the state’s limited water supply.”

Such a flexible system could be critical in the event of an emergency, including a levee breach or oil spill, the researchers noted. The sensors could be thrown into action from a dock, shore, boats, or even helicopters.

“If something spills in the water, if there’s a contaminant, you need to know where it is now, you need to know where it’s going, you need to know where it will be later on,” said Andrew Tinka, the lead graduate student on the project. “The Floating Sensor Network project can help by tracking water flow at a level of detail not currently possible.”

The launch in Walnut Grove, Calif., marked a milestone in the project, which is supported by CITRIS and the Lawrence Berkeley National Laboratory. It was the first time researchers deployed their full arsenal of floats, each equipped with GPS-enabled mobile phones encased in 30 cm (12 in.) long water-tight capsules marked with fluorescent tape. The researchers wrote specific programs to run on the open-source platforms used in the robots and on the smartphones.

The project is an evolution of earlier research led by Bayen called Mobile Century and Mobile Millennium, which used GPS-enabled smartphones to monitor traffic flow. Instead of a map of traffic, the mobile phones in the Floating Sensor Network created a map of water flow.

Every few seconds, the phones in the floats transmitted location data back to servers at Berkeley Lab’s National Energy Research Scientific Computing Center (NERSC), where the data were assimilated using a computer model called REALM (River, Estuary, and Land Model). The information was processed to create a map that allowed researchers to track the devices on computer monitors.

“Not only is this project interesting from a data collection perspective, but it also presents a new challenge for us on the data processing side,” said Shane Canon, head of the Technology Integration Group at NERSC. “While the total amount of data is not unusual, the streaming rate is higher than we usually see, and the researchers are looking to access the data in near real-time.”
The REALM model was developed by researchers at the Berkeley Lab and the California Department of Water Resources. It was later expanded to integrate data from mobile robots by Qingfang Wu, a UC Berkeley graduate student in civil and environmental engineering.

“Part of the novelty of this project is the use of the NERSC computer cluster to run large-scale data assimilation problems,” said Wu. “The floating sensor project demands the ability to process hundreds of parallel versions of REALM and integrate the results into an estimate of the hydrodynamics of the delta.”

Although the sensors in the test were set up to monitor the speed of water currents, the researchers said the floats could be equipped with sensors for a variety of measurements, including temperature, salinity, or a contaminant of interest.

Of the 100 floats in the fleet, 40 were autonomous devices fitted with propellers to help them move around obstacles or targeted areas. “The major constraint on floating sensors in inland environments is their tendency to get stuck on the shores,” said Tinka. “Currently, using floating sensors requires close human supervision. We are developing autonomous, actuated sensors that can use propulsion to avoid obstacles.”

The Floating Sensor Network’s fleet of robots includes prototypes with advanced capabilities, including models that can dive below the surface of the water, versions equipped with salinity sensors to measure water quality in rivers, and versions with depth sensors that can map the shape of the channels in which they float.

“Our development efforts show the versatility of this technology and how it can adapt to the challenges faced in different applications,” said Bayen. “For example, the capability to measure depth is particularly important in situations where it is impractical or dangerous to send personnel to do the job, such as in combat zones. Floating sensor fleets also provide capabilities that can be used to improve our understanding of the shape of domestic rivers and deltas.”

The floating sensor network has been tested in collaboration with the U.S. Department of Homeland Security and the U.S. Army Corps of Engineers to assess water discharge downstream from broken levees. The researchers are also planning a deployment to monitor the ecosystem of Lake Tahoe in the coming months.

The floats are retrieved at the end of experiments, but the researchers acknowledged the possibility that devices can get lost. The researchers said they expect the expense of individual sensors to go down with continuing advances in mobile communications so that the system can better tolerate a certain level of device dropout.

“In the future, cost and size will go down, while performance and autonomy will go up, enabling monitoring at unprecedented scales,” said Bayen. “We expect this to become an invaluable tool for the future management of a critical resource in this state and around the world.”

For more information, contact Sarah Yang, UC Berkeley News Center, scyang@berkeley.edu. For a Youtube account and pictures, log on to http://newscenter.berkeley.edu/2012/05/09/floating-sensors-track-delta-water-flow/.
**Precision rain for precision irrigation**

*In Brief:* Many of Australia’s wine-producing regions may soon have a way of reducing salt in their products. Scientists Rob Stevens and Tim Pitt from the South Australian Research and Development Institute (SARDI) are investigating ways of making better use of rainfall to flush salt from soils.

Supplementary irrigation using saline groundwater can add upwards of a metric ton of salt for every million liters applied. In the past, too much salt in the soil has led to too much salt in the fruit and subsequently reduced wine quality.

