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RESOURCE

Engineering & Technology for a Sustainable World



The Farm of the Future

PUBLISHED BY ASABE – AMERICAN SOCIETY OF AGRICULTURAL AND BIOLOGICAL ENGINEERS

ASABE and the Future



This issue of *Resource* is about the future of agriculture, so let's talk about the future of ASABE. Universities have adapted extremely well to the changes that have happened in industry, and the academic world has a very bright future. In particular, student enrollment is increasing in ag and bio engineering programs. That's

good news, because these bright young people are our future. However, if we do not attract them to our Society, then ASABE is doomed to extinction.

I mention this because we are not seeing a concomitant increase in our membership. To address this, ASABE needs to provide a value-added service to these students that will carry over into their careers, providing them with a reason to join ASABE and to continue their memberships. We must market our Society to attract this next generation of students. The broad and diverse discipline that we call agricultural and biological engineering is changing, and we must adapt, just as the academic world has adapted to changes in industry.

To this end, past-president Jim Dooley is working with the E-05 committee to develop the branding message for ASABE that will move us forward and carry us into the future. At our recent Board of Trustees meeting, there were several unofficial discussions on this subject. For example, past-president Bob Gustafson defined us as "engineers who deal with agricultural and biological systems." Trustee Chad Yagow suggested that our society is "the pre-eminent resource concerning expertise in food, fiber, water, and

renewable energy resources." Ultimately, how we brand ourselves needs input from you, the member. What do you think ASABE is, or should be?

If we position ourselves properly, then our future is bright. As the world continues to demand more from the earth's limited resources, we have a huge challenge, and a huge opportunity. A recent issue of *Friday Notes*, published by the Council for Agricultural Science and Technology (info@cast-science.org), contained an article about the future. Here is an excerpt:

"The global nature of agriculture is not in the future, it is now, and the sub-continent nation of India may be the best example of this. During the next two decades, India will become the most populous country, and that means consumer markets will continue to grow and agricultural conditions in India will have major implications for the world. Forecasts show that India will surpass China in population sometime near the 2030 mark when it reaches nearly one and a half billion residents. Those millions need to eat ..."

... and they will need shelter, water, and energy. ASABE has a major role to play as our world continues to grow. The students who are graduating from our universities will become the innovators who define the future. How will ASABE serve them, and how will we support their work?

In the meantime, don't forget about our "Just One" campaign. It's an easy way to help our Society grow now to meet the demands of the future.

Ronald L. McAllister
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events calendar

ASABE CONFERENCES AND INTERNATIONAL MEETINGS

To receive more information about ASABE conferences and meetings, call ASABE at (800) 371-2723 or e-mail mtgs@asabe.org.

2011

- Jan. 5-7 **Agricultural Equipment Technology Conference.** Held in conjunction with AgConnect Expo 2011. Atlanta, Georgia, USA.
- Aug. 7-10 **ASABE Annual International Meeting.** Louisville, Kentucky, USA.
- Sept. 18-21 **International Symposium on Erosion and Landscape Evolution Conference.** Joint conference with AEG. Anchorage, Alaska, USA.

ASABE ENDORSED EVENTS

2011

- March 2-4 **NFBA Frame Building Expo.** Indianapolis, Indiana, USA. Contact Dan Weinstock, dweinstock@nfba.org.
- March 14-16 **BioPro Expo.** Atlanta, Georgia, USA. Visit www.bioproexpo.org.
- April 18-20 **6th CIGR Section VI International Symposium: Towards a Sustainable Food Chain.** Nantes, France. Contact Da-Wen Sun, dawen.sun@ucd.ie.
- Oct. 8-12 **2011 GSA Annual Meeting—Archean to Anthropocene.** Minneapolis, Minnesota, USA.

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ON THE COVER

Author and illustrator Simon Blackmore envisioned and designed a future farm machine, called "Scamp," for AGCO. On the cover, Scamp is weeding, and on this contents page, Scamp is shown at right (top to bottom) seeding, harvesting, and scouting.

ERRATA

In the November/December 2010 issue, the cover photo was incorrectly attributed to Paul J. Funk. It was taken by Tye L. Lightfoot, supervisory engineering technician, USDA-ARS Southwestern Cotton Ginning Research Laboratory, Mesilla Park, N.M. The Visual Challenge photos on page 21 were submitted by A.J. Both. His name mistakenly printed as A.J. Booth. *Resource* regrets the errors.



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The Farm of the Future

In my home country of The Netherlands, we have an expression: “One fool may ask more questions than ten wise men can answer.” Questions regarding the future of agriculture are so broad, and concern such complex issues, that no single person, no matter how wise, can grasp them all. Since I have always regarded answers containing the words “trust,” “faith,” or “hope” as rather unsatisfying, I wondered if I could simply ask people who possess some factual knowledge to offer their opinions on this broad topic.

I was somewhat surprised that people wiser than I are not that hard to find. This did not surprise my wife, which, in turn, did not surprise me. Fortunately, most of the wise men and women in our agricultural global village were happy to respond to my request. I sensed some mild hesitation from several of my techie colleagues, because ag engineers are modest about their knowledge, but after some gentle persuasion they all delivered. The question that I asked them was simple: “Please share your perceived view regarding the role of agriculture in the world in the future.” Their answers resulted in the issue you are currently reading.

Early humans morphed from widely scattered hunter/gatherers into settled social creatures. Discovering the secret of converting grain into beer probably facilitated that transition. Subsequently, farming has provided food, clothing, energy, and building materials for eons, an honorable profession indeed! However, nowadays, we seem to be taking our food, and by association its producers, for granted. In fact, the young generation of Future Farmers of America prefers to no longer be known by that name. It is sad that these kids feel the need to defend themselves against a perceived stigma surrounding farming. In addition, quite a few university ag departments have removed the word “Agricultural” from their names. Outside of our profession, how many people know who Norm Borlaug was and what the Green Revolution accomplished? And this indifference to agriculture is happening in a country where people will drive four hours to get their hands on a McRib sandwich, where small-town grocery stores stock fresh produce from around the world, and where obesity has surpassed smoking as the main cause of preventable death.

America’s obsession with food should logically imply that its producers would be revered, respected, and at the center of public attention. They are not, of course, and perhaps this is because

farming also has another face. Agriculture is largely responsible for a 6,000-square-mile hypoxic zone in the Gulf of Mexico due to agrochemical runoff from the Mississippi Basin. This same region produces huge amounts of corn-based ethanol, which consumes massive amounts of aquifer-borne water. The resulting industry thrives only by virtue of a \$7 billion annual subsidy, and whether corn ethanol is net energy positive is still under debate.

As a society, we have chosen to accept these levels of pollution and inefficiency because they seem congruent with our high standard of living, and because many of us are simply unaware of the real costs. However, if we expect to maintain our quality of life, then change is needed. We have made our agricultural system work, but not necessarily efficiently, and without putting a realistic price on the required ecological resources. In addition, we need to respond to serious looming challenges, such as climate change, the water crisis, the end of oil, and global population growth.

If we have become complacent, then understandably so. Technology has elevated our standard of living to unprecedented levels, and this quality of life is so well established that it feels permanent. For most of us, overabundance of food is a bigger health threat than food scarcity, and few of us have a direct connection to the land. Today, more Americans live on golf courses than live on farms.

But the costs to the planet, and to our fossil fuel supply, have been great. Can we expect technology to save the day, yet again, without that once inexhaustible supply of black gold? Will agriculture be able to produce enough food and fuel to sustain ten billion people in 2050? Are bio-energy crops the answer to fossil fuel depletion? Should we encourage development of solar, wind, and water energy, or should we put our trust in more exotic solutions like ITER, the attempt to create sustained nuclear fusion? So many questions, and no oracle in sight.

In the meantime, the authors in this issue will shed some light on the future of what *Resource* readers hold dear: agriculture in all its shapes and forms. I am in great debt to these authors for their wise and informed submissions, and my special thanks go out to the ASABE editorial staff—Sue Mitrovich, Glenn Laing, and Melissa Miller—for their outstanding work.

Enjoy!



Tony Grift, Guest Editor

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Farms of the Future in Revitalized Rural Communities

By Tom Vilsack

The Obama Administration and the USDA are committed to building a strong agricultural economy to support our producers and their work to provide a reliable, affordable, safe, and abundant food supply for Americans.

But the dynamics are changing. In the past 40 years, the United States has lost more than one million farmers and ranchers. We have a “disappearing middle”—meaning that most of our farms are either very large or have annual profits of less than \$2,500. Fewer than half of our nation’s farmers and ranchers list farming as their primary occupation. Less and less family farm income comes from farming.

That is why, even as we work to maintain a strong farm safety net for operations of all sizes, we are also working to build “farms of the future” that are more productive than ever, with access to new income sources. And we are working to build a thriving companion economy to complement production agriculture in rural America.

In addition to agricultural production, the farm of the future must produce renewable energy to fuel our transportation system and provide electricity to our homes and factories. The USDA is working to create a diverse renewable energy economy that functions in every corner of the nation. We are helping to develop private businesses that use innovative technologies like solar, wind, biofuels, biomass, methane, and geothermal energy generation. Small towns across the nation will be home to biofuel plants. And we will create good jobs that can’t be exported.

Farms of the future must have better access to both domestic and international markets. Last year, the USDA launched “Know Your Farmer, Know Your Food” to promote local and regional food systems.

Farms of all sizes should be able to access processing, distribution, shipping, and sales in their region, to sell directly to consumers or to large institutional buyers. At the same time, we are working to expand export markets so that we can continue to provide high-quality agricultural products to nations around the world. Increased broadband internet access will help facilitate access to these markets while also providing producers with up-to-the-minute commodity and weather information to make the best decisions for their operations.

Emerging technologies hold the promise ...

Investing in research will also play a critical role in our efforts to help build a stronger agricultural economy. We will help advance biotech products that better tolerate drought, toxicity, disease, pests, and salinity. And we will continue to produce high yields while limiting inputs, moving toward a more sustainable American agricultural economy. Much of this technology will have an even greater impact for the world’s poorest farmers.

The USDA’s 2011 research budget reflects this commitment, requesting an increase of nearly \$40 million over the enacted 2010 budget. And we are working to transform our in-house and external research programs. Using the National Institute of Food and Agriculture as a kind of research startup company, we will rebuild our competitive grants program from the ground up to focus on priority areas that generate real results.

For example, the USDA works to promote agricultural biotechnology—with and without genetic engi-

neering—because it’s a powerful tool that can boost agricultural productivity and build prosperity for producers around the world. Emerging technologies hold the promise of creating crops that tolerate drought, toxicity, disease, and salinity. Over the last few decades, new biotech varieties of corn have dramatically reduced the need for chemical inputs of herbicide and insecticide, and there is more progress to be made.

The USDA is working toward the day when farmers and landowners are rewarded for taking care of the environment. Markets for water, wetlands preservation, carbon, and habitat enhancements will expand to offer new income and investment opportunities for the farms of the future. Our research programs are working to quantify the environmental benefits of natural resource management—building the capacity, analytical tools, and metrics necessary to creating accurate and verifiable markets for ecosystem and conservation. We recently ramped up our Ecosystem Markets Office to help farmers and investors take full advantage of these opportunities.

Over the last 70 years, the average American farmer has gone from feeding about 20 people to feeding about 155. The USDA wants to improve on this incredible productivity and strengthen farm income by investing to ensure that American farms of the future remain world leaders in providing a reliable, affordable, safe, and abundant food supply. When we are successful in our efforts, we will have also built a thriving economy in rural America, so that the farms of the future—and rural America in general—remain the best places in this nation to live, work, and raise a family.

Tom Vilsack is the current U.S. Secretary of Agriculture.



The European Farm of Tomorrow

By Simon Blackmore and Katerina Apostolidi

Farming in the European Union has become more complicated than it used to be. The social demand for environmentally friendly farming resulted in the new Common Agricultural Policy (CAP), which, despite significant variations in each EU member state, requires that farmers are subsidized based on their compliance with regulations and standards. The volume of their production is no longer a criterion.

In addition to the common EU regulations, each member state has its own regulations, and even a local jurisdiction can impose rules concerning farming. The same is true for the different standards and guidelines, which then require cross-compliance between them. How can a farmer be compliant with all these rules in order to receive subsidy support? How can a farmer even find out what the rules are?

FutureFarm is an EU project that addresses this problem, among others. FutureFarm is an EU-funded three-year research project (2008-2010), involving 15 partners from ten EU countries. The project consortium has proposed that the integration of information and communication technologies (ICT) in European farming is a key requirement that will allow European farmers to gather, analyze, report, and utilize the data coming from inside as well as outside their farms.

Modern farms already use ICT, don't they? Yes, but it's not fully integrated with both on-farm data and off-farm guidelines. On a modern farm, there is software for sensors, software for controlling the tractor, and software for production forecasting, but of course, no software for rule compliance. FutureFarm's main goal is to find a common language between all these pieces of software, so that they can exchange information with each other.

FMIS and EU standards

To achieve this goal, FutureFarm has proposed the Farm Management Information System (FMIS) as a core component. The FMIS can provide whole-farm management by integrating data collection, operations scheduling, record keeping, and all other management functions into a single, comprehensive system. The FMIS will also provide information to farmers about applicable regulations and standards.

Scientists working for FutureFarm have allocated significant effort to translate rules and regulations within the EU (at both the local and EU level) from plain text into a machine-readable format, so that the rules can be shared across platforms and integrated into the FMIS. Specifically, the researchers have defined how the information should be structured and stored electronically, the information architecture of the FMIS, the architecture of the published rules, and the communication between them. The working prototype was presented at the most recent Agritechnica trade fair in Germany and can be viewed at <http://test.futurefarm.eu>. This

prototype is open source, so that anyone interested can use it.

