Knowing the back-breaking tedium of growing up on a family dairy, grain, and vegetable farm, I have spent most of my career trying to improve the design, manufacturing, control, and use of agricultural equipment, or teaching others to do so. Improved equipment makes farming better for the farmer, as well as for the crops and soils that produce the food, fiber, feed, and fuel that our modern consumer society requires. Improved equipment should maximize the productivity and efficiency of a farming operation in a way that is economically, environmentally, and socially sustainable.

Good dairy farmers treat every cow in the barn as an individual to maximize her production and health. But as for the feed for those cows, farmers may treat all their fields the same, no matter what the differences are between or within fields. It would be better if farmers could respond to field variability the way they respond to differences in their cows, and that response should be an integrated optimum response to spatial variability, combined with temporal variability and the weather.

Just as computer technology has allowed mass customization in manufacturing, it has the potential to treat each square meter of soil and each plant in the best way possible.

Therefore, my goal for 2050 is that plant agriculture will be optimized for maximum sustainability at small spatial and temporal scales.

That, rather than fancy technologies, is what precision agriculture is all about. It can mean applying the right rate of the right fertilizer at the right location to maximize production without contributing to nutrient runoff. Or it can mean applying herbicides only to weeds and at the moment of peak herbicidal efficacy.

The overpopulated world of 2050 is not going to be fed by the United States alone. Accordingly, I will continue to share information during about a half-dozen international trips yearly, as well as through a variety of media for technical and farmer audiences. I intend especially to encourage the adoption of yield maps and maps of other crop and soil properties, leading to increased production while protecting the environment.

Farmers should first be encouraged to respond to these maps with intelligent analyses leading to appropriate strategic decisions, such as changing field boundaries, removing areas from production for economic or environmental reasons, adding drainage or irrigation, or changing agronomic practices. They should then be encouraged to make appropriate tactical decisions, such as controlling water, fertilizer, or pesticide applications in a spatially and temporally variable manner as the season progresses. This requires better technologies in such areas as sensors, computer algorithms, and dynamically accurate variable-rate applicators. More
proaches through bioengineering offer new opportunities to achieve variation and thereby increase efficiency.

Over the past 50 years, the mechanism of photosynthesis has been studied to the extent that it is now the best understood of all plant processes. All the discrete steps have been described, and the relevant genes, proteins, and metabolites are well described. As a result of this knowledge, and with the availability of high-performance computers, the entire process has been represented as a complete dynamic model, allowing millions of permutations to be tested to find optimal approaches to increasing efficiency. At the same time, bio-engineering has become routine for our major crops, allowing practical testing of computer-based designs.

New areas of research are emerging from these new techniques. For example, cyanobacteria, from which crop chloroplasts evolved, have their own CO₂ concentrating mechanism that was lost in the evolution of land plants, which occurred at a time when earth’s atmosphere contained many times the CO₂ concentration of today. Re-introducing this mechanism to crop chloroplasts could, in theory, increase photosynthetic efficiency by 60%.

Computer-based design can also be applied at the level of the leaf canopy. A recent analysis has shown that altering the distribution, angles, and albedo of leaves within a canopy substantially increases the photosynthetic efficiency of solar energy, water, and nitrogen use. In total, combined improvements at the cell, leaf, and canopy level could more than double the conversion efficiency of today’s major C₃ crops, which is no longer possible with interception efficiency and harvest index, the other two efficiencies that govern yield potential.

Although we are far from achieving these improvements in practice, bioengineering of model species, including tobacco, has shown significant and reproducible improvements in conversion efficiency in controlled environments. It now remains to be seen if these improvements can be replicated in realistic field conditions with major food crops. Recent analyses show that, given current improvement trajectories, future global yields of the four largest food crops will fall far short of projected 2050 demand, possibly by as much as one-third. Genetic improvement of photosynthesis is an unexplored opportunity to deliver significant yield increases before that happens.

S. Long, Gutgsell Endowed University Professor of Plant Biology and Crop Sciences, Institute for Genomic Biology, University of Illinois at Urbana-Champaign; slong@illinois.edu

X.-G. Zhu, Plant Systems Biology Professor, CAS-MPG Partner Institute for Computational Biology, Chinese Academy of Sciences, Shanghai, China;xinguang.zhu@gmail.com

Long Way to Go

Many reform efforts have been made, including the establishment of research centers. Although the agricultural research community has made strides in the right direction, it has a long way to go. To maximize our progress toward solving the needs of 2050, significant changes are needed in the agricultural public sector. State and federal departments of agriculture, extension services, and land-grant universities have a long history of contributing to the advancement of agricultural practices. However, inertia and administrative demands are hindering our progress toward meeting the needs of 2050. For example, despite much rhetoric and many feel-good proclamations about support for interdisciplinary and multidisciplinary approaches, the current reporting, staffing, financing, and other administrative structures, regulations, and procedures effectively discourage work between disciplines.

Dealing with these constraints is time-consuming and distracting when one discipline is involved, but the detrimental effects are multiplied when multiple disciplines are involved. Something must be done to remove the common perception that interdisciplinary and multidisciplinary work is painful—and detrimental to one’s career—so that the gaps in knowledge between disciplines can be removed. One reason for the creation of research centers was to solve this problem, but it seems to have led instead to more administrative burdens. And those research centers have siphoned potential funds from smaller activities that are generally more efficient in generating significant outcomes.

Another needed reform in the public sector is the removal of matching fund requirements. Truly innovative and revolutionary projects of the type needed to make disruptive changes in crop production to feed the world in 2050 will not result from approaches that are “business as usual.” Unfortunately, those approaches are comforting familiar, and therefore receive widespread support.

J. Schueller, Professor, Mechanical and Aerospace Engineering and Agricultural and Biological Engineering, University of Florida, Gainesville; schuejk@ufl.edu

Reprinted from the November–December 2014 issue of Resource magazine with permission of the publisher the American Society of Agricultural and Biological Engineers.