“We’ve found that in vineyards suffering this damage, the salt tended to accumulate in the soil under the vines, but the soil in the mid-row remained salt free,” Rob Stevens said. “With supplementary irrigation, rainfall flushes the salts. If soils are too salty, then they are not exposed to enough rain.”

Two years ago, the SARDI scientists set up a proof-of-concept field trial to test whether re-directing rain falling on the mid-row to the soil under the vine could reduce salt in the vine. The SARDI research is now in its second season, and analysis of leaves in late spring has shown, for a second year in a row, that redirecting rainfall reduces salt levels by up to 30 percent.

“In addition,” Stevens said, “Analyses of data from the last harvest showed that redirecting rainfall had no effect on either yield or traditional measures of fruit quality, except that it reduced sodium concentrations in grape juice by up to 20 percent.”

This method of salt management under supplementary precision irrigation is also applicable to other perennial horticultural crops.

For more information, contact Terry Price, SARDI Marketing and Communications, terry.price@sa.gov.au, or visit www.sardi.sa.gov.au.

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**Nanotechnology may damage plant DNA**

*In Brief:* Incorporating nanotechnology into biotechnology for crop breeding hit a snag recently. Scientists at the National Institute of Standards and Technology (NIST) and the University of Massachusetts (UMass) at Amherst recently discovered that engineered nanoparticles can accumulate within plants and damage their DNA.

Chemists have been successful at crafting three-dimensional molecular structures, a breakthrough that unites biotechnology and nanotechnology. Scientists believe that nanoparticles can serve as “magic bullets” containing herbicides, chemicals, or genes that target particular plant parts to release their content. Nanocapsules can enable effective penetration of herbicides through cuticles and tissues, allowing slow, constant release of active substances.

However, the NIST/UMass research team showed that, under laboratory conditions, cupric oxide nanoparticles have the capacity to enter plant root cells and generate many mutagenic DNA base lesions. This is a problem because cupric oxide is an oxidizing agent. Oxidation has been shown to induce DNA damage in certain organisms.

Researchers first exposed radishes and two ryegrasses to both cupric oxide nanoparticles and larger-sized cupric oxide particles (bigger than 100 nanometers) as well as to simple copper ions. For the radishes, twice as many lesions were induced in plants exposed to nanoparticles as in those exposed to the larger particles. Additionally, the cellular uptake of copper from the nanoparticles was significantly greater than the uptake of copper from the larger particles. The DNA damage profiles for the ryegrasses differed from the radish profiles, indicating that nanoparticle-induced DNA damage is dependent on plant species and nanoparticle concentration.

For more information, contact Colleen Scherer, managing editor, AgProfessional, csherer@vancepublishing.com. ©2012 Vance Publishing Corp.
Polymer from brown algae may replace harmful solvents in batteries

In Brief: By looking to Mother Nature for solutions, researchers have identified a promising new binder material for lithium-ion battery electrodes that could boost energy storage and eliminate the use of toxic compounds currently used in manufacturing these components.

Known as alginate, the material is extracted from common, fast-growing brown algae. In tests so far, it has helped boost the energy storage and output for the graphite-based electrodes used in existing batteries and for the silicon-based electrodes being developed for future generations of batteries.

The research—a collaboration between scientists and engineers at the Georgia Institute of Technology and Clemson University—was supported by the two universities as well as by a Honda Initiation Grant and a grant from NASA.

“Making less-expensive batteries that can store more energy and last longer with the help of alginate could have a large and long-lasting impact,” said Gleb Yushin, assistant professor in Georgia Tech’s School of Materials Science and Engineering.

These batteries could contribute to a more energy-efficient economy with extended-range electric cars, as well as cell phones and notebook computers that run longer on battery power—all with environmentally friendly manufacturing technologies.”

Working with Igor Luzinov, a professor in Clemson’s School of Materials Science and Engineering, the scientists looked at ways to improve binder materials in batteries. The binder is a critical component that holds the silicon or graphite particles that actively interact with the electrolyte to provide battery power.

“We specifically looked at materials that had evolved in natural systems, such as aquatic plants, which grow in salt water with a high concentration of ions,” said Luzinov. “Since electrodes in batteries are immersed in a liquid electrolyte, we felt that aquatic plants—in particular, plants growing in such an aggressive environment as salt water—would be excellent candidates for natural binders.”

Finding just the right material is an important step toward improving the performance of lithium-ion batteries, which are essential to a broad range of applications, from cars to cell phones. The popular and lightweight batteries work by transferring lithium ions between two electrodes—a cathode and an anode—through a liquid electrolyte. The more efficiently the ions can enter the two electrodes during charge and discharge cycles, the larger the battery’s capacity will be.

