

Toward Sustainable Agricultural Systems in the 21st Century

U.S. farmers are under pressure to satisfy multiple, often competing demands, such as to produce more crops, pollute less, fulfill consumer preferences, pay fair wages, and make a living—all with increasingly scarce natural resources such as land and water. To evolve farming systems that meet all of these demands, national agricultural policy, research programs, and food markets will need to shift away from emphasizing low costs and high production exclusively and develop a more holistic perspective of how farms provide benefits to society. This report recommends reaching this goal through two parallel efforts: an incremental approach, in which ongoing endeavors to develop sustainable agricultural techniques are expanded; and a transformative approach, in which multiple research areas are brought together to design farming systems that balance the competing demands from the outset.

Modern agriculture has had an impressive history of productivity that has resulted in relatively affordable food, feed, and fiber for domestic purposes, accompanied by substantial growth in agricultural exports. Farm output in 2008 was 158 percent higher than it was in 1948, and farmers today are producing more food with less energy

per unit output than ever before. Despite these advances, much of the recent progress in agriculture has been primarily on satisfying food, feed, and fiber needs, and secondarily on goals such as enhancing environmental quality or increasing the number of farming jobs. For example, the fertilizers and pesticides used to boost crop growth have infiltrated and polluted rivers and waterways.

With global populations rising rapidly, U.S. agriculture faces the challenge of producing



enough food, feed, and fiber to meet increasing demand in conditions of changing climate and scarce natural resources. Innovative policies and new farming approaches based on a strong scientific foundation are needed to tackle the challenge of increasing production while also meeting environmental, economic,

and social goals.

This report, produced with the support of the W.K. Kellogg Foundation and the Bill & Melinda Gates Foundation, reviews progress and identifies future actions that can be taken to improve agricultural sustainability. It also explores how lessons learned in U.S. agriculture could be relevant to agriculture in different regions and settings, specifically in sub-Saharan Africa. It provides an update to the 1989 National Research Council report *Alternative Agriculture*,

which catalogues knowledge gained about the productivity, environmental, and economic impacts associated with different agricultural practices and systems.

Research to Improve Sustainability

At the heart of the goal to meet those multiple demands is the idea of sustainability in agriculture. The report's authoring committee defined sustainability not as any particular end state, but rather as progress towards four goals: (1) producing enough to satisfy human needs; (2) enhancing environmental quality and protecting the natural resource base; (3) being profitable; and (4) increasing the quality of life for farmers, farm workers, and society as a whole. Farm systems also must be flexible enough to adapt to natural and economic stresses as they strive towards the four goals.

Over the past two decades, research has led to the development and adoption of many agricultural practices designed to improve various aspects of sustainability. Progress made so far has not been enough to meet all these multiple challenges simultaneously, in part because not all farmers have adopted the best practices identified by researchers, and in part because most research has focused on relatively narrow goals, with less emphasis on understanding how all the components of a farming system relate to each other. For example, significant research has focused on solving specific problems such as crop breeding to improve yield or irrigation technologies to reduce water use, but less research has investigated how those techniques could be combined to address multiple problems at the same time.

Accelerating Progress Toward Greater Sustainability

Current efforts towards agricultural sustainability will need to be accelerated to be able to meet the rising global demands for food without negatively impacting environmental resources or ignoring broad social and economic concerns such as farm income, the quality of life for farmers and farm workers, and animal welfare. Although all farms have the potential and responsibility to strive towards all four goals of sustainability, variations in scale and type of farm present differing challenges and opportunities. To ensure continuous improvement in sustainability of

U.S. agriculture, the committee concluded that two parallel and overlapping approaches are needed to improve the overall performance of farms:

1. **Incremental Approach.** The incremental approach expands and enhances ongoing efforts to improve sustainability on all farms, irrespective of size or farm type. The goal is to identify and develop farming techniques that can improve specific aspects of sustainability, such as new strategies for water conservation, pest management, novel marketing approaches for increasing farm income, and to accelerate their adoption. One example is the use of "conservation agriculture", which combines the use of reducing tillage practices with appropriate crop rotations to boost productivity and improve soil quality.
2. **Transformative Approach.** This approach seeks to design farming systems that balance the four goals of sustainability from the outset. These systems might depart significantly from the present-day mainstream of agricultural production in United States, and would require new thinking about farming practices and the natural environment, food markets, and communities in which they are embedded. Multidisciplinary research on aspects of these novel farm systems would be needed to develop a knowledge base to inform future policies and practices. Some insights could be gained from examining the differences among existing farm types or practices. For example, comparing organic and conventional farms in different environments and markets could provide information on the efficiency, resilience, environmental, and social impacts of the practices used in these farm types.
 - *Landscape level research*
New research suggests that the distribution of farm types and activities across whole landscapes could be better designed to achieve improved sustainability on local and regional scales. Such landscape-level analysis is particularly important as U.S. farmers begin to incorporate new types of crops, such as biofuel crops, into their farming systems. Challenges to incorporating this approach include:
 - Sparse scientific foundation and data to date for developing the approach

The report provides an update on the farms featured in case studies in the 1989 report *Alternative Agriculture*. A series of new case studies is also included to illustrate practices and concepts discussed in the report. The Bragger Family Dairy, pictured here, was one of three dairy farms selected for study along with three specialty crop farms and three field crop farms.

PHOTO SOURCE: UW-Discovery Farms, reprinted with permission from the University of Wisconsin-Extension.



- Underdevelopment of public policy tools that could be effective in shaping patterns of the agricultural practices or land use at the landscape level.
- The need to adapt agricultural landscape scheme to different locations, because each “agro-ecosystem” involves unique types of soil, hydrology, vegetation, climate, wildlife and other features.
- The necessity to tailor landscape patterns to local conditions and meet particular community needs effectively.

Toward a Better Understanding of the Indicators of Sustainability

Two decades ago, the report *Alternative Agriculture* emphasized the importance of a “systems approach” to agricultural research. Such research is needed to understand the components of farming practices in relation to whole farm systems, and their collective relationship to ecological, economic, and social outcomes.

Yet today, the majority of research funding in agriculture is targeted to improving productivity and reducing production costs. Only about one-third is devoted to exploring environmental, natural resource, social, and economic aspects of farming practices.

On-farm experimentation has inspired much of the innovation that has developed more sustainable agricultural practices. The report recommends “participatory research,” in which farmers work with scientists in development, extension, and outreach processes to identify effective new farming methods

and to encourage the adoption of those methods. In addition, it recommends that farmers’ networks and farmer-to-farmer mentoring programs can help spread knowledge gained from research and lead to the adaptation of techniques to local conditions. Efforts to engage farmers in research and outreach to improve agricultural sustainability will require institutional support from USDA and other agencies. It also recommends that cooperative research and extension programs at the state and regional levels can play a critical role as facilitators for fostering interaction among the various stakeholders and for providing educational programs and access to current information.

Relevance of Lessons Learned to Sub-Saharan Africa

Farmers in sub-Saharan Africa face many different challenges than farmers in the United States. African farmers often produce a wide variety of crops using diverse farming systems, most farms are rain-fed and many soils severely depleted of nutrients, and a lack of infrastructure often inhibits access to outside resources and markets. Despite these differences, the concepts of sustainability and broad approaches presented in this report are relevant to farms in sub-Saharan Africa. With appropriate strategic planning, Africa could reduce or avoid many of the difficulties the United States has faced in meeting the sustainability goals by selecting from the suite of successful and promising integrative approaches. The committee concluded that:

- An interdisciplinary approach is essential to address the improvement and sustainability of

African agriculture. Simple technical fixes are unlikely to address all four sustainability goals. Integrated systems approaches are more likely to be successful and should be adapted to local conditions.

- Research programs need to actively seek input and collaboration from farmers to ensure technologies are developed to meet their needs.
- Women, who play a pivotal role in African agriculture, need to be provided with educational and training opportunities and be involved in the development of research agendas
- Technologies are needed to address soil, water, and biotic constraints, but they have to be integrated with local ecological and socioeconomic processes. Farming systems that make use of locally available resources and natural biophysical processes are likely to offer the greatest potential.
- Examples of promising technologies include soil organic matter management, reduced tillage, integration of crops and livestock, water harvesting, and stress-resistant crop varieties.
- Expanding market access for farms of all sizes will be essential to increase productivity and enhance livelihoods in rural Africa.

Key Drivers of Change

A number of drivers including market forces, public policies, advances in knowledge, and farm operators' individual goals and resources shape decision to use a particular farming practice. Markets and public policies are influenced by societal expectations on how agriculture should be organized and how food should be produced and distributed, and therefore provide critical incentives and disincentives for a shift toward the use of more sustainable farming practices. The certification and branding of food produced using particular farming practices, such as organically produced fruits and vegetables, can enhance the value of the products, developing strong markets that motivate farmers to adopt agricultural techniques that meet sustainability goals.

Although market, policy, and other institutional contexts are important drivers of the overall trajectory of U.S. agriculture, the decisions of individual farmers about which farming techniques to use are complex. Efforts to promote adoption of farming practices and systems to improve sustainability will require a better understanding of how new approaches address the specific goals and objectives of diverse farm operators.

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The National Academies appointed the above committee of experts to address the specific task requested by the Bill & Melinda Gates Foundation and the W.K. Kellogg Foundation. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.



For more information, contact the Board on Agriculture and Natural Resources at (202) 334-3062 or visit <http://nationalacademies.org/banr>. Copies of *Toward Sustainable Agriculture in the Twenty-First Century* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.

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