Other important aspects

FutureFarm has addressed a number of other important aspects regarding the application of ICT in agriculture. A specification for the ideal farm portal has already been produced, and a prototype is under development. The development process includes feedback from farmers and other stakeholders.

A survey of farmers' assessment of information systems and precision farming has also been conducted. This survey covers Denmark, Greece, Finland, and

Germany and addresses such issues as the amount of time that farmers spend on administrative tasks (paperwork, meetings, etc.), their adoption of precision farming techniques, their use of automated systems, and their attitude toward information systems.

What about robotics?

The FutureFarm project has investigated some aspects of robotics, too. The question posed was whether centralized management of robots would improve the economic efficiency of a farm. The result was that, by adopting specific fleet-management algorithms and techniques, significant savings could be achieved.

The vision of robots working on a farm is not too far into the future. In July 2009, the FutureFarm project demonstrated this by sponsoring the Robot Field Event in The Netherlands, which brought in agricultural robots from Denmark, Germany, and the United Kingdom to show what they could do.

In addition to the topics already mentioned, the FutureFarm project has addressed broad issues of development, including public awareness, compliance with recognized management standards, socio-economic impacts, energy efficiency, and biofuels. The resulting technology will take the already extensive experience in precision farming research and integrate it into farmer-based prototype stems. The main outputs from the FutureFarm project are structured in the form of 55 deliverables from eight work packages, which are available at www.futurefarm.eu.



ASABE member Simon Blackmore is a professor at the Center for Research and Technology, Thessaly, Greece, and project manager of FutureFarm, www.FutureFarm.eu.

Katerina Apostolidi is the project administrator based at CERETETH in Greece.

Preserving Our Agricultural Capital

By Howard Buffett

For a business to survive, it must anticipate where it should be in the future, and it must adapt to changing demands. Agriculture is no different. If a business has shareholders, a farmer has soil. Without healthy, productive soil, you cannot collect any future dividends.

Over the past two centuries, we have lost 50 percent of our native soil's organic matter as a result of tillage-induced erosion—not a very good track record. However, we have also made great strides in production. We produce five times the amount of crops on 20 percent less land than we used in 1930. Additionally, we use 36 percent less fertilizer to grow corn than we used 30 years ago. If we tried to achieve today's production levels using 1950's technology, we would need to plow under six billion more acres!



Still, we can do better

We have new technology to increase our efficiency, but technology is only half the answer; we also need Mother Nature. Most of us know that crop rotations are better for soil health and pest control, even though rotations are not always economical. We also know that to average 300 bushels of corn per acre, part of our field must yield 400 bushels, even though that increased productivity has less desirable consequences.

In very simple terms, if we want to increase yields for the long term, we can-

not simply depend on bigger machines, better varieties, or stacked traits. I could farm for the rest of my life in central Illinois with little concern about productivity, but that is short-term thinking. The optimum production system must recognize nature's benefits by combining past lessons with future opportunities.

In addition to soil, water is our other form of agricultural capital. Since 40 percent of our agricultural production is a result of irrigation on 18 percent of our arable land, better water use is essential. Think of it this way: 18 percent of arable land represents about 2.4 million square miles, which is equal to the combined size of the nine countries that comprise the Amazon basin! Therefore, the option is not to reduce irrigation; to do so would require bringing an immense amount of land into production to compensate for lower yields. Instead, the answer is to use water more efficiently.

If all of the existing 20-year-old pivot systems were converted to new, low-pressure systems, we would conserve 167 trillion gallons of water each year—more than half of the current annual consumption for industrial and domestic uses combined. If this is true for pivot conversions, think of the huge savings that we would achieve by converting flood-irrigated acres to pivots.

A plan that focuses on simply increasing yields, while ignoring other factors, is not sustainable. We cannot farm as if certain pieces of the puzzle can be ignored. Instead, we must focus on systems. To maximize production while reducing our environmental footprint, we need to adapt our systems, and we can choose to do this now or eventually be forced to do it through regulations. And we must accept

that it is irresponsible to use technology simply as a convenience. We must focus on best practices, especially where technology has driven poor behavior or complacency.

A combination of solutions

Improved varieties, genetic breakthroughs, strip-till, no-till, cover crops, and multiple crop rotations combined with equipment efficiencies and innovations will provide many of the answers. But we also need to consider the benefits of biological approaches and synthetic inputs. The best systems will likely combine aspects from a variety of practices and philosophies.

If our focus remains primarily on how to attain top yields without investing in broader systems and soil and water conservation, then we will eventually file agroeconomic bankruptcy.

Speaking from experience

Having been to almost 100 countries, traversed many ecosystems, and met farmers who are net buyers of food and cannot even feed their own families, I have come to realize how privileged Americans are. However, privilege bears responsibility. We owe it to those who depend on our food assistance, as well as to those who will farm our land in the future, to leave them with the means to be successful.

By combining traditional farming lessons—using nature as a guide—with state-of-the-art technology, and by combining flexible thinking with the proper government policies, we can integrate the best of past, current, and future practices. **Our future dividends will be substantial, but only if we protect our agricultural capital.**

Howard Buffett is president of the Howard G. Buffett Foundation, Decatur, Ill., USA.

Photo: "Backseat," supplied by the Howard G. Buffett Foundation.



Out of the Rut

By Len Corzine

I see exciting times ahead for American agriculture because we have gotten out of the rut of traditional demand for our products. There are new demands and new opportunities to provide a wide variety of products from domestic, natural, and renewable sources. For example, we have learned that we can produce just about anything from corn and soybeans that we previously produced from petroleum. That's great news for our society and our environment. Plants, using photosynthesis to capture energy from the sun, can provide for more of our needs.



It all starts with the seed

With these new market opportunities, we have a need for increases in production. With corn in particular, we are seeing innovations in seed genetics and biotechnology. We also need to continue to improve our seeding technology. Seed placement and the quality of grain coming out of the field become more important as value and profit potential increase. This effort will involve plant and yield protection, too, to help seeds maximize their potential in both good and bad weather conditions.

Less must make more

What we are talking about is producing more with less. We are already developing tools to better utilize and protect the natural resources that we are blessed with in the United States. For example, from 1987 to 2007, U.S. corn farmers reduced their land use by 37 percent, soil loss by

69 percent, irrigated water use by 27 percent, energy use by 37 percent, and total emissions by 30 percent to produce each bushel of corn. This is a great story, and the news continues to get better.

Infrastructure must keep up

We have the resources for more efficient production than anywhere else on the planet. However, if we are to take advantage of our opportunities, American agriculture needs infrastructure development. The production capability is in place and increasing, but our infrastructure has not kept up. The markets for agricultural production are growing in the United States and around the world, and problems arise when we can't get our production to these markets efficiently.

The need begins at the farm gate. Grain elevators, once the pride of the prairie, are obsolete. Antiquated drying, conditioning, and handling systems have not kept pace with the demands of modern production. We need higher capacity systems, and I don't mean just the size of grain legs. There has been some success with container systems, but this technology needs continued development.

In addition, our roads have not had a major initiative since the Interstate Highway System in the 1950s. Since then, the beltways around major metropolitan areas have been the sole additions. Our railroad system actually regressed for a long time, from the 1960s through the 1990s, and it is now inadequate to meet our needs. And our river transportation system is in danger of collapse. We built extensive lock and dam systems in the 1930s with a life expectancy of 50 years. However, we have not been able to get the federal government to move forward, and now a major upgrade is 30 years past due.

The inaction of our government is unfortunate. A big advantage of U.S. industry has been our ability to get products to markets more efficiently than our competitors. With our deteriorating infrastructure, that advantage is slipping away.

On the bright side, infrastructure improvements would provide long-term job opportunities at a time when unemployment is the biggest weight on our unstable economy. In fact, we already have solutions for many of the challenges that we face, from managing production to marketing products. We also have opportunities for further innovation. In the future, I think these exciting challenges will draw more young engineering talent into agriculture.

Out of the rut and into the future

By necessity, due to funding issues, our universities will become more integrated with private research, and this change will have some real benefits. Academic institutions working with private firms will be able to both develop and commercialize new products from renewable sources. For example, corn and soybeans have been grown for generations, but as we move forward we are already learning they are much more than commodities. Biotechnology and transgenic processes will help us customize these and other products with specific characteristics for specific markets. The added value will help provide the incentive needed to build the infrastructure necessary to get these products to their end users.

With more opportunities and more risks than ever before, these are indeed exciting times for American agriculture. To meet these challenges, our generation must provide the path for the next generation to follow. We can't afford to fall back into the rut.

Leon "Len" Corzine is chairman and past president of the National Corn Growers Association, Washington, D.C., USA.

Photo supplied by the author: "21st Century Opportunity ... 21st Century Production ... 21st Century Needs"



A Bavarian Perspective

By Markus Demmel

The future of agriculture in the world will be as versatile as farming itself, our societies, and our countries are. In reference to my colleagues' and my work at the Bavarian State Research Center for Agriculture, I want to highlight the "future farm" from a specific point of view, focusing on agriculture in southern Germany, particularly the pre-alpine region of Bavaria. Farming here is dominated by small dairy farms with mainly grassland and pastures, little or no arable land, and often forests. In contrast to many other rural areas, this region is densely populated and has some economic hot spots (such as the city of Munich) and therefore has a high number of commuters. For these people, the "countryside" has become their home. Like much of the urban population, they are often well educated and have high family incomes. The regional unemployment rate is low. Most of the region also serves as a recreation area. These conditions influence the daily work of the local farmers and determine the future development of agriculture in the region.

Although the current situation for agriculture in this region seems to be quite clear, farming will not develop in a single direction in the future. Especially in this region, scientists, extension specialists, and other experts are proposing "multifunctional agriculture" as a way to combine farming and the prospects, needs, and requirements of larger society. Farmers will produce top-quality, healthy, and safe agricultural products, and they will contribute to meet other demands.

Number one on the list of additional products or services is renewable energy. Again, there will not be a single type or source of agricultural bio-energy. Some farmers will combine biogas production with animal production, possibly also using low-value or low-priced plant materials. Today, most of the 4,500 agricultural biogas plants in Germany, with a total installed electrical output of 1,600 MW,

convert gas into electrical energy and feed it into the national electric grid. In the future, new technology will be able to clean the gas and feed it directly into the natural gas grid. As another example, in addition to delivering construction timber, farmers' forests can provide wood chips for private firing and for small- and medium-sized combined heat and power stations.

A challenge for farmers in the situation described above will be to maintain their income from selling traditional agricultural products, such as milk and grain, while creating added value by processing the additional products. Again, this will be achieved in different ways for the different products and services. In some cases, processing will take place on the farm. For niche mar-



kets, milk can be processed to high-value products typical of the region, such as specialty cheeses. Similarly, instead of selling low-value wood chips, a farmer could sell heat to private homes or public users. In other cases, this added value will only be achieved by the cooperation of several farmers combining their different inputs, specialized knowledge, and economic resources.

The recreational aspects of the region strongly influence the conditions for farming, but they also offer new possibilities for multifunctional agriculture. Tourists tend to seek out attractive and well tended rural landscapes, and only farming can provide this service without enormous costs. Farmers can benefit directly from this situation. Offering "bed and breakfast" accommoda-

tions has a long history in the region. Following society's changing preferences, an increasing number of farmers are also offering vacation rentals and other recreation possibilities. Although mobility has reached a high level, there is an increasing demand for such services in the countryside near metropolitan areas.

A key element to help farmers realize multifunctional agriculture is optimizing the organization of their enterprises in regard to work and mechanization, and this is where agricultural engineers will contribute. Machines, structures, and production processes must be designed both to allow farmers to be successful in their core business—animal and plant production—and to develop the new activities

and services described above. Substantial ecological, animal welfare, and landscape architecture concerns have to be respected to ensure social acceptance and to raise the value of local farming. Modern technology that can increase the accuracy and efficiency of agricul-

tural processes, such as electronic control elements and automation that document the process quality and results, and modern farm buildings that are optimized for the animals, the people, and the landscape will smooth the way to the "farm of the future" in Bavaria.

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Illustration: Axonometric projection of Bavarian dairy farm of the future for 160 milking cows with cow-kennels, two milking robots, automatic feeding, biogas plant, and photovoltaic cells on all roofs. By J. Simon, B. Haidn, J. Harms, C. Biermanski, P. Stötzl, E. Rivera-Gracia, and J. Zahner.

Adapting to Climate Change

By Otto C. Doering III

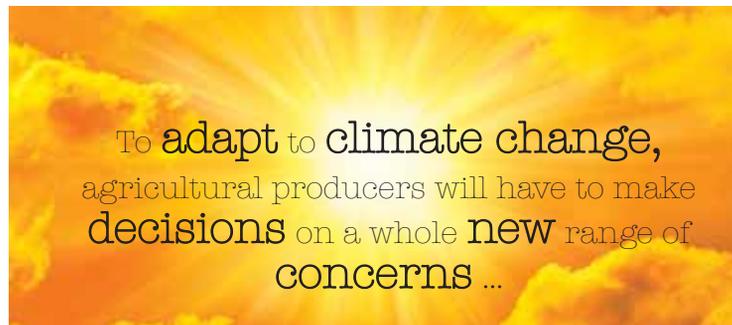
Management time is one of the scarcest resources available to those working in agriculture today. Given increasing challenges of all sorts, management time is likely to be even scarcer in the future, and adapting to climate change and the various environmental constraints that climate change represents will require increasing amounts of valuable management time.