Existing lithium-ion batteries rely on anodes made from graphite, a form of carbon. Silicon-based anodes theoretically offer as much as a ten-fold capacity improvement over graphite anodes, but silicon-based anodes have so far not been stable enough for practical use.

Among the challenges for binder materials are that the anodes must allow for the expansion and contraction of the silicon nanoparticles, and that existing electrodes use a polyvinylidene fluoride binder manufactured using a toxic solvent.

Alginates—low-cost materials that are already used in foods, pharmaceutical products, paper, and other applications—are attractive because of their uniformly distributed carboxylic groups. Other materials, such as carboxymethyl cellulose, can be processed to include the carboxylic groups, but that adds to their cost and does not provide the naturally uniform distribution of alginates.

The alginate is extracted from the seaweed through a simple soda (Na₂CO₃) based process that generates a uniform material. The anodes can then be produced through an environmentally friendly process that uses a water-based slurry to suspend the silicon or graphite nanoparticles. The new alginate electrodes are compatible with existing production techniques and can be integrated into existing battery designs, Yushin said.

The use of alginate may help address one of the most difficult problems limiting the use of high-energy silicon anodes. When batteries begin operating, decomposition of the lithium-ion electrolyte forms a solid electrolyte interface (SEI) on the surface of the anode. The SEI must be stable, allow lithium ions to pass through it, and yet restrict the flow of fresh electrolyte.

With graphite particles, whose volume does not change, the SEI remains stable. However, because the volume of silicon nanoparticles changes during operation of the battery, cracks can form and allow additional electrolyte decomposition until the pores that allow ion flow become clogged, causing battery failure. Alginate binds the silicon nanoparticles to each other and to the metal foil of the anode, and it coats the silicon nanoparticles and provides a strong support for the SEI, preventing degradation.

Thus far, the researchers have demonstrated that alginate can produce battery anodes with reversible capacity eight times greater than that of today’s best graphite electrodes. The anode also demonstrates a coulombic efficiency approaching 100 percent and has been operated through more than 1,000 charge-discharge cycles without failure.

For the future, the researchers hope to explore other alginites, boost the performance of their electrodes, and better understand how the material works.

Alginates are natural polysaccharides that help give brown algae the ability to produce strong stalks as much as 60 m in length. The seaweed grows in vast forests in the ocean and can be farmed in wastewater ponds.

“Brown algae is rich in alginates and is one of the fastest growing plants on the planet,” said Luzinov. “This is a case in which we found all of the necessary attributes in one place: a material that will improve battery performance, that is relatively fast and inexpensive to produce, and that is considerably safer than some of the materials that are being used now.”

For more information, contact John Toon, jtoon@gatech.edu; Abby Robinson, abby@innovate.gatech.edu; or Tom Hallman, thallma@clemson.edu.

RESOURCE

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MSU to begin work on energy-producing anaerobic digester

In Brief: Michigan State University (MSU) is poised to begin work on a new anaerobic digester, a system that will re-use waste from MSU’s farms and dining halls and create energy for on-campus buildings.

The MSU Board of Trustees authorized the university administration to begin work on the project, an approximately $5 million venture that should pay for itself in less than 15 years. When it is completed, probably in the summer of 2013, the system will provide a source of renewable energy that will produce electricity for several of the buildings south of the main MSU campus. It also will prevent organic waste produced at the university from going to landfills.

An anaerobic digester is a sealed tank in which organic waste is degraded, without oxygen, at an elevated temperature. This process causes the waste material to decompose quickly and produce methane, which can be captured and used as fuel.

“Once complete, this system will be the largest anaerobic digester on a college campus in the U.S.,” said Dana Kirk, a specialist from MSU’s Department of Biosystems and Agricultural Engineering, who is overseeing the project. “It will be the largest in volume and in energy output.”

Here is how it works: manure, food waste, and other organic matter are placed in the airtight tank, which will hold about 1,476,000 L (390,000 gal) of material. The tank’s contents are maintained at roughly 38°C (100°F) for 20 to 30 days. The organic material is decomposed by a group of naturally occurring microorganisms found in livestock manure. The result is biogas and a slurry of partially decomposed organic matter, water, and nutrients.

“Only about 20 percent of the energy produced is used to sustain the process,” Kirk said. “The other 80 percent is available for other uses.” In comparison, a smaller anaerobic digester already in use at MSU for research purposes uses nearly all of the biogas produced to run the system.

