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AGRICULTURE

Transforming U.S. Agriculture

Achieving sustainable agricultural systems will require transformative changes in markets, policy, and science.

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Agriculture in the United States and many other countries is at a critical juncture. Public investments and policy reforms will inform landscape management practices to be used by farmers and ranchers for sustaining food and ecosystem security. Although U.S. farms have provided growing supplies of food and other products, they have also been major contributors to global greenhouse gases, biodiversity loss, natural resource degradation, and public health problems (*1*). Farm productivity and economic viability are vulnerable to resource scarcities, climate change, and market volatility (*2*). Concerns about long-term sustainability have promoted interest in new forms of agriculture capable of (i) enhancing the natural resource base and environment, (ii) making farming financial viable, and (iii) contributing to the well-being of farmers, farm workers, and rural communities, while still (iv) providing abundant, affordable food, feed, fiber, and fuel.

A 2010 report by the U.S. National Research Council (NRC) (*1*) identified numerous examples of innovative farming systems that contribute to multiple sustainability goals but noted they are not widespread. This report joins others [e.g., (*3–6*)] critical of aspects of mainstream, conventional farming systems. We argue that the slow expansion of such innovative farming systems in the United States is as much a policy and market problem as a science and technology problem. Incentives for appropriate markets, reform of U.S. farm-related policies, and reorientation of publicly funded agricultural science are needed to hasten implementation of more sustainable agricultural systems.

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Incremental, Transformative Approaches

To improve sustainability of U.S. agriculture, the NRC report proposes both incremental and transformative approaches. The former are practices and technologies that address specific production or environmental concerns associated with mainstream, conventional farming systems. Examples include 2-year crop rotations, precision agriculture using geospatial technologies that describe field variation, classically bred or genetically engineered crops, and reduced or no tillage. Although incremental approaches offer improvements and should be continued, in aggregate, they are inadequate to address multiple sustainability concerns.

In contrast, the transformative approach builds on an understanding of agriculture as a complex socioecological system. Transformative change looks to whole-system redesign rather than single technological improvements. Examples of such innovative systems make up a modest, but growing, component of U.S. agriculture and include organic farming, alternative livestock production (e.g., grass-fed), mixed crop and livestock systems, and perennial grains (*1*). Such systems integrate production, environmental, and socioeconomic objectives; reflect greater awareness of ecosystem services; and capitalize on synergies between complementary farm enterprises, such as between crop and livestock production.

The existence of innovative agricultural systems in the United States suggests that technical obstacles are not the greatest barrier. Rather, change is hindered by market structures, policy incentives, and uneven development and availability of scientific information that guide farmers' decisions (see the figure) (Fig. 1).

Market Structures

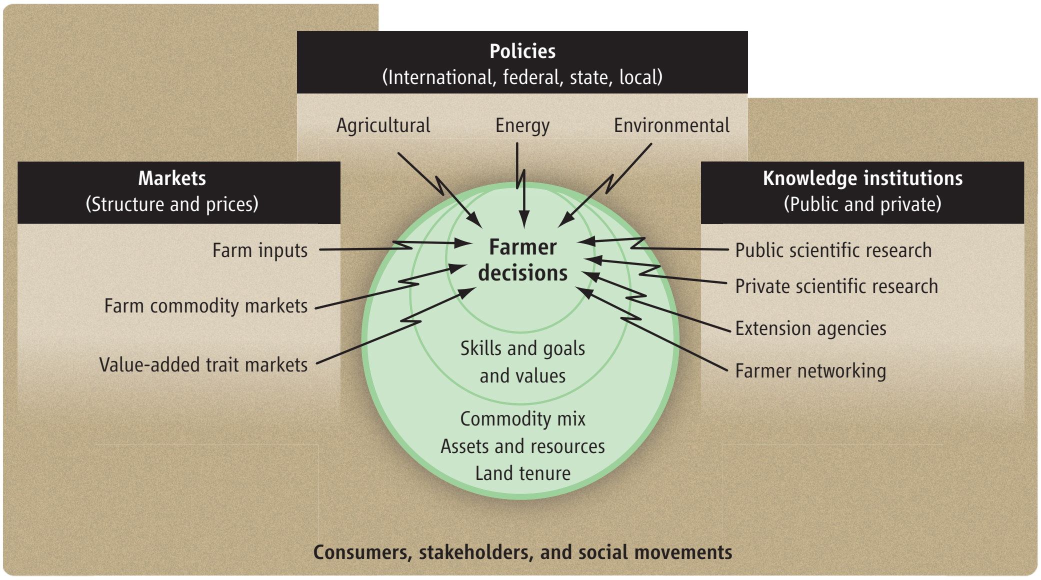
Most U.S. farmers sell products to a highly consolidated global agri-food industry rewarding primarily the provision of large volumes of low-cost food, feed, fiber, and fuel, often constrained by contract requirements of food processors and retailers. Meanwhile, consumer food consumption habits associated with modern life-styles have sustained mainstream farming systems and food markets and have contributed to a national obesity and health crisis. Part of transforming U.S. agriculture is educating more consumers to take responsibility for what they eat and how much they eat (*7*).

