Impact of Technology on Agriculture

By Orville G. Bentley, *assistant secretary for science and education, USDA,* and
Paul F. O'Connell, *staff assistant to the deputy chief for research, Forest Service*

"The capacity to develop and to manage technology in a manner consistent with a nation's physical and cultural endowments is the single most important variable accounting for differences in agricultural productivity among nations." (Ruttan, Vernon W., *Agricultural Research Policy*), Minneapolis, University of Minnesota Press, 1982). As Ruttan's statement implies, technology policies for the food, fiber, and forestry sectors are of crucial importance if these sectors are to be productive.

Past U.S. technology policies have had a substantial degree of success because of the diversity and efficiency of the food and agriculture system. American consumers spend only 16 percent of their disposable income for food, and the sale of American agricultural and forestry products represents 24 percent of total U.S. exports, contributing substantially to the balance of payments. As an industry, American agriculture since World War II has had a high rate of growth in productivity—a rate more than three times as high as that of the nonfarm industrial sector.

Past achievements will not automatically assure continued future growth in productivity and industry well-being. Vast changes are underway in the social and economic fabric of our society.

- There is a supply and demand imbalance in U.S. agriculture, causing a severe pinch on profitability.
- Rate of technology adoption in other agricultural countries of the world has increased significantly in recent years, creating more competition for U.S. farmers.
- There are continuing concerns about agricultural and forestry production practices and the environment.
- The knowledge of molecular genetics and cellular biology is increasing rapidly, creating and expanding opportunities in improving agriculture worldwide.
- There is increased public awareness of the relationship between personal well-being and diet. Changing life styles and the increasing average age of U.S. citizens has led to questions about nutritional needs.

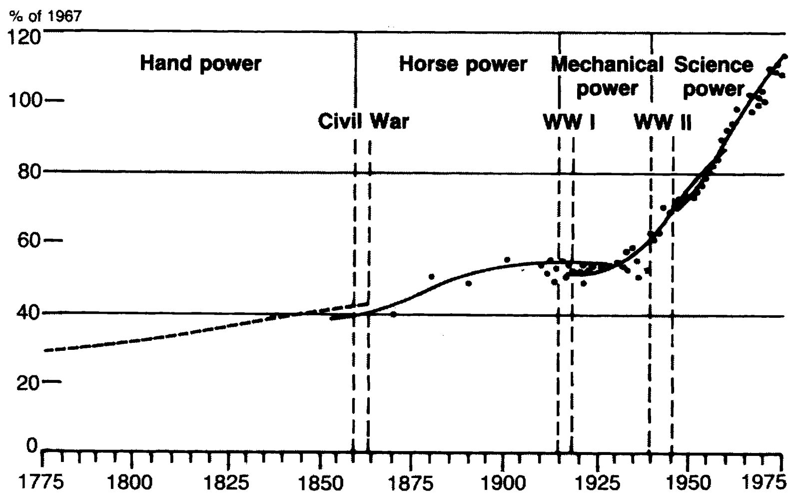
Research and education programs can help in providing options for these and other issues facing agriculture. The long-term answer to farmers' financial squeeze is improved productivity and higher quality products. Environmental and human health goals can be enhanced by developing safer chemical systems. Human nutrition requirements can be better linked to agricultural production by developing plant and animal products that meet changing market demands. Technologies have had a major impact on agriculture in the past and will likely have greater impact in the future.

Productivity and Technology

When a society's resources are being fully used, the real income status of both producers and consumers can be improved only through productivity gains, in periods of commodity surpluses as well as in periods of shortages. Yet one source of uncertainty about what constitutes appropriate productivity and technology policies is confusion about the meaning and use of the term *productivity*. When used accurately, it always refers to the ratio of output per unit of total input. In this measure, the several inputs used in the production of goods and services—land, labor, buildings and equipment, energy, and others—are value-weighted and aggregated so that changes in output can be related to changes in total input. If such a total productivity measure is constructed carefully, it can be interpreted as a reasonably accurate depicter of technical efficiency and used to measure changes in efficiency over time.

From the beginning, improving productivity has been a prime motive for agricultural science and education programs. From the Civil War to World War I, the change from human power to horse power and continuous inventions and improvements in farm implements heralded the first phase of productivity increases. These innovations resulted in an almost twofold increase in labor productivity. During this period, the United States made a commitment to scientifically based agriculture institutionalized in the land-grant college system and the U.S. Department of Agriculture. The period between World Wars I and

U.S. Agricultural Productivity Growth During the Past 200 Years[1]



SOURCE: Lu, Yao Chi and Quance, Leroy, "Agricultural Productivity: Expanding the limits," AIB 431, U.S. Dept. Agr., Econ. Res. Serv., 1979

II saw thc second phase of productivity increases in agriculture, based primarily on internal combustion tractors powered by cheap fuel. Along with the increased use of fertilizer, massive water projects, and a cooperative extension service to transfer this new knowledge, productivity doubled again. Both labor and land productivity increased tremendously in the post-World War II period, because of the application of technologies stemming from the first full phase of scientific agriculture. The key factors were the use of hybrid crop strains, widespread use of pesticides and herbicides, improved nutritional and medical practices in animal husbandry, and the increased use of energy and fertilizers.

Examples of Improved Productivity

The evolution of a science-based agriculture has led to many spectacular changes.

Hybrid Corn. From 1929 to 1933, before the commercial use of hybrids, corn yields averaged 24 bushels per acre. In 1958, hybrid corn varieties accounted for 94 percent of planted corn acreage and U.S. average corn yields exceeded 50 bushels an acre. Twenty

Jack D. Lake

With the introduction of hybrid corn in 1958, corn yields have rapidly increased. The U.S. average is almost 5 times greater than it was 50 years ago. (Michigan, corn bin.)

years later the U.S. average yield broke the 100-bushel mark. These yield increases were made possible by genetic plant improvements which permitted intensive planting practices (high plant populations, better drainage and moisture control, and higher levels of fertilizer and pesticide use) and by the reduction of harvest losses through improved harvesting and drying technology.

The success of hybrid corn also has stimulated the breeding of other crops, such as sorghum hybrids, a major feed grain crop in arid parts of the world. Sorghum yields have increased 300 percent since 1930. Approximately 20 percent of the land devoted to rice production in China is planted with hybrid seed, reported to yield 20 percent more than the best nonhybrid varieties. And many superior varieties of tomatoes, cucumbers, spinach, and other vegetables are hybrids. Today virtually all corn produced in the developed countries is from hybrid corn.

Broiler Chickens. Changes in the broiler chicken industry have been phenomenal over the past 30 years. U.S. broiler production quadrupled, and annual consumption of chicken meat jumped from 23 pounds to over 54 pounds a person in

George A. Robinson

Technology changes in the broiler chicken industry have been phenomenal over the past 30 years. U.S. broiler production has quadrupled and annual consumption of chicken has increased to over 50 pounds per person. (Mississippi, broiler farm.)

1984. The farm price of broilers fell from 36¢ per liveweight pound in 1948 to 33¢ in 1984. After adjustment for inflation, the