MSU’s Anaerobic Digestion and Research and Education Center, established with a grant from a southwest Michigan foundation, went into operation in 2008 and is used for academic and industrial research and education.

Presently, about 19,000 metric tons (21,000 tons) of manure and 1,360 metric tons (1,500 tons) of food waste are generated every year at MSU. This system will re-use a large amount of that waste. Any material left over from the digesting process will be used as fertilizer.

In addition, food waste from local sources outside of the university will be included in the system’s organic matter. “Anaerobic digestion has proven to be a feasible technology to convert waste to a resource while minimizing negative impacts on the environment,” said ASABE member Ajit Srivastava, chair of MSU’s Department of Biosystems and Agricultural Engineering.

For more information, contact Tom Oswald, Media Communications, tom.oswald@cabs.msu.edu, or Dana Kirk, Biosystems and Agricultural Engineering, kirkdana@anr.msu.edu.
NEBRASKA WATER CENTER DIRECTOR
UNIVERSITY OF NEBRASKA

The University of Nebraska is seeking a dynamic and creative leader to be the Director of the Nebraska Water Center in the Robert B. Daugherty Water for Food Institute (WFI) at the University of Nebraska. The Director will provide leadership for Water Center programs and will be part of WFI’s senior management team. The Directorship is a 12-month, full-time position, and faculty rank and tenure will be available to candidates with a terminal degree and appropriate academic accomplishments. However, faculty appointment is not essential for the successful candidate. Duties will include administering all programs of the Nebraska Water Center; catalyzing new research and education initiatives; leading communication campaigns; and interacting with water resource stakeholders. The successful candidate will also be expected to develop a research, extension, or teaching program in the Institute of Agriculture and Natural Resources that complements the mission of the Nebraska Water Center.

To succeed in this position you will need an advanced degree, preferably a Ph. D., in a relevant discipline, including but not limited to agricultural, environmental, or water resources science; engineering; law; or policy. Preference will be given to candidates with knowledge and experience related to managing water resources at both state and regional levels; demonstrated management, organizational, and interpersonal skills; and excellent verbal and written communication skills. The position will require travel.

The Nebraska Water Center is part of a national network of Water Resources Research Institutes serving Nebraskans and the nation. The Center implements and facilitates water and water-related research, extension, teaching and public outreach programming within the University of Nebraska system. The Nebraska Water Center recently became part of the Water for Food Institute which was established in 2010 with a $50 million founding gift commitment from the Robert B. Daugherty Charitable Foundation. The WFI will conduct research, policy analysis and educational programs on the efficiency and sustainability of water use in agriculture, the quantity and quality of water resources, and the human issues that affect the water decision-making process. Additional information on the position and the University of Nebraska can be found at: http://waterforfood.nebraska.edu, http://watercenter.unl.edu and http://unl.edu/.

To apply for this position, access the web site: http://employment.unl.edu, search for requisition number 120142, and complete the faculty academic administrative information form. Attach a 1-2 page letter of application detailing your relevant experience and how it fits with the vision of the Nebraska Water Center, curriculum vitae, and contact information for three professional references that must include mailing address, phone number, and e-mail address. Review of applications will begin June 22, 2012 and will continue until the position is filled or the search is closed.

The University of Nebraska has an active National Science Foundation ADVANCE gender equity program, and is committed to a pluralistic campus community through affirmative action, equal opportunity, work-life balance, and dual careers.

WASHINGTON STATE UNIVERSITY
CROP PHYSIOLOGY

WSU-Crop and Soil Sciences is seeking to fill a 9-month, 80% Research-20% Academic Programs tenure-track position at the assistant or associate professor rank based on background and qualifications. Develop an internationally recognized research program in crop physiology with a focus on fundamental aspects of cereal crop responses to biotic or abiotic environmental stress, to nitrogen, and/or to factors that improve yield and teach graduate and undergraduate courses in crop plant physiology and actively contribute to student recruitment and retention. This is part of a cluster hire initiative intended to contribute to the development of crop plants and crop management systems that support highly productive agriculture within challenging and dynamic environments. Required: Ph.D. in crop science, plant biology, plant physiology, crop physiology, plant biophysics or related field and an academic record and experience sufficient to achieve tenure, if applying for associate professor rank; outstanding record of publishing in peer-reviewed journals commensurate with career level; and demonstrated ability to collaborate with other scientists. Preferred: outstanding communication skills, both written and verbal; demonstrated working knowledge of molecular biology, genetics and/or genomics; demonstrated record of competitive grant success commensurate with career level; demonstrated knowledge and ability to work effectively with individuals and groups of diverse cultures, backgrounds, and ideologies. Screening: 8/15/2012. To apply, visit https://www.wsujobs.com. Submit a letter of application addressing all listed qualifications and include your research interests as well as a statement of vision for teaching, a current CV, copies of official graduate transcripts, and provide the names and contact information of four people willing to serve as references. Direct questions about the position to Dr. Michael M. Neff, mmneff@wsu.edu, 509-335-7705. EEO/AA/ADA.
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http://www.asabe.org/resource/index.html
M ost agricultural engineers, including yours truly, enjoy working with statistics about as much as undergoing a root canal. This statistical aversion starts early in our careers. For example, at every doctoral student’s dissertation defense, there’s always that unobtrusive statistician seated in the middle of room, who keeps silent until the data slides appear. Meanwhile, the student feels comfortable, since the committee seems to appreciate the slides in which the instrumentation, algorithms, and software are discussed. But with the appearance of the data, it’s time for the statistician to rant. He slams the experimental design (or lack thereof), he criticizes how the analysis was done, he gripes about the lack of skewness and kurtosis measures, and he condemns the improper testing, the lack of statistical power, the improper use of significance measures, and the conclusions based on small regression coefficients. The student is stunned, and in desperation looks to the rest of the committee for help, but the committee members are too busy trying to remember whatever statistics knowledge they still have on tap since they graduated themselves.

Engineers tend to make a mess of statistics. We do a poor job even in basic work like regression analysis, and often we don’t go beyond simple means and standard deviations. We report numbers with too many significant digits (often by converting from English to metric units) and without error margins, mostly because we either have only one rep or we don’t want to draw attention to imperfections in the data. This is inherent in our way of thinking: there is something irreconcilable between engineering and statistics. As engineers, we develop systems in which we try to control everything, and we measure phenomena as accurately as possible. Our mission in life is to beat errors into submission, not to embrace them! In college, we all took classes in linear differential equations, with their beautiful, smooth solutions. But now we have to make sense of a bunch of dots with a regression curve. Every time I look at a regression plot, I wonder: where did we go wrong and who is to blame?

That’s a bad habit, I know. Variability is the essence of nature, and I have been doing this kind of work for 20 years, so I should be able to accept the reality of it. But, alas, I can’t. I have many arguments with my colleagues in crop sciences, who are sometimes satisfied with a regression coefficient of 0.5. I tell them that they don’t understand half of the problem, and I usually get yelled at for that. This is another trait of engineers: we want to understand the whole thing. In fact, our designs require complete understanding before we can build a reliable artifact. Science, as it is pursued in crop sciences, is different. The crop sciences crowd seems to be content with understanding half of the problem. But maybe that’s a misconception on my part.

Before pursuing my doctorate, I used statistics in a “they tell me I have to so I will” kind of way. I vividly remember how hard it was to understand concepts in books whose titles always seemed to start with a misleading “Introduction to...”. Student’s t-test to compare means was about as far as I would go, and forget about anything multivariate. However, during my doctoral studies, I learned a little more about statistics. I worked on a sensor for granular mass flow measurement with Kate Crespi, a bio-statistician at UCLA. She took me to the cleaners many times when I tried, once again, to transform stochastic circles into deterministic squares. With Kate’s help (a lot of it, I might add), I realized that, to measure a granular mass flow accurately, it is essential to have a fully developed, Poisson-driven, random arrival process. In other words, make the biggest mess possible, and then the theory (and the measurement) actually works!

It seems to me that we only have a good grip on problems when they are either completely deterministic (Engineer-land) or completely stochastic (Stat-land), but what if they are somewhere in between? Fortunately, with the exception of self-organizing systems, if we leave a system alone, it tends to become more disorderly with time: just wait a while, and you’ll be drawn closer to Stat-land. This realization is not that intuitive, and it even baffled the editor of a prestigious journal, who rejected a paper that Kate and I wrote on the subject, with the comment that our data were “too good to be true.” This same paper received the Biosystems Engineering Outstanding Paper Award in 2010, which is awarded to one out of a hundred papers. In the end, this confirmed to me once more that data are much more valuable than any one person’s opinion.

After all these years, I still have not become a statistics fan, but at least I can appreciate the work of statisticians, and I have developed a détente with them. I hope this editorial can convince some engineers that statisticians are like cactuses. They can be very helpful when approached with care. Have you hugged your statistician today?

**Embracing Variability:** How to Hug a Cactus

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**RESOURCE**

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**ASABE member Tony Grift**, associate professor, Department of Agricultural and Biological Engineering, University of Illinois, Urbana-Champaign, USA; grift@illinois.edu.
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