If the rule for real estate is location, location, location, then the rule for climate change is variability, variability, variability. Most projections of climate change show increased climate variability as a major factor, in addition to overall temperature and rainfall changes. The indirect results of this are critically important as well. With increased climate variability comes increased yield variability, and with this comes increased financial risk.

Over the past fifty years, we have developed technology that allows increasingly predictable “recipe farming.” In a sense, we have turned large parts of agricultural production into an industrial process. Herbicide-tolerant corn and soybeans are the ultimate expression of this approach, which has had multiple benefits within the production system. Herbicide-resistant crops have reduced farm labor requirements, allowing one operator to cover more acres in a timely fashion. No-till cropping makes recipe farming simpler to manage, and there can be substantial conservation benefits, such as reduced soil erosion (although it is the labor and time savings, not conservation, that often drives the decision). Climate change will disrupt this model, and with increased variability more of the production process will be outside of the bounds of recipe farming. Will we be able to develop technology and management systems that maintain our current style of industrial-scale

recipe farming, or will a continuation of today’s recipes, which once simplified the decisions and actions of farm operators, end up requiring even more management and operating time while providing less benefit? If the future follows what current climate change projections indicate, then we can expect the latter.

Adaptation to climate change brings real challenges to production agriculture, and crop choice is one of them. Many areas that are well suited for certain crops will likely remain so; the central Corn Belt



will continue to be the best place to grow corn. However, the western Corn Belt is a different matter. This area is already deficient in rainfall, and production will become even more challenging with increased climate variability. In general, the fringe areas of established production regions are where critical cropping decisions will have to be made.

Irrigation will not necessarily solve such problems. Projections of climate change in central Illinois have demonstrated that irrigation will not solve the projected heat problem in that region. If a plant simply doesn’t have the physiological capacity to transpire sufficiently to cool itself, then it doesn’t matter how much water is at the root level.

To adapt to climate change, agricultural producers will have to make decisions on a whole new range of concerns, including crop and cropping system shifts, timing of planting (to minimize stress during reproduction), new challenges of pest man-

agement, and greatly increased risk management—both financial risk and production risk. Concentrating on one or two primary crops may no longer be sensible for an agricultural enterprise. There will also be secondary impacts of climate change, which are often overlooked. With less frequent and more intense rainfall, soil erosion can be expected to increase substantially. As a result, our definition of “highly erodible” land and our systems to control erosion will have to change as well.

Some of these difficulties will be mitigated by technology. New plant varieties will be developed to meet some of the challenging conditions (moisture variability, heat, etc.), but yields may be adversely affected. In general, engineering solutions for the challenges of climate change will be difficult because we will be operating where the conditions for our production systems are much less certain.

How can agricultural producers position themselves to adapt successfully? The first requirement is to admit the possibility of climate change, and plan for the eventualities being projected by reputable agricultural and climate scientists. Second, even if the outcome is not yet certain, producers must devote some management time to climate change eventualities, as risk insurance. Developing the agronomic, engineering, and financial risk management tools for climate change adaptation is a long-term project. As the evidence accumulates, those who adapt most quickly, by developing plans for adapting to climate change, have an increasing probability of surviving in a more difficult world.

ASABE member Otto C. Doering III is professor of agricultural economics and director of the Climate Change Research Center, Purdue University, West Lafayette, Ind., USA.

Precision Agriculture for Small Growers

By Reza Ehsani

In the future, small growers will be able to obtain high-resolution, multi-band aerial images of their farm at an affordable cost. So far, most technologies that have been developed for precision agriculture have primarily been adopted by larger growers and row crop producers. In general, small farmers and specialty crop producers in the United States and other countries have not been able to take advantage of precision agriculture technology in their operations, mainly due to the cost of the technology. This will change in the near future, and more affordable tools will be available for smaller growers.

Significant increase in the spread of disease and pests is one of the unwanted consequences of globalization. For instance, citrus growers are now dealing with a destructive dis-

ease called citrus greening, or HLB. Managing HLB requires scouting and detection of the disease at its early stages. Scouting alone costs about \$100 per acre. Tools such as high-resolution multi-band imaging could potentially reduce this cost.

Once such future precision agriculture advancement is a new low-cost flying platform that is being used at the University of Florida to acquire timely aerial images of small farms. The platform, called the Octocopter, can take off and land vertically like a helicopter, which allows it to be launched and land in any terrain. The camera mount installed on the Octocopter automatically corrects for yaw and pitch angle and keeps the camera's field of view parallel to the ground. This eliminates the need for geometric corrections of the images.

The Octocopter can be flown using a normal RC transmitter and can lift a pay-

load of about 0.9 kg (2 lbs). The system has the capability of flying to a GPS waypoint or according to a pre-assigned flight path. This latter feature is important, as flying the same flight path over and over again allows comparison with previously collected data. The collected pictures can be stitched together using any of several commercially available software programs to create an image of a larger area. The components of this system currently cost about \$4,000. If demand increases, the price will be much lower in the future, and it could therefore be affordable for many small growers.

The main advantages of this system over existing systems are its ability to collect images at a desired time, lower cost, and higher resolution. This system is more suitable for taking aerial images of small fields of 100 acres or less, and most high-value crops fall into this category. Using a multi-band imaging camera, we collected false-color and NDVI images of a citrus orchard. This type of image can provide rapid assessment of tree or crop health. On small farms, this system can be used for the following applications:

- Crop scouting
- Bare soil imagery
- Irrigation and drainage planning
- Yield estimation and monitoring
- Crop inventory
- Academic and extension education.

Two decades ago, low-cost aerial imaging meant taking an aerial shot of the ground using a 35 mm camera from a low altitude while flying a small airplane. Today, we have platforms that can take a more sophisticated, multi-band, geo-referenced image. In the near future, this type of technology will be commonly used by growers.

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Top: Octocopter with camera mount and multi-band camera.
Below: False-color image (left) and NDVI image (right) of a citrus orchard obtained by the Octocopter. Healthier trees are shown by darker green color.



Some Notes on Future Farming

By P. L. Gautam, C. Thomson Jacob, G. Venkataramani, and Y. Singh

In the late 18th century, Thomas Malthus famously warned that unchecked population growth would inevitably outstrip food production, leaving society destitute. Advances in technology have kept us fed, so far, but the planet's resources are overtapped, and the global population is estimated to reach 9 billion by 2050, requiring that current food production be doubled.

Present-day farm practices have raised production substantially but are also dubbed “exploitative.” Around the world, there has been widespread deforestation to clear new pastures and arable land. There has been alarming overextraction of fresh water from underground aquifers. And modern agriculture leads to depletion of biodiversity, vulnerability of crops to new pests, and excessive use of chemicals and inorganic fertilizers.

Considering the state of our natural resources, the business-as-usual approach may not be enough to feed the growing global population. New technologies, spurred by radical new thinking, are needed to meet the challenges. Conservation and sustainability should be the guiding principles.

Production options

Precision agriculture has the potential to dramatically change agriculture in the 21st century. Based on information technology, it enables the producer to monitor production, control operations, and collect data for better decision-making. Conservation agriculture, which involves minimal disturbances of the soil, retention of residue on the soil surface, and crop rotation to manage pests and diseases, will also increase. Initially practiced in Brazil and Argentina, it now covers large areas of the United States and is spreading in Europe and Asia.

There will also be more interest on integrated farm management. Even in marginal areas, successful farming is possible with proper management. In hostile climates, high-value crops can be grown in greenhouses. Soil-less, controlled-envi-

ronment agriculture (such as hydroponics and aeroponics) can be scaled into vertical farming operations for large-scale urban agriculture. Such technologies are currently being developed. In these high-rise farm-scrappers, vegetables, fruit, fish, and even livestock may be sky-farmed using well established methods.

Genetic improvements

Genetic techniques will revolutionize farming by enhancing farm productivity and income. Designer crops based on novel genetic combinations are now becoming available. New varieties that combine resistance to stresses with improved nutritional qualities may benefit farmers who are struggling to improve crop quality and yield under unfavorable growing conditions.

Future farming will also focus on bio-prospecting for new genes, compounds, and microorganisms for therapeutic and agricultural applications. Tissue culture methodologies have significant implications for production of low-cost, high-quality biological materials.

Aquaculture

Aquaculture will continue to grow to meet increasing demand. Sea farming, which includes cultivation of fish and other aquatic animals and plants, has boosted the economies of south Asian countries, including Vietnam and Thailand, and there is increasing demand for their products in the United States, Europe, and Japan. And aquaculture is more than just seafood. Macro-algae have many commercial uses as food, feedstock, for the production of alginates, and other products.

Resource use and energy efficiency

Efficient use of all resources and inputs—including seed, soil, water, fertilizers, agrochemicals, and machinery—requires sustained efforts. Efficient water management, along with better soil and nutrient management, will ensure high

yield per unit of input. For rainfed crops, water harvesting and watershed management will enhance productivity.

Renewable sources will play a key role in ensuring clean and reliable energy, preventing the release of pollutants, and helping combat global warming. Equally important, renewable energy technologies will contribute significantly to local economies, creating jobs for local people. Dedicated energy crops, such as *Miscanthus*, seaweed, switchgrass, and others, produce high biomass on a sustainable basis and can help us meet our energy needs in the future.

Other trends

Which way will food habits change: more meat consumption or more vegetarianism? Vegetarians' food habits lead to conservation of water, compared to a meat diet, although more effective ways of converting vegetation to animal products may change that balance.

Adaptation strategies related to climate change may require changes in land use, management practices, and the farming system as a whole. Policies aimed at resource conservation and green technologies will help by increasing carbon sequestration, but they may affect yields.

Future farmers will have aspirations that are different from those of today's farmers. The “evergreen revolution” precludes the use of mineral fertilizers, chemical pesticides, and genetically modified crops and calls for integrated pest and nutrition management practices and cultivation of appropriate crop varieties. This vision will inspire the pursuit of sustainability, energy efficiency, and environmental stewardship in production agriculture.

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The Future Starts Now

By Dick Godwin

Addressing the “future farm” presents a challenge in setting a balance between reality and fantasy. To solve the dilemma, I asked myself, “When does the future start?” The answer has to be “Now!” Therefore, instead of addressing some “way out” futuristic issues, I’ll consider some aspects of agriculture that we have recently been researching but that have yet to make an impact. Our long-term goal is the development of agricultural production in an environmentally sustainable manner, as we fight to improve food security through greater self-sufficiency and as fuel, fertilizers, and water become limiting factors.

In order to sustain agricultural output, we must maintain and improve soil structure. Hence, we need to reduce soil compaction by using vehicles with rubber tracks, lower ground pressure tires, and automatic inflation control. In addition, controlled traffic systems have shown yield improvements of at least 10 percent over conventional traffic management. Adoption of these systems becomes easier with the improved accuracy of global positioning systems (GPS) and vehicle steering aids. Many farmers have adopted some components of these systems but have yet to fully integrate them.

In addition to soil structure, the maintenance of soil fertility is a major concern as fossil fuel supplies dwindle, creating risks to both the price and long-term supply of nitrogen. As a result, to improve efficiency, farmers adopt spatially variable application. The same concept applies to phosphorus and potassium. Hence, there are greater opportunities for the increased use of organic materials, animal manures, and bio-solids. One sewage utility in the United Kingdom is developing a product that we call “super pooh,” a pelletized sewage sludge that is coated in urea to produce a balanced N:P:K fertilizer. Greater utilization of animal manures will cause an increase in the number of mixed arable/livestock farms.

In the United Kingdom, irrigated agriculture accounts for only 1 percent of water extraction and 4 percent of the cropped area; however, it accounts for 20 percent of total agricultural crop value. One-third of all potatoes and a quarter of all fruit and vegetables are grown in the driest part of the country (eastern



England), hence the need for moisture conservation practices, such as matching water application to soil moisture holding capacity and using techniques that cut off irrigation depending on the depth of the wetting front. Variable plant spacing within the row to match the available water has also proven beneficial in areas where irrigation is not possible.

Use of GPS positioning to identify soil-type boundaries will be linked to other forms of implement control to optimize tractor energy use during tillage, especially with regard to depth control for minimum tillage when operating with controlled traffic systems. This has been taken further with the optical guidance of hoes to remove weeds between rows and between plants within the row. Large-scale vegetable growers quickly recover the cost of these machines through reduced herbicide costs while satisfying consumer demands for products grown with fewer agricultural chemicals.

The combination of spatially variable agrochemical application with built-in traceability can target weed or pest problems, reducing the amount of agrochemi-

cal used and ensuring that the operator applies the correct chemical at the recommended rate. The stored data can be used in production management, in the food chain, and through to the consumer. Recently, a colleague reminded me that the same traceability systems could be adapted for livestock production.

I have been involved in work to compare organic and conventional livestock farming systems and their effect on soil conditions. Due to the lower stocking densities on organic livestock farms, soil compaction is less. Hence, infiltration is greater, and runoff and the potential for flooding are reduced. That said, and even though I spent

time walking the fields with the manager of an organic farm, I still believe that organic techniques alone will not be able to feed the world. While net margins can be higher, primarily due to affluent customers willing to pay for the perceived benefits, crop yields are significantly lower, and there is a higher labor demand in an industry that already has skill shortages at all levels. Organic farming can provide more sustainable production methods in a world with scarcer resources, but these methods should not be in conflict with our need for the next generation of genetically modified crops.

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Photo courtesy of Tillet and Hauge Technology Ltd.: Garford Robocrop InRow mechanically controls weeds growing between plants within rows of transplanted salad and leafy vegetables.



The Genetics + Management Paradigm

By Graeme Hammer

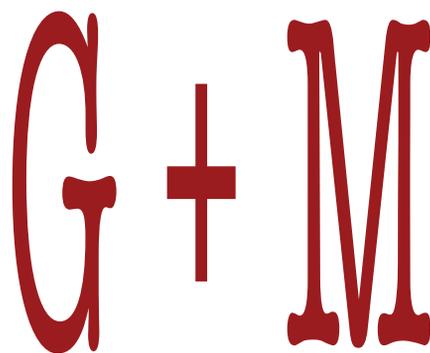
Farming is facing a future that will be very different from the current state of agriculture, and future agriculture will depend heavily on technology. During the next 40 to 50 years, the world will need to nearly double its production of agricultural biomass equivalents to meet increasing demands due to population and consumption trends. For example, the consumption of meat products increases as economies develop.

A long-term strategic view is needed to avoid scarcity. Some potential remains for expansion of cropping, and thus short-term amelioration of shortages, but this potential is limited. In some cases, rates of yield increase are actually slowing, partly due to the recent cycle of reduced public sector investment in agricultural research. Supplies of traditional production inputs (water and nutrients) are becoming limited. The cost of energy is influencing energy-intensive production systems. Beyond the increases in temperature and CO₂, and the clear need to manage emissions, the effects of climate change (for example, on rainfall) remain less certain. There is also increasing pressure on the use of biomass for biofuels. Given this context, the future of agriculture appears difficult. Nonetheless, agriculture will assume an even greater importance in securing the future of our world.

We must intensify the sustainability of agricultural production systems while becoming more efficient in our use of energy, water, and nutrients. That won't be easy, but it is possible. The rapid advances in knowledge of plant genetics (G) must be combined with advanced approaches to agronomic management (M) to deliver the required intensification in productivity.

This G+M paradigm can open new pathways to improved capture and more efficient use of resources such as water, light, and nutrients. In fact, the G+M paradigm will be obligatory. Miracle genes alone will not do it. And attempting to

change dietary preferences is also unlikely to prevail. Plants and systems specifically designed for improved efficiency (such as water use efficiency or nitrogen use efficiency) are possible by combining genetic factors with improved management, such as targeted delivery of nutrients and pesticides.



We must intensify the sustainability of agricultural production systems while becoming more efficient in our use of energy, water, and nutrients.

Combined with efforts to optimize resource capture and resource use efficiency, monitoring the availability of water and nutrient resources will also be necessary. Ideally, this approach will provide a means to minimize the current yield gap between possible and currently realized production levels, and it may even raise the bar for productivity.

In addition to sensors and imaging technology, achieving this improved productivity will require improved photosynthetic systems, root systems, and plant architecture. The technology will also incorporate advanced weather prediction to make the most effective possible use of rainfall during the growing season.

This G+M paradigm may be the future of agriculture, but it must be adopted within farming operations that maintain their soil health and minimize energy use and greenhouse gas emissions. Efficient machinery and minimum tillage or no-till cropping will be required, combined with effective farm-scale nutrient capture and return systems. Precise placement, targeting, and timing of inputs using advanced technologies, such as encapsulation, will become common. Improved understanding and consequent management of soil biota will provide an avenue for these innovations. Production of energy will also be an integral feature of these farms, wherever possible. On-farm energy production will likely include solar and wind sources as well as biomass.

Investment-driven technologies for advanced agricultural systems will provide the mainstay for the increased global food production that our world will require in the next few decades, and this increased production will likely be associated with higher food prices. However, while such technologies relate mostly to developed agriculture, there is also great need to improve the production of resource-poor farmers in developing countries, where input use is low and the supporting infrastructure poor. Investment in development programs to help these farmers will be vital for our global health and well being.

Graeme Hammer is a professor of crop science, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Brisbane, Australia.



The Future Demands Efficiency

By Jerry L. Hatfield

Increasing demand for food, feed, fuel, and fiber will require increasing efficiency from our agriculture production systems, as well as resilience to climate change, enhanced quality of the product, and new insights into management. These may sound like impossible challenges; however, the solution lies in our ability to implement practices now that will serve as the foundation for the future. Management decisions focused on optimum production for a given natural resource base will lessen the environmental impact.

Efficiency-based evaluation

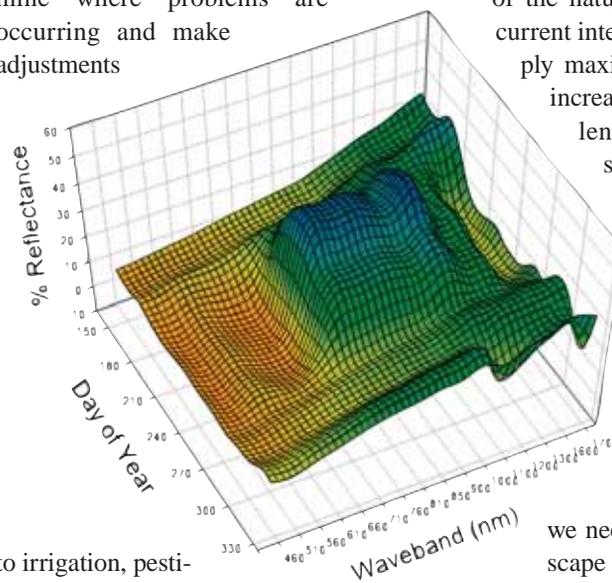
Return per unit of investment is a measure of efficiency, and there will be more emphasis on the return that crop and animal production systems derive for each input. Concepts like water use efficiency, nitrogen use efficiency, or radiation capture efficiency have been around for decades. However, until now, these concepts have not been part of the decision-making process, nor have they been used as metrics for evaluating the performance of a production system. For example, in animal production, we have traditionally used rate of weight gain as a measure of efficiency.

Developing tools that producers can use to evaluate efficiency will open up new areas for precision agriculture. Our current decision-making process is limited when we try to evaluate the impacts of previous decisions, and we often limit performance evaluations to crop yield, and even then at a cursory level rather than a comprehensive analysis. Using an efficiency-based approach, we will evaluate fields not only on their yield but also on their return per unit input of water, nutrients, or light, as well as the impact of improved genetics and management practices.

To support this efficiency-based evaluation, integrated sensors will provide accurate estimates of plant water use, leaf nitrogen status, and light interception at a fine resolution across the field. During the growing season, these sensors will detect

nutrient deficiencies, weeds, insects, or even emerging diseases. Analysis of this information will indicate where pest or nutrient problems are most likely to occur, to guide adjustments for future growing seasons. In addition, field maps will be generated from high-resolution hyperspectral reflectance images from drones, small-scale helicopters, or even geostationary satellites that collect data over a specific area.

As a result, producers will have nearly real-time information, so they can determine where problems are occurring and make adjustments



to irrigation, pesticide application, or other inputs. This field-level information will become a resource for production decisions, along with information about genetics, fertilizers, or pesticides. At harvest, production information will include both yield quantity and quality (such as grain protein, oil, and starch).

Integrating for balance

Assembling, storing, and sorting all this information may sound like a daunting task, but existing technology already allows for the automatic integration of such data into easily viewed field maps during the growing season and as overlays of previous seasons to compare the impact of management decisions. And this huge volume of information can be accessed

and sorted with simple queries.

Integrating these concepts will enhance both productivity and environmental quality. When extrapolated to the landscape scale, this efficiency will reshape regional production in ways that will increase the overall productivity of the land. The resulting multifunctionality of the landscape will allow us to balance agricultural production, environmental concerns, and recreation. To achieve this balance, we will view the landscape as a mixture of crops intended to optimize use of the natural resources, as compared to current intense cropping systems that simply maximize production. The need to increase our food supply will challenge this concept and create some tensions about the multiple uses of landscapes. At the same time, development of alternative fuel supplies from non-food crops, such as wood chips, perennial grasses, or other alternatives, will lessen the potential conflict between food and fuel production.

We already have the tools we need to evaluate alternative landscape designs, and these tools will become more widely used as the need for more rigorous planning develops and the outcomes of efficient planning are realized by both producers and customers. These developments will add to the richness of our landscape and increase the diversity of our agricultural economy.

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Illustration: Hyperspectral reflectance provides a unique view of a crop canopy during the course of a year. The changes in reflectance are not constant across different wavelengths; they provide insights into and are related to changes in crop growth and development. Changes in patterns can be used to develop measures of crop response to biotic and abiotic stresses across a field. This information will become part of the decision-making process in the farm of the future.

A Philosophical Perspective

By Charles N. Merfield

Any discussion of the farm of the future has to be more philosophical than scientific. Science is unequivocal that predicting the outcome of complex systems is impossible, and the days of experts prophesying the future are over.

Further, I concur with John Gray, the British political philosopher, that the days of grand utopian visions are over, along with the monolithic philosophies that spawned them. If we are to plot the future, it has to be brick by brick. Therefore, this is not a prediction, but an analysis of the issues that I believe matter for farms in the future.

This analysis has two perspectives: “bottom up” (that is, the processes of the natural world, which are knowable through science), and “top down” (that is, ethics, morals, and politics, a society’s collective decisions about right and wrong, which are outside of science). In addition, when considering the future, time scale is everything. This analysis must be commensurate with the slowest agricultural process (that is, pedogenesis), so my time scale is multi-millennial.

The bottom-up perspective

The biosphere is an open system that uses energy from the sun to “excrete” entropy, allowing it to build low-entropy complexity, such as life. Farms are holons of the biosphere, and their job is exactly the same: to use photosynthesis to create complexity, such as food, fiber, and chemical energy. However, for the first time in human history, other pursuits (science and technology) have now bypassed agriculture as the dominant source of complexity in human civilization. The primary means of doing this have been fossil fuels (which are also complex chemicals). Because fossil fuel reserves are minuscule compared to their rates of consumption, a crunch

point is coming, after which substitute sources of complexity will be required. In addition, because of the huge amount of energy used by modern societies, agriculture will never again be a significant source of energy.



Chemical complexity is a different matter. While chemists have been able to create an astounding variety of synthetic materials, they still cannot replicate the foundational chemistry produced by farms. Further, many of the complex materials that chemists have produced are made from fossilized photosynthesis or fossil fuels. Therefore, farms will likely continue as civilization’s foremost source of complex chemistry, particularly for food, and especially the food that feeds our cultural needs rather than solely our biological needs. For that reason, farms will continue to be the bedrock of civilization. Hopefully, the farmer of the future will be recognized and fully compensated for this pivotal role.

Science and technology have also allowed us to manipulate agriculture beyond our current understanding, for example by altering biogeochemical cycles (by short-circuiting the nitrogen cycle) and by intervening in ecological processes (by applying pesticides). These manipulations are increasingly found to have unintended consequences, many of which are harmful or undermine the manipulation’s objectives (for example, targeted pests eventually evolve pesticide resistance).

To lessen these consequences, the farm of the future needs to be built on a deep knowledge of geology, ecology, and biology, not just superficial chemistry. The most important aspect of this approach needs to be a return to husbandry of the soil. As with fossil fuels, we are consuming the soil faster than it is being created. When the soil is exhausted, farming stops. This is not just a problem for food production. Soil is the interface for all of the biogeochemical cycles. We are as reliant on soil for the air we breathe and the water we drink as we are for the food we eat. Good husbandry of the soil is the most important task for agriculture, and one for which the farm of the future must be recognized.

The top-down perspective

It is impossible to have a farm without a farmer. The utopian visions of the past, which included completely mechanized farms, have morphed into dystopias. Farming is the primary profession in which people interact with the natural world, a world to which we are utterly tied and to which we still have strong emotional and cultural bonds. Even if it were feasible to create people-less farms, managed by algorithms, I would not want to have anything to do with such an inhuman system. The farm of the future, like the farm of the past, is the bedrock of civilization, and farmers must be recognized for providing us with the fundamental requirements (air, water, food, fiber) on which civilization is built. In short, we need to put the “culture” back into “agriculture.”

Charles N. Merfield is an independent ecological agronomist based in New Zealand and currently freelancing, undertaking research and advising while establishing PhysicalWeeding and Agro-Ecological as part owner and director of both firms.

Photo by the author: “Well husbanded soil”—the foundation of good agriculture and all human civilization.

Down Home and High Tech

By Clay Mitchell

At dinner today, I was trading wisdom with an Argentinian farmer friend. Waving a bit of Patagonian lamb at the end of his fork, he said, “My marketing advisor calls me every Thursday. Regardless of the advice, it forces me to deal with my grain positions at regular intervals. Otherwise, I could put it off for months.”

Earlier, I had been pondering how the right combination of features—inertial sensors, large memory, color displays, cameras, keyboards, GPS—have led to the success of smartphones. However, while many popular apps exploit these synergies, I was puzzled by all the popular apps that don’t. Most of them could have been written for PDAs a decade ago. Looking around at all the other diners, who all had a fork in one hand and phone in the other, I had an epiphany.

The key difference between smartphones and PDAs (as well as cameras and all the other devices that smartphones have displaced) is that making and receiving phone calls shackles the users to their phones, and that minor annoyance is the smartphone’s greatest benefit. The smartphone’s requirement-to-carry can enforce certain behaviors, like when my friend receives those regular calls from his marketing advisor.

On the farm of the future, the ubiquity of the smartphone can make everyone a walking hot spot. When a farmer gets in his truck, tractor, or combine, the machine can download his preferences and adjust itself. The implement can then use the smartphone to access a central database, and video monitors in the cab can display all the information received through the phone. Event-driven pop-ups on the monitor will mirror the smartphone. The smartphone

can also be the basis for vehicle communication: the combine can know where all the grain carts are, and vice versa.

Smartphones will impact agriculture worldwide, but adoption of other technology will vary by region. In much of the United States, the narrow windows for planting and harvesting create short-duration sprints to get the work done. With every farmer running the same race, the highest priority of U.S. farmers will be capacity and reliability.

Until now, discretionary spending on machinery has sought out extra features. In the future, American farmers will avoid technologies that slow them down, even if it means a trade-off with the quality of work. For example, real-time nitrogen sensing will remain a niche. While plant color is a proxy for future nitrogen need, it

consolidations. As a result, they will place a high premium on machines that can be self-serviced, and extensive diagnostic capabilities will become increasingly accessible. This will be especially true for the megafarms that have a high level of in-house expertise.

With the costs of machinery and biotechnology increasing relative to labor and management costs, new methods will develop for managing these risks. For equipment manufacturers, the quantitative work surrounding warranties previously involved relating the costs of increasing reliability to the probability of warranty costs. New effort will be put into analyzing the insurance value of warranties. More extensive warranty coverage will develop, and it will depend on pricing that is actuarially efficient. For example, many farms that are unwilling to sustain the risk of catastrophic failure of a \$500,000 combine can easily pay the cost of the probability of failure. Similarly, an obvious way of increasing farmer’s willingness to pay for biotechnology is to return the technology fees if the crop is destroyed by hail, as has been done with biotech canola in Canada.

Tomorrow is a new day, and I will likely change my mind about many things, including my predictions about technologies on the farm of the future. But what will not change is that winning technologies will depend on the farmer. In the future, as in the past, the farmer will sift through what’s new and choose only what works. This wise process is as inexorable as the slow settling of the dust that trails the farmer as he shuts down for the night and walks through the field toward home.

Clay Mitchell is a farmer (www.mitchell-farm.com), a Harvard-trained biomedical engineer, and a Saltonstall Fellow at Cornell University, Ithaca, N.Y., USA.

Photo by Greg Nielsen: Smartphone farmers Ted Crosbie and Robb Fraley visiting the Mitchell farm.



only works when it is layered with so many heuristics that its use becomes impractical.

Because of technology, farmers’ relationship with agricultural implement dealers has already changed. Dealer-dependent service has been designed into the machines. Farmers who might have overhauled their own engines in the past must now go to the dealer to have new firmware flashed. At the same time, farmers are extremely averse to the monopolies that have resulted from massive dealership



The Future of Specialty Crop Farming

By Francis J. Pierce

What will drive the specialty crop farm of the future? A critical factor will be the cost and availability of labor. Here in the Pacific Northwest, Washington state already has the highest minimum wage in the United States, at \$8.55 per hour, with Oregon second at \$8.40. In some years, farm labor shortages in the Pacific Northwest result in losses due to unharvested crops. In the future, labor availability could be further diminished by changes in U.S. immigration laws, since U.S. farm workers are largely foreign-born and, by reliable estimates, half of them lack legal authorization to work. Here's how labor availability will affect the future of two important crops in the Pacific Northwest, sweet cherries and organic vegetables.

The sweet cherry industry in the Pacific Northwest is particularly threatened by the cost and availability of labor because labor constitutes 60 percent of the cost of production. A cherry harvester was developed in the late 1990s and showed promising reductions in labor costs. However, the harvester removes cherries at the fruit-stem junction, yielding stem-free cherries. As a result, there are three major limitations to this harvest approach: the market for stem-free cherries is untested and undeveloped, most sweet cherry orchards are not suited to mechanical harvesting, and not all sweet cherry varieties have the required abscission characteristics.

A current USDA-funded project is intended to address all aspects of sweet cherry production, from genetics to the table, to develop an automated, stem-free sweet cherry industry. The focus of the project is on new genetics and new orchard architecture that facilitates automation of pruning, thinning, and harvesting, which could reduce labor up to five-fold. In addition, because the end product is a stem-free cherry, fruit processing and marketing are also critical components of this project. Automation is the key to the sweet cherry farm of the future, but implementing it will require a



systems approach that integrates biology, engineering, and marketing.

As with cherries, labor is also a major cost in organic vegetable farming, particularly the labor required for hand weeding and crop thinning. Consumer demand for organic foods has increased organic fruit and vegetable production nearly three-fold over the last decade, and labor costs exceed 50 percent of the cost of production. Even in large operations, where RTK-GPS-guided cultivators control weeds between the rows, controlling weeds within the rows, in close proximity to the crop, remains a problem. One grower told me that weeding costs average \$3,000 per hectare and can exceed \$12,000 per hectare in high-value crops. There is also an increasing consumer demand for “greener” practices on the farm, such as non-chemical approaches to weed control. As with sweet cherries, the organic farm of the future will need automation. This automation will include new technology that facilitates within-row weed control as well as other tasks, such as ultra-precise planting and targeted nutrient and pest control application.

What does the specialty crop farm of the future look like? Automation that replaces human labor, that increases the efficiency of inputs, and



that facilitates adaptive management in response to climate change, environment concerns, and consumer preference will be the norm. Economic forces will demand it, and engineers will provide it.

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Photos by the author. Top: Upright fruiting offshoot (UFO). Bottom: Traditional sweet cherry tree orchard architectures.

Skyfarming: An Alternative to Horizontal Croplands

By Joachim Sauerborn

Agriculture is an ancient human activity that is still a major force for global change. Agriculture's current prominence is the result of population growth, climate change, and the growing biofuel industry. Because of the increasing popularity of meat- and dairy-based diets and the expansion of the biofuel industry, which competes with food production for grain and productive land, the question remains of how the large demand for agricultural products can be met in the coming decades. A further complication is that climate change is predicted to reduce global crop production by 9 percent by 2050.

Fundamentally, two possibilities exist to increase agricultural yields: increase the area of production or intensify production, which means increase the yield per unit area. Until the middle of the 20th century, the increasing demand for foodstuffs was predominantly met through the expansion of agricultural production areas. However, from the beginning of the 1960s until the end of the 1990s, the global production area grew by only 11 percent, while at the same time, the world population roughly doubled. Therefore, in effect, available agricultural land has decreased by 40 percent (from 0.43 ha to 0.26 ha per person).

Global agricultural production now faces realities of limited biogeochemical resources. In addition, we face a trade-off in land use between urbanization and agriculture. Land use patterns are also of major importance for global carbon and water budgets. And agriculture is still dependent on phosphorus, which is a non-renewable resource; current global reserves may be depleted in 50 to 100 years. Thus, innovations in agriculture and engineering are necessary to achieve efficiency.

Skyfarming—indoor crop production in a purpose-built, multi-story building—is an innovative concept that could resolve the problem of rampant urbanization competing for fertile land by boosting food crop productivity without increasing the area of production. With skyfarming, the production of staple food is transferred to a technically optimized building envelope. Skyfarming thus allows high productivity under optimized growth conditions without seasonal interruptions. Unlike traditional production methods, skyfarming follows an efficient strategy, using technical innovation to reducing resource consumption per production unit.

In a skyfarming production system, the crop is moved continuously on a con-

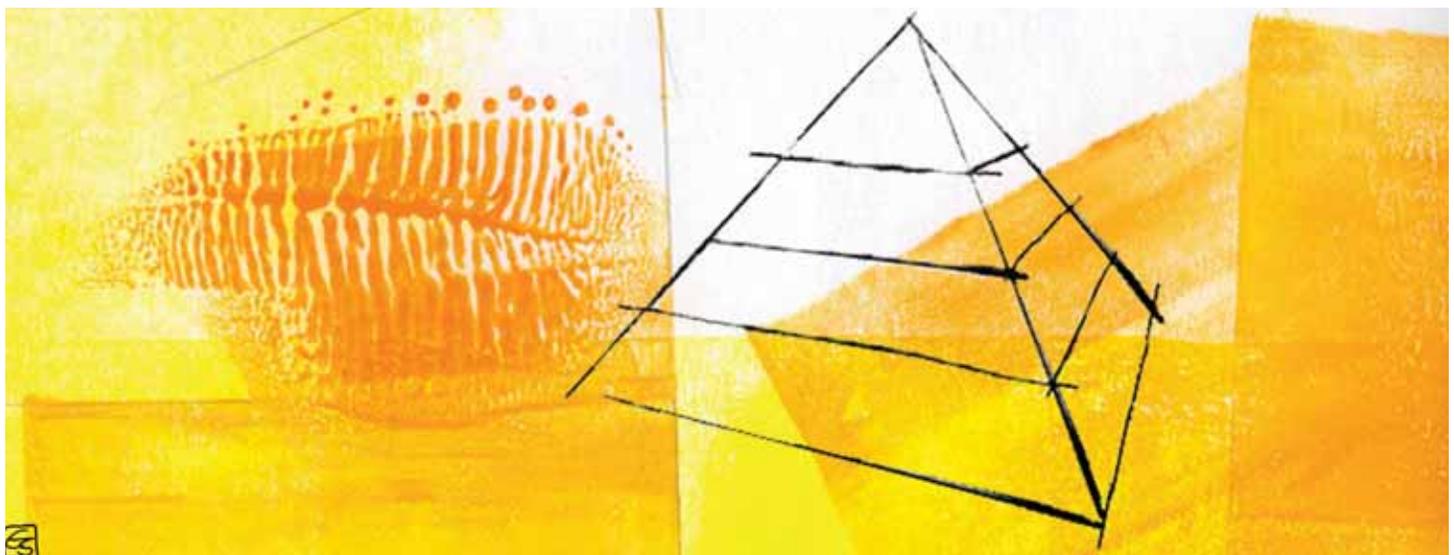
veyor system, from seed to harvest. Instead of soil or hydroponics for the water and nutrient supply, an aeroponic system supplies a nutrient-rich mist in the root zone. A technical challenge lies in the consistent separation of the root and shoot areas when plants are moved. Additional challenges include:

- Development of the aeroponic system
- Efficient recirculation of water and nutrients
- Control of pests and diseases
- Achieving optimal light exposure
- Recycling of material and energy resources.

Some of the technical components required for skyfarming are already available, although they have not yet been tested under the objectives of this approach. However, the results of some previous studies suggest that skyfarming can be a resource-effective production system for staple foods that can complement conventional production methods. If so, skyfarming may allow us to produce even more food with even less land.

Joachim Sauerborn is the dean of faculty, the University of Hohenheim, and professor, Institute of Plant Production and Agroecology in the Tropics and Subtropics, Stuttgart, Germany.

Illustration by the author: "Skyfarming"



A Report from 25 Years Hence

By John Schueller

The typical U.S. crop farm of 2035 is not that different from the typical farm of 2010, in the same way that the 2010 farm was not the artificially intelligent, self-sufficient, robotic paradise that many predicted way back in 1985. But the continued application of effectively free computing power and the surprisingly slow, but steady, development of additional sensors and algorithms have converted farm workers from operators to supervisors who exhibit practically omniscient telepathy and telekinesis with each other and with the farm's equipment.



The evolution of data handling and control capabilities followed the paradigm of the proliferation of computers in facilitating great flexibility. Current production systems go far beyond 2010 precision agriculture and allow timely, sustainable, profit-maximizing, strategic and tactical responses to spatial, temporal, weather, and market variabilities.

For example, although controlled traffic is practiced to minimize the soil area that is affected by equipment, the cultivars (and even the crops) within fields are varied in response to variations in soil, water, and topography.

The long-term trend of farm consolidation continues, as the economies of scale and the concentration of assets to economically astute managers were not effectively overridden by sociopolitical concerns about monopolization of the food supply. Given the need for timeliness

in these large farms, field operations are very fast and productive. Consequently, the 2035 farm is in some respects an efficient materials handling operation. Huge quantities of fertilizers and other inputs are delivered in the spring, and even larger quantities of grain are trucked off the farm in the fall. The multiple robotic vehicles that transport these materials between staging areas and the equipment in the fields are even less supervised by the farm workers than the planting, crop protection, and harvesting machines. As a result,

although the machines have advanced sensors and redundant remote shutoffs, access to the fields is strictly controlled due to safety and liability concerns.

Drone aircraft, with wingspans of just ten centimeters, carry vision and spectroscopic cameras over the fields at frequent intervals. Other than that, the need for high productivity and materials handling requirements did not allow the proliferation of herds of small, robotic agricultural equipment, as predicted in 2010.

In fact, average equipment productivity continued to increase, although most of the increase was due to automation, advanced materials, and 24-hour operation rather than the moderate size increases limited by roads, facilities, and other constraints.

The most challenging aspect of attempting to increase food production, in response to increasing population and increasing per capita demands, has been responding to pests' increasing resistance to pesticides at a time when new pesticide modes of action are not being approved. Both traditional and robotic mechanical weed control have become commonplace. Rather than an integrated pest management model based on economic thresholds, a "no tolerance"

model has become widespread. All weeds on the farm are removed to reduce future seed banks. Given the larger farm size, the perimeter over which weed introduction has to be strictly controlled is not a large percentage of the farm area. Insect and disease infestations, while minimized through the use of new highly resistant cultivars, sophisticated control technologies, and large-scale rotations and isolations, remain a management challenge.

Although biomass removal is limited as a part of sustainability considerations, the farm is a net exporter of energy. Where appropriate, a large mobile pyrolysis unit travels through the fields after harvest, generating liquid and gaseous fuels for farm use and external sale. In addition, the federal government pays the farmers for the carbon sequestered as pyrolysis biochar if the soil limit for biochar in that field has not been exceeded. Once every six years, the pyrolysis unit is operated in the much slower "full-consumption" mode in which all the biomass is consumed to generate heat to sterilize the soil.

As in 2010, in 2035 there is a huge variation in agriculture between countries, within countries, and even from neighbor to neighbor. This farm, while typical of an average (not advanced) farm, represents just one of many different existing models of technology adoption and management. However, it is worrying that plant agriculture (and animal agriculture) continues to reduce genetic and cropping system diversity. Already struggling to feed 8.5 billion people an advanced diet on less arable land than in 2010, the stability and robustness of the world's food production system are becoming questionable.

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Illustration: "Autonomous Grain Cart Concept" by Corbett Schoenfelt.



The Challenges of Farming on Marginal Land

By Christopher Wathes

Often the hardest issues in farming concern management of the land. No one would argue that arable farming does not face its share of problems, but these problems are often easier to solve than the problems affecting livestock farmers, especially those farming on marginal land.

Typically, the hardest decisions have to be made about marginal farm land, such as the rolling hills and dales of Great Britain or the Appalachian Mountains of North America. Such marginal land has been used for centuries for livestock production. In contrast, the rich, arable prairies of East Anglia in England or of the American Midwest will always have a secure future because of the ever-increasing demand for grain by an expanding world population with a large disposable income and a growing appetite for grain-fed products, such as meat, eggs, and milk.

Of course, farmers make many different decisions about their business, but increasingly the consumer is the one who decides how land is, and should be, managed. On the livestock farms of the future, the farmers will have to satisfy many more customers than they do at present. This is because they will be as much managers of the land as producers of food and fiber. Intensive poultry, dairy, and pig farms will have to deal with environmental pollution, employment, food safety, and animal welfare, all while

turning a profit, but on marginal land these challenges will be especially tough. Here, the land has to:

- Provide food and fiber
- Support the tourism industry by maintaining the attractive countryside that so many love to visit
- Contribute to the supply of potable water and prevention of flooding
- Sustain the bio-diversity of the local flora and fauna.

Livestock farmers on marginal land will have a particularly hard job because, in addition to making a living, they will have to manage their land according to these multiple objectives, which may conflict at times. And there is the additional objective of ensuring that the farm animals have a satisfactory standard of welfare, or a “life worth living” in the new parlance. National governments will play a more prominent role as guardians of farm animal welfare to ensure that minimum standards are maintained and that agricultural policies are reasoned, reasonable, and responsible. As guardians, governments will have to set aside powerful vested interests and economic forces to juggle the interests of consumers, farmers, and farm animals.

The old-fashioned approach to balancing farm finances relies on support from the public purse or taxpayer. Whether blatant or hidden, subsidies—for that is what support payments are—have been

the bedrock support of much farming in many countries in the developed world. Only recently has the World Trade Organization become tougher in its opposition to this type of financial support, and the age of austerity that is now upon us means that the taxpayer's dollar will have to go even farther than it has in the past.

What will be the role of bio-engineers? Agricultural technology will play an increasing role in raising productivity, as it has ever since the tractor displaced the horse in the early 20th century. In addition, bio-engineers will play a part in ensuring that the livestock farm of the future is sustainable, where sustainability not only means environmental impact, animal welfare, and food safety and security but also profitability. Bio-engineers will have to be imaginative—ever ingenious—in coming up with technological solutions, as well as financially astute, and acutely aware of the changing politics of farming.

Christopher Wathes is professor of Animal Welfare, the Royal Veterinary College, University of London, U.K. He is a Fellow of the Institution of Agricultural Engineers.

Photo provided by the author: “On the livestock farm of the future, farmers on marginal land will have to satisfy multiple objectives covering tourism, biodiversity, and water management, as well as producing food and fiber profitably.”



Biomass Supply Chains for a Bioenergy Future

By Heather Youngs and Caroline Taylor

It's difficult to reflect on the farm of the future without including a role for energy crops. Recent policy shifts toward renewable energy are opening up new opportunities for farmers to diversify their crops and bring idle land back into production. As a result, farm practices will have an enormous impact on the economic viability and commercial development of next-generation bioenergy.

The development of new bioenergy feedstocks, whether dedicated crops or harvest residues, requires a concomitant development of production networks and market demand. In the bioenergy sector, two main organizational structures link the biomass supply to the energy producer: vertical integration (which occurs when the bioenergy producer supplies the feedstock in-house) and procurement systems (in which feedstocks are supplied from biomass producers to bioenergy producers by means of spot markets or contracts). The relative balance of these two strategies reflects their technical difficulties, perceived risks, and marginal economies.

Forward vertical integration is by far the most common strategy in bioelectricity production. When the technical expertise required for competitive biomass production is a barrier but the conversion technology is well established, biomass producers may move into energy production (for example, electricity production by forest products companies, addition of ethanol refining to sugar mills, and installation of anaerobic digesters at dairy farms to produce biogas). This internalizes the cost savings but also confines the supply risk entirely to the energy producer.

Alternatively, backward integration, that is, acquisition of biomass production capability by a bioenergy producer (for example, acquisition of plantations in Brazil and southeast Asia by fuel producers) is likely to result when conversion is the main technical barrier. Less common in bioelectricity and first-generation biofuel production, this strategy is emerging in advanced

biofuel production, where joint ventures may involve fuel producers, conversion technology innovators, and large farms.

At present, vertical integration dominates the bioenergy industry. Only 25 percent of the bioenergy producers surveyed in 2008 obtained biomass (wood, food, or agriculture residues) exclusively through procurement. Half of all producers were fully integrated, while another 25 percent employed a hybrid strategy to produce some biomass internally while augmenting their supply through procurement. Only 6 percent of procurements were through spot markets, emphasizing the role of short- and long-term contracts in reducing risk in this emerging industry. Limitations on large-scale land purchases will likely spur an increase in the number of hybrid arrangements and increase the procurement opportunities.

This variation in biomass supply has implications for biomass cultivation. The wide range of potential bioenergy crops allows for niche applications, such as riparian protection and verging, along with traditional cropping and intercropping patterns. One intriguing scenario involves development of dispersed pre-processing technologies capable of using diverse feedstocks, which allows the industry to overcome the barrier of biomass transport economics and provides additional local value. Emerging contract and hybrid structures could support a broader range of farm sizes, shifting away from the past decades' trend of ever-greater consolidation and allowing large-scale operations to exist alongside smaller operations and family farms that share the developing networks.

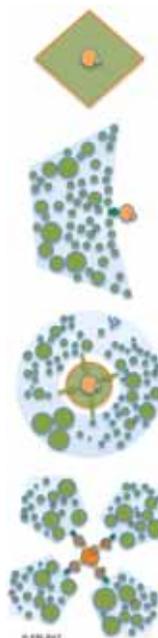
At the same time, the technical barriers to economic biomass production threaten the establishment of supply networks for external procurement of feedstocks. High perceived risk of failure during the establishment period for

perennial crops negatively effects the farmer's willingness to diversify, which is a crucial step for early adopters of new feedstocks.

Cooperative energy farming structures have had some success in Europe and the United States in facilitating access to specialized equipment for planting, maintenance, and harvest. In addition, as economics will likely become more strained in the agricultural sector, access to and application of precision farming techniques, advanced breeding for environmental and biotic stress tolerance, and design of more efficient planting, harvest, and maintenance equipment will play pivotal roles in the successful future farm.

In spite of the continued optimism for an increasing bioenergy crop industry in the United States, real-scale data for the most promising new feedstocks are limited.

The absence of local data—including proven establishment, growth, economic harvest yields, and environmental impact measurements—adds uncertainty to an already risk-adverse lending climate, reducing future opportunities for farmers to change their practices and implement new technology. By directing research efforts toward identifying the best-fit feedstocks for emerging technology and eco-regional limitations, agronomists and agricultural engineers can reduce farmer risk and enable farming communities to successfully incorporate energy crops into their future portfolios.



Heather Youngs and Caroline Taylor are bioenergy analysts at the Energy Bioscience Institute, University of California, Berkeley, USA.

Illustration: first figure, plantation model; second figure, distributed growers; third figure, hybrid plantation and external procurement; and fourth figure, distributed pre-processing.



Guidance Assistance for Improving Productivity

By Ian Yule

When we look to the future, it is a good idea to take a quick look over our shoulders at the recent past. There are huge technical opportunities awaiting farmers, but how will farmers react to them? An example from the decade just passed has been the widespread adoption of guidance assistance and autosteer systems for tractors and field implements. However, with autosteer being one of the most expensive technologies available to them, farmers appear less ready to adopt other precision agriculture tools.

Guidance assistance gives its users immediate benefits in driving accuracy. The driver responds to a simple light signal: green means you are on track, and red means you are heading off track. Although the GPS receiver may be operating at 5 Hz, the driver typically responds at a much slower rate, depending on the driver's attentiveness and what else is happening in the cab. Autosteer takes this process further by allowing the RTK-DGPS-based system to take over the steering of the tractor. It operates at 5 to 10 Hz to provide rapid feedback and precise control.

Guidance assistance and autosteer have had a major impact on the agricultural industry. Within 15 years, we have gone from a simple lightbar indicator to fully automated control of tractors and implements. The enabling technology has been in place for that entire period, although one could argue about its price and availability.

So what about the rest of precision agriculture? Why have other forms of precision agriculture not been as widely adopted, and what can we learn from the last decade to derive a better plan? In his keynote address to the 2009 ASABE Annual International Meeting, Kenneth Cassman, Director of the Nebraska Center for Energy Sciences Research, pointed out that very few producers achieve anything like the full potential of their land. Why do we accept a level of performance in which the average farmers are achieving only half of their poten-

tial? The reason is likely to be because of sub-optimal performance of one or more aspects of the crop growing process. Maybe we should start by giving each of these aspects a lightbar. For example, we could link field sensors to indicator lights to prompt some action by the producer.



Could such a simple fix have a positive impact without adding further complexity? We often start with a simple idea that seems logical, but then we discover that many complex and dynamic factors lie behind it. How can we deliver the required accuracy without making the system unusable through its inherent complexity and slow response time? One way to conceptualize this situation is to separate the technology framework from the knowledge framework. The technology framework appears to be well developed. We could use it to measure factors affecting yield and crop growth. The weakness appears to be the knowledge framework. Using guidance assistance as an analogy, we need to drive along an A-to-B line of producing high yields consistently. Therefore, we need to have a knowledge framework in place to set our lightbar for the different conditions that we are likely to encounter.

So how do we develop the necessary knowledge framework? Here is one example: a dairy farmer friend here in New Zealand showed me that, when regular measurements were conducted on his farm, the resulting accurate pasture allocation allowed him to increase the use of his pasture, increase pasture production, and

increase the productivity of his cows. By simply reducing the errors in his system, he achieved increases in productivity that would make any scientist proud. A further factor is that the new system allows him to focus on the correct questions and informs him of the next question that needs

answering. By analogy, he has redefined the A-to-B line from straight parallel paths to a more complex shape, while using a higher-frequency feedback loop to reduce off-track errors.

Having superior control of tractors and implements should provide the basis for other technological improvements. That has not happened yet, and this technology gap is of huge concern, as there are many exciting possibilities that could help farmers. But the technology, by itself, is not enough. To properly utilize the technology, and to inform us of the next parts of the technology framework that require construction, we must develop the necessary knowledge framework. Developing a more complete and accessible knowledge framework will have the greatest immediate benefit for producers, and it will foster widespread adoption of precision agriculture, which will have global benefits.

Ian Yule is a professor of precision agriculture, Institute of Natural Resources, Massey University, Palmerston North, New Zealand.

Montage by the author: "New Zealand agriculture has many unique aspects, but it is governed by the same objective of safe food, produced efficiently with minimum environmental impact."

Challenges and Opportunities in India

By Usha Barwale Zehr

The recent food price inflation in India highlights the need to look at our country's production and productivity. The increase in food prices has had the greatest impact on the segment of the Indian population that can least tolerate price increases. Combine this with shrinking farming land, small farm sizes, constraints on water and fertilizer use, and climate change, and it becomes imperative to take a close look at how farming can meet our growing needs in a sustainable manner.

The last large-scale yield gains in India were seen with the introduction of high-yielding, semi-dwarf varieties of wheat and rice, which launched the Green Revolution and shifted India from a "ship to mouth" existence to becoming self-sufficient in major food grains. The 3.6 percent growth per year in wheat production during 1966-1979, and similar production increases in developing countries, came from the use of these new varieties and improved cropping practices, along with favorable policies and institutional support. However, recent data show declining or stagnating growth trends in all major crops, and thus the urgent need to look at how this challenge can be met and overcome.

Rice and wheat are the major source of calories in the Indian diet. Wheat (with more than 23 million ha of production) and rice (with approximately 42 million ha) provide livelihoods for many of the 600 million farmers and families who are engaged in agriculture in India. The farms of the future that cultivate rice and wheat will need to improve their productivity. In

addition, the current highest-yielding areas, such as those in Punjab and Haryana, are also the areas that will be least sustainable in the future due to salinity, water availability, fertilizer use, and rising temperatures. New varieties and hybrids of wheat, rice, and other crops will need to be able to tolerate the challenging environments in which they are cultivated.



Scientific progress presents tremendous opportunity for addressing the challenges faced by the Indian farmer. As a first step, the agronomic practices that we are following today need to be updated. In addition to simple improvements (such as installing irrigation systems, leveling fields before sowing crops, and weed control methods that allow use of direct-seeded rice crops rather than flooded crops), more technological methods (such as selecting better genetics, precise application of fertilizer, and appropriate use of transgenic traits) are essential for the farms of the future.

The introduction of hybrids in wheat and rice, and farmer's adoption of superior genetics, already shows in productivity gains. In addition, the farm of the future will have to grow more with less, and with less labor, and the trend toward automation is already visible. **Access to markets and other information via cost-effective cell phone networks has empowered the local farmer.**

The challenge is large, and the required tools are available. While Indian farms continue to be small, they can be economically viable. An important step is to establish partnerships that bring together the best in agronomy, genetics, agricultural engineering, and environmental science to benefit the farmer and the community as a whole.

The recent introduction of Bt cotton has shown how small farms can transform their production sector and have a positive impact for the farmer, the community, and the nation. At the farm level, because there is less pesticide use, the farmer faces less pesticide exposure. At the community level, the environmental impact is reduced due to decreased use of these chemicals. At the national level, India has almost doubled its productivity and has become the second largest cotton producer in the world, after China. Eight years after the introduction of Bt cotton, more than 90 percent of India's cotton growing area is under insect-protected production, the fastest adoption of any technology in our history. Similar transformations are possible in rice and wheat, and we will surely see them happen in the coming years.

Usha Barwale Zehr is the joint director of research at Maharashtra Hybrid Seed Co., Ltd., Jalna, India, and a member of the International Rice Research Institute Board of Trustees.

Photo © LeungChoPan/dreamstime.com



Traditional Livelihoods in Rapid Transition

By Robert S. Zeigler

Rice is the most important food crop in the developing world, and it is the staple food for more than half the world's population. Rice cultivation has been described as the world's single largest economic activity. More than one billion people depend on rice cultivation for their livelihoods, and almost 160 million ha are harvested annually.

In many ways, rice cultivation is also among the smallest economic activities. In Asia, where 90 percent of the world's rice is grown, there are more than 200 million rice farms, most of which are smaller than one hectare. Over 550 million people live on less than \$1.25 per day in rice-producing areas, so most of the rural poor in Asia depend on rice for a significant share of their earnings.

About 75 percent of the rice harvest is currently grown on flooded soils that are then "puddled" (that is, heavily tilled to convert the soil into mud that can hold water at the surface instead of allowing it to drain freely). Seedlings are transplanted into the mud, and across most of Asia, this transplanting is still done by hand. The standing water controls most weeds, but the crop still needs to be hand weeded. Transplanting and weeding are typically done by women and children, and up to 10,000 L of water may be used to produce one kilogram of rice.

The dramatic changes in Asian economies are rapidly driving major changes in rice farming. Rapid industrial and urban growth is creating competing

demands for water and labor. Governments are increasingly diverting water away from agriculture, and young people are leaving the countryside for opportunities in urban areas. After all, it is not hard to imagine an attractive alternative to walking backward in calf-deep mud and bending over 10,000 times to transplant 250,000 seedlings per hectare.

In tropical Asia, a rapid shift from hand-transplanted rice to direct-seeded rice is taking place, especially where labor is scarce. Soils are still flooded where there is abundant water, but increasingly farmers rely on dry methods. This change will dramatically alter weed management. Direct seeding does not lend itself to hand

weeding, and the forces driving it—that is, labor scarcity—also mitigate against hand weeding. Inevitably, Asian farmers will move to more mechanized methods.

Small land holdings will consolidate into larger management units. How fast this occurs will depend on several factors. In the former socialist countries, some sort of title to the land will have to be secured before farmers can invest and lenders can provide credit. In countries that have seen aggressive land reform, mechanisms must be in place to allow farmers to retain title while participating in larger management units.

As farm sizes increase, cash investment per hectare will also increase to replace the decreased investment in labor. Dramatic increases in herbicide use will

be the most obvious change, and the rice will also change. Today, most rice grown outside of China is of a pure breeding type, and farmers save their seed from one season to the next. Hybrid rice, pioneered in China, has a higher yield potential, but farmers must purchase seed every season.

As rice farming becomes increasingly commercial, hybrid rice will increase to at least 25 percent of the production area in the coming decades. This will engage private seed companies, and there will be a major shift from informal and government-based seed systems to a system that involves the private sector, much like in European and North American farm communities.

Finally, almost all rice farmers in Asia will soon have access to the Internet and other information resources through cell phones and related technologies. The adoption rate of information technology in rural Asia is already astounding. The public and private sectors are building systems that will allow farmers to access real-time advice on crop management, and these systems will be geo-referenced to meet the specific requirements of a given field, season, or variety. Farmers will also be able to access credit using their cell phones.

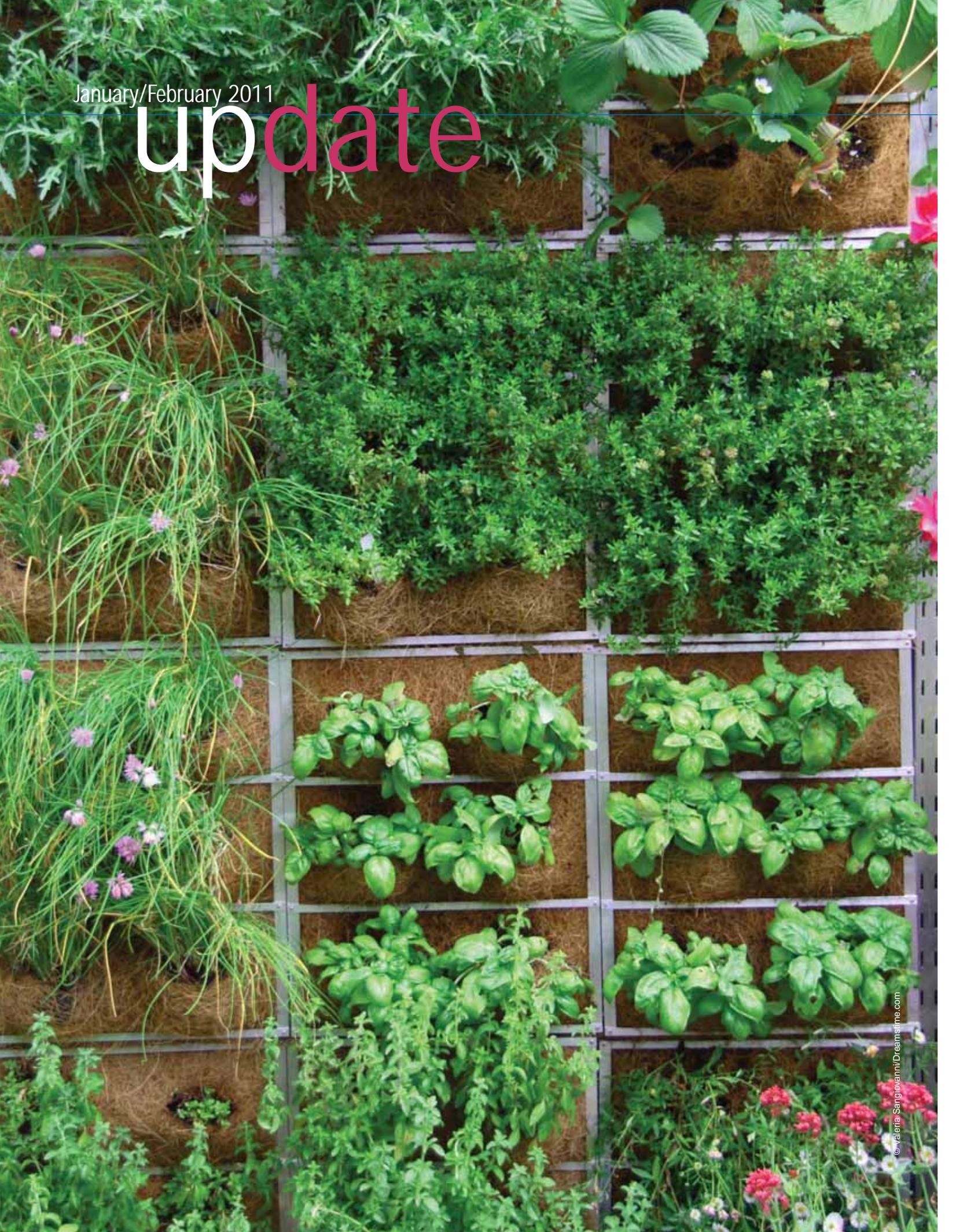
Most importantly, farmers will have real-time access to market information for inputs and harvests. This will be the final step in the conversion of rice farming from a largely subsistence activity to a dynamic commercial enterprise. Thus, we will see an enormous transformation of rural Asian communities. The forces that are driving these changes are already in place. It is not possible to prevent them from transforming rural life, but it is possible for policy makers to ensure that the net social and environmental impacts are positive.

Robert S. Zeigler is director general of the International Rice Research Institute, Los Baños, The Philippines.

More than one billion people depend on rice cultivation for their livelihoods, and almost 160 million hectares are harvested annually.

January/February 2011

update



New buzz on vertical farming

In Brief: With the recent publication of *The Vertical Farm: Feeding the World in the 21st Century* by Dickson Despommier, retired professor of microbiology and public and environmental health sciences at Columbia University, articles and reviews have been published and posted, and the media are blogging and tweeting. Here's a sampling of what's out there, including comments from the author.

“By the year 2050, nearly 80 percent of the earth's population will reside in urban centers. Applying the most conservative estimates to current demographic trends, the human population will increase by about 3 billion people during the interim. An estimated 10⁹ ha (2.5 billion acres) of new land (about 20 percent more land than is represented by the country of Brazil) will be needed to grow enough food to feed them, if traditional farming practices continue as they are practiced today. At present, throughout the world, over 80 percent of the land that is suitable for raising crops is in use. Historically, some 15 percent of that has been laid waste by poor management practices. What can be done to avoid this impending disaster? A potential solution: farm vertically.”

Dickson Despommier, www.verticalfarm.com. See Despommier on YouTube and in other videos at this site.

“The Vertical Farm has excited scientists, architects, and politicians around the globe. These farms, grown inside skyscrapers, would provide solutions to many of the serious problems we currently face, including: allowing year-round crop production; providing food to areas currently lacking arable land; immunity to weather-related crop failure; re-use of water collected by de-humidification of the indoor environment; new employment opportunities; no use of pesticides, fertilizers, or herbicides; drastically reduced dependence on fossil fuels; no crop loss due to shipping or storage; no agricultural runoff; and many more. Vertical farms can be located on abandoned city properties, creating new urban revenue streams. They will employ skilled and unskilled labor. They can be run on wind, solar, tidal, and geothermal energy. They can be used to grow plants for pharmaceutical purposes or for converting gray water back into drinking water.”

Review from www.amazon.com.

“Despommier envisions a system for farming that would use energy from burning human waste and biofuels from the vertical farm itself to help power extremely energy-efficient grow lights. Fish and poultry could be raised in the buildings, along with fruits and vegetables.

Some of those steps are taking place already on a smaller, lower-tech scale. In Milwaukee, for example, former pro basketball player and urban farmer Will Allen has created a self-sustaining system of fish and vegetable farming.

And companies such as Valcent Products Ltd., based in Cornwall, U.K., make systems to grow indoors in warehouses or other buildings. Valcent's CEO Chris Bradford credits Despommier for pushing the boundaries of what might be possible. Bradford expects his company's VertiCrop system to begin being used in the United States in early 2011.

Majora Carter writes in the book's foreword: 'If the skyscraper farm is like a 747 jetliner, we are now at the stage of the Wright Brothers.' But, Despommier notes, that's still a point from which to start.”

David Runk. “Dickson Despommier's 'The Vertical Farm' tout visionary agriculture methods.” *The Huffington Post*, www.huffingtonpost.com/2010/10/28/dickson-despommiers-the-v_n_775284.html.

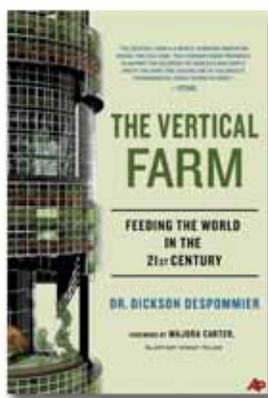
“Vertical farming imagines a utopian future, but can it price out? Now that there are hardly any farmers left to migrate from the cornfields to the city, farms themselves are poised to make the big move. This, at least, is the premise of Dickson Despommier's new book in which the medical ecologist envisions a utopian future

where plastic skyscrapers rise out of 'squalid urban blight' to produce bumper crops of high-tech veggies and turn even our filthiest municipalities into 'the functional urban equivalent(s) of a natural ecosystem.' Despommier thinks we should be producing our food closer to where we eat it. He embraces a techno-progressive approach that out-industrializes the so-called Big Ag factory farms that locavores typically loathe. For him, transparent buildings made out of self-cleaning plastic, sterile grow rooms with double-locking doors, and genetically modified plants that can detect and warn against verboten pathogens are the keys to environmental sustainability and healthier food.”

Greg Beato. “Growing skyward: Vertical farming imagines a utopian future, but can it price out?” *Monterey County Weekly*, December 9, 2010.

“When people ask me why the world still does not have a single vertical farm, I just raise my eyebrows and shrug my shoulders. Perhaps people just need to see proof that farms can grow several stories high. As soon as the first city takes that leap of faith, the world's first vertical farm could be less than a year away from coming to the aid of a hungry, thirsty world. Not a moment too soon.”

Dickson Despommier. “A farm on every floor.” *The New York Times*, August 23, 2009, p. A19.





The University of Georgia

Department of Food Science
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ASSISTANT PROFESSOR - TENURE TRACK FOOD ENGINEER - 60% RESEARCH, 40% TEACHING (12 MONTH, TENURE TRACK)

The Department of Food Science and Technology is seeking a highly motivated and creative individual to develop research and teaching in the area of food processing and value-added products processing. A PhD in Food Science, Engineering or equivalent program is required with demonstrated interest in food engineering and processing. Individuals seeking more information should go to our website (<http://www.foodscience.caes.uga.edu/>) or contact Dr. Mark A. Harrison (mahfst@uga.edu). The deadline is April 1, 2011, or until a suitable candidate is identified.

The University of Georgia is an Equal Opportunity/ Affirmative Action Institution. Women and Minorities are encouraged to apply.

NORTH CAROLINA STATE UNIVERSITY BIOLOGICAL AND AGRICULTURAL ENGINEERING RENEWABLE ENERGY ENGINEERING, TENURE TRACK POSITION

Responsibilities: A cluster hire consisting of potentially two faculty positions are sought to provide leadership in developing academic and research programs to increase the understanding, application and efficiency of renewable energy and biofuel. Each position will be expected to teach 2-3 courses annually in support of the undergraduate and graduate programs and to establish a nationally recognized research program focused on one of the following different areas: 1) energy conservation and green structures engineering; 2) bioenergy machine systems engineering; or 3) bioseparations or biosensors engineering. The successful candidates will join an interdisciplinary team and work collaboratively with faculty in the Colleges of Engineering, Agriculture and Life Sciences, and Natural Resources with a joint appointment in COE and CALS. The focus of this hire will be at the Assistant Professor level, but consideration will be given to candidates satisfying criteria for higher academic rank (Associate or Professor). Full position description is available at: <http://www.bae.ncsu.edu/bae/>

Qualifications: Candidates must have a PhD in Biological and Agricultural Engineering or a closely related engineering field. Excellent verbal and writing skills are required. FE designation is required and registration as a professional engineer in North Carolina by the time of tenure is expected.

AA/EOE: NC State University is an equal opportunity and affirmative action employer. All qualified applicants will receive consideration for employment without regard to race, color, national origin, religion, sex, age, veteran status, disability, or sexual orientation. In its commitment to diversity and equity, NC State University seeks applications from women, minorities, and persons with disabilities.

ADA Accommodations: Betsy Maness, email: betsy_maness@ncsu.edu; phone 919-515-6701; fax: 919-515-6719.

Application Procedure: Applications should be submitted electronically to: <https://jobs.ncsu.edu> (search Position #7002) and attach a letter of intent describing qualifications and interests along with a statement of career goals, curriculum vitae, copies of academic transcripts, and the names and contact information of three references. Review of applications will begin January 15, 2011 and continue until the position is filled.

SCHOOL OF AGRICULTURE DEPARTMENT OF AGRICULTURE SCIENCE AGRICULTURE SYSTEMS TECHNOLOGY

Position: Assistant Professor in Agriculture Systems Technology. This is a 9 month position with responsibilities in teaching, service and research in the School of Agriculture.

Location: Department of Agriculture Science, Murray State University, 213 Oakley Applied Science South, Murray, Kentucky 42071.

Responsibilities: The successful candidate will be responsible for developing and teaching undergraduate and graduate agricultural systems technology curriculum such as metal work, tractor, combines and field implements, buildings and construction, electricity, agriculture processing, and agricultural education support classes. Individual must assist with recruitment and advising; participate in community service, scholarly and research activities; establish rapport with regional agriculture systems industry leaders; conduct field days and contests; serve on committees and take active roles in providing support and leadership to agriculture. Teaching methods must emphasize hands-on, practical educational learning.

Qualifications: Candidates must have minimum of 3 years successful teaching experience, earned bachelors, masters, and doctorate in agricultural systems technology or closely related field. Candidates with an ABD and documented plan of completion by end of fall 2011 semester will be considered.

Salary: Commensurate with qualifications and experience.

Benefits: The Murray State University benefits package include a retirement plan, health and life insurance, worker's compensation, vacation days, sick days and other benefits.

Other Information: Murray State University is a regional institution in Murray, KY, with 10,416 students with 770 in the School of Agriculture <http://www.murraystate.edu/agr.aspx>. The School of Agriculture has three departments - Agriculture Science, Animal Equine Science and Pre-Vet/Vet-Tech. The Agriculture Science Department consists of Agriculture Education, Agriculture Science, Agriculture Systems Technology, Horticulture, Agronomy, and Agriculture Business. Four university farms are within a 3 mile radius of the main campus.

Applications: Interested candidates should send a letter of application describing how their qualifications meet the position and position requirements; resume/vita; copies of transcripts; names and contact information of three references to HR at <http://www.murraystatejobs.com>.

Starting Date: August 15, 2011

Closing Date: Applications will be reviewed starting March 4, 2011 and will continue until vacancy is filled.

Resource is published six times per year: January/ February, March/April/, May/June, July/August, September/October, and November/December. The deadline for ad copy to be received at ASABE is four weeks before the issue's publishing date.

Advertisements are \$140 per column-inch length (column width is 3.5 inches) and include free placement on the ASABE Career Center at www.asabe.org/membership/careercenter.htm. The minimum ad size is 2 inches—approximately 100 words—to qualify for the free online listing.

For more details on this service, contact Melissa Miller, ASABE Professional Opportunities, 2950 Niles Road, St. Joseph, MI 49085-9659, USA; 269-932-7017, fax 269-429-3852, miller@asabe.org, or visit www.asabe.org/resource/persads.html.

professional listings

ASSISTANT/ASSOCIATE PROFESSOR OF ENVIRONMENTAL SCIENCE WEST TEXAS A&M UNIVERSITY

West Texas A&M University, a Member of The Texas A&M University System, invites applications for the position of Assistant/Associate Professor of Environmental Science. This is a twelve-month, tenure track position that reports to the Head of the Department of Agricultural Sciences. WTAMU is seeking an innovative and dynamic individual with a professional record of leadership and scholarly activity to develop a nationally recognized teaching program and extramurally funded research program in environmental science related to animal agriculture. WTAMU is a four-year academic institution with more than 500 students in the department granting Bachelor, Master of Science, and Doctoral degrees. Qualifications include a Ph.D. in Agricultural, Environmental, or Biological Sciences, or equivalent engineering discipline from a regionally accredited University by first day of employment. Responsibilities will include undergraduate and graduate teaching (50% appointment), development of a nationally-recognized research program in agricultural/environmental science (40% appointment) and development of collaborations and interactive research with other professionals (10% appointment in professional service). Review of applications will begin March 15, 2011 and the search will continue until the position is filled. Position is available for the Fall 2011 semester. Salary and benefits are competitive and commensurate with qualifications and experience. Electronic applications are encouraged. Applicants should provide a letter of interest, copies of official transcripts, resume, and a statement of current and future research interests. Also, applicant should arrange for at least three letters of reference to be sent to: Dr. Ty E. Lawrence, Search Committee Chair; Department of Agricultural Sciences; WTAMU Box 60998; Canyon, TX 79016-0001; Phone: (806) 651-2560, Fax (806) 651-2938; E-mail: tlawrence@wtamu.edu; Texas law requires that males, age 18 through 25, be registered w/Selective Service. AA/EOE.



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Feeding the World

Success Feels Good to Jimmy Butt

by Kathy Zerler

Few people can claim the perspective earned from a lifetime of experience in one field. Jimmy Butt is one of those unique individuals.

The contentment Butt has gained from a life spent striving to feed and clothe the world with good food and natural fibers shows on his face. His smile is kind and reaches out from his eyes to focus directly on the person he is with. It is clear that he cares about helping people.

Following his college graduation with a degree in agricultural engineering, Butt spent four years as an artillery officer in the U.S.

Army. After combat experience in Europe, he came home to earn a master's degree, also in agricultural engineering, at Auburn University in Auburn, Ala. There, he joined the faculty as a research engineer and studied the artificial drying and storage of seeds, grain, hay, and peanuts.

"I can't think of a more noble purpose than to find new ways to meet the needs of a hungry world," says Butt, who created a career out of his passion for that purpose and for his great love of humanity. "I suppose what launched me in the direction I followed was my tendency to like affiliating with people. I became the per-



manent secretary of the Alabama section of ASABE and was active in the southeast region. This record, I suspect, is why I was recommended as a candidate for the position here.”

In 1956, Butt moved his young family to southwestern Michigan so he could work for the Society. He and his late wife, Jane, were married 64 years and have three children, Janie Lake Berry, Maryanne Butt, and Jimmy Jr.

Butt explained that, at that time, the Society was entering a period of growth in all areas—both nationally and internationally. He was hired in as the CEO, a position he held for 31 years. When he retired, he was elected President of the Society.

“As head of the ASABE international headquarters, I had a strong desire to meet the wishes and requests of our members. To the best of my knowledge, no letter or call went unanswered, some painfully so.

“I was heavily involved in leading the staff through major expansions in all its major functions. This work required extensive travel, so I was away from home a lot,” he says, adding that he reviewed the names and the specific concerns of the people he was traveling to see while on the plane. “In my field, being with people is crucial to success; remembering their names and their families is a part of that. I have always been people-oriented, and I easily connect.”

His people skills held him in good stead as he traveled to Europe for international meetings, to Egypt to lead a team of irrigation specialists, and to every U.S. state to meet with ASAE/ASABE sections. Additionally, there were frequent trips to Washington, D.C., and New York to interact with government officials and representatives of sister societies and affiliated groups.

“The challenge was to glean bits of information or ideas that would be useful to my staff and to our members,” he says. “And whenever I was successful, it felt good. Though I never clocked them, I’m certain that my normal week was far more than the customary 40 hours.”

Thoughtful work and long hours in the top job also required associations in professional and community-based groups. Again, Butt gravitated toward activities involving direct contact with people.

At the start, he was active in campus politics, then came civic clubs and church membership as well as several agricultural organizations.

“My rewards have always been the compliments offered by members and colleagues, and the satisfaction of accomplishment,” he says. “Success is starting something and completing it so that it benefits people. It could be as small as helping someone who has difficulty walking find a comfortable seat or as big as launching a new program.”

Now 89 years old, and a 46-year member of ASABE, this southern gentleman was born in the village of Tippto, Tallahatchie

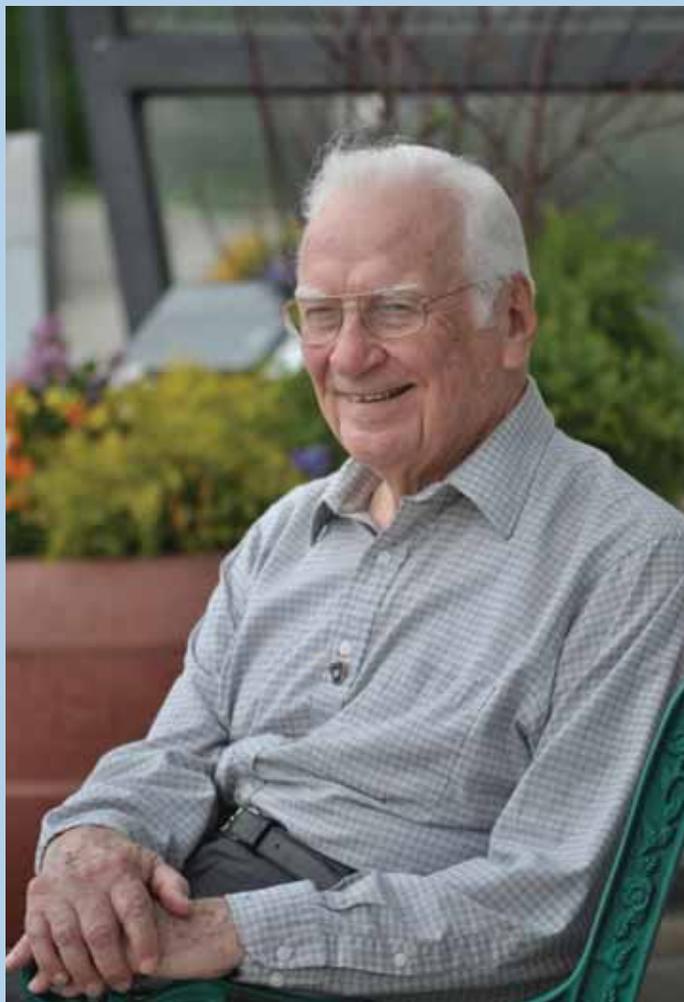
County, Miss., and raised there until his parents died when he was 16. Then, he moved to live with an uncle in Wetumpka, Ala., where he graduated from high school.

He has been active in the St. Joseph community on several levels—from serving on the committees and boards of local non-profit agencies to hands-on activities like driving a van for the Senior Center and delivering Meals-on-Wheels. In 1996, he was named Krasl Art Center’s Volunteer of the Year, and he has served in numerous capacities at St. Joseph’s First United Methodist Church and in the St. Joseph Lions Club.

“My hobbies include doing things with those groups, like playing the piano for the Lions,” he says. “I am an avid reader of current events and happenings around the world.”

Seeing the growth and maturation of a professional organization first hand, as well as researching its past, has helped him to pass along a strong outline for the future of agriculture.

With his background in research, Butt said his greatest satisfaction has come from expanding the technical journals and developing a database for members worldwide, affording ASABE members opportunities to exchange ideas and supporting the continuing development of industry standards, which make farming safer and more productive.



Kathy Zerler is a freelance writer and author. She lives on Lake Michigan with her husband, Glenn Zerler, and can be reached at zerler@sboglobal.net.

Photos courtesy of John Madill, [The Herald Palladium](#), St. Joseph, Mich., wherein this article first appeared.

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