Consumer demand is also growing for more environmental and social accountability from farmers, including considerations of animal welfare, ecosystem services, worker safety and welfare, and resource conservation. In response, "value-added trait" foods and "sustainability brands" have emerged in the marketplace, e.g., U.S. Department of Agriculture Certified Organic and Food Alliance Certified. U.S. and global markets for these value-added trait products have driven the spread of local, organic, and grass-fed livestock systems. Market forces could be accelerated through public-policy incentives.

Policy Incentives

Many international, federal, state, and local agricultural, credit, energy, risk management, and environmental policies influence farmer decisions (see the figure). A major policy driver for U.S. agriculture is the Farm Bill, traditionally renewed by the U.S. Congress every 4 to 5 years, with the next version expected in 2012. The best-funded provisions of the Farm Bill include financial assistance for low-income families to purchase food; commodity subsidies paid to farmers (mostly for corn, cotton, rice, soybeans, and wheat); crop insurance and disaster relief; and conservation programs (*8*). Although only roughly a third of U.S. farmers receive commodity or conservation payments under the Farm Bill, it has a major influence on what, where, and how food is produced.

Most elements of the Farm Bill were not designed to promote sustainability. Subsidies are commonly criticized for distorting market incentives and making our food system overly dependent on a few grain crops mainly used for animal feed and highly processed food, with deleterious effects on the environment and human health (*9*, *10*). Redesigning the bill will be a complex undertaking in light of political and budgetary constraints, as well as knowledge gaps. However, much of the information necessary for Farm Bill redesign is available and



Drivers and constraints that affect farmers' decisions. Farmers make choices based on market structures, policy incentives, and knowledge institutions, all affected by consumers, stakeholders, and social movements [Modified from (*1*)]

not being used (*11*). Spending needs to be reduced on programs, such as subsidies, that mask market, social, and environmental risks associated with conventional production systems. Funding needs to be reallocated to encourage markets for sustainability brand products (e.g., by standardizing and defining sustainable product attributes) and to increase support for farming systems that balance all four sustainability goals and are more resilient to resource scarcities and global market variability.

With a new version of the Farm Bill due next year, we think the time to start reform is now. In addition, progress in other policy arenas is needed to address conflicting incentives and unintended consequences. Unless we integrate agricultural sustainability into debates over biofuels and other energy policies, climate change, trade agreements, immigration reform, and environmental regulation, we are unlikely to see major changes in policies that created and continue current production systems.

Agricultural Science and Knowledge

The publicly funded agricultural science portfolio could be reoriented toward agricultural sustainability, as this research is less likely to yield marketable inventions for private agribusinesses. The bulk of public and private agricultural science in the United States is narrowly focused on productivity and efficiency, particularly on technologies that fit into existing production systems and lead to private benefits (*1*, *12*). A major vehicle for public agricultural research is the National Institute for Food and Agriculture (NIFA). Despite NIFA efforts to solicit proposals addressing sustainability, most NIFA and other federal research grant programs still primarily support incremental research. What is needed is reallocation of public funds to support transdisciplinary systems research that explores such interlocking issues as farm productivity and resilience at field, farm, and landscape scales (*13*).

Transition toward transformative agricultural systems currently relies on a smaller, emerging knowledge base developed largely by farmers and nonprofit organizations independent of traditional scientific institutions. Agricultural science and farmers would benefit from an easily accessible information database of farm innovations. Moreover, pilot projects could be funded by reallocation of Farm Bill subsidies to measure multiple sustainability indicators on conventional and innovative farming systems at the landscape or watershed scale (*11*, *14*).

Final Recommendations

To make difficult choices among competing goals requires public dialogue about what kind of food and agriculture we want, in addition to identifying the roles of markets, policies, and science in delivering them (*15*). Successful implementation will require organizations spanning political and institutional boundaries and integrating complex components of agricultural transformation—from research to on-farm implementation, to markets, and to the dinner table. The Green Lands Blue Waters Initiative (*16*) to achieve "systemic transformation in the agricultural systems" in the Mississippi River basin is an example of such an effort. This involves community organizers, policy experts, scientists, and farmers from more than a dozen nonprofit organizations, five universities, and multiple government agencies from the Upper Midwest to the Gulf of Mexico.

The goals of agricultural sustainability are not unique to the United States. Although specific market, policy, and science solutions will need to be appropriate to diverse contexts, the importance of viewing sustainability as more than a technical problem applies to developed and less-developed countries. Lessons from experiences in developed countries can help less-developed countries avoid some problems associated with contemporary, industrialized agricultural systems and can reduce exposure to market volatility and climate change risks. Likewise, U.S. farmers can learn from sustainable agricultural practices of less-developed nations.

References and Notes

1. National Research Council, *Toward Sustainable Agricultural Systems in the 21st Century* (The National Academies, Washington, DC, 2010).
2. D. S. Battisti, R. L. Naylor, *Science* **323**, 240 (2009).
3. International Assessment of Agricultural Science and Technology for Development, *Agriculture at a Crossroads: Global Report* (Island Press, Washington, DC, 2009).
4. J. Rockström *et al.*, *Nature* **461**, 472 (2009).
5. O. De Schutter, *Report Submitted by the Special Rapporteur on the Right to Food* (United Nations, Geneva, 2010).
6. H. C. J. Godfray *et al.*, *Science* **327**, 812 (2010).
7. U.S. Department of Agriculture and U.S. Department of Health and Human Services, *Dietary Guidelines for Americans, 2010*. (U.S. Government Printing Office, Washington, DC, 2010).
8. J. Monke, R. Johnson, *CRS Report for Congress* (R41195, Congressional Research Service, Washington, DC, 2010).
9. T. L. Dobbs, J. N. Pretty, *Rev. Agric. Econ.* **26**, 220 (2004).
10. C. Cox, in *Managing Agricultural Landscapes for Environmental Quality II: Achieving Effective Conservation*, P. Nowak, M. Schnepf, Eds. (Soil and Water Conservation Society, Ankeny, IA, 2011), pp. 81–94.
11. S. S. Batie, *Front. Ecol. Environ* **7**, 380 (2009).
12. W. E. Huffman, R. E. Evenson, *Science for Agriculture: A Long-Term Perspective* (Blackwell Publishing, Ames, IA, ed. 2, 2006)
13. G. P. Robertson *et al.*, *Bioscience* **58**, 640 (2008).
14. J. Sachs *et al.*, *Nature* **466**, 558 (2010).
15. L. Busch, *Nat. Sci. Soc.* **17**, 241 (2009).
16. Blue Lands Green Waters, www.greenlandsbluewaters.org.

17The authors comprise the Committee on Twenty-First Century Systems Agriculture of the National Research Council who wrote the 2010 NRC report (*1*). We thank L. Klein, J. Glover, and E. Sorensen for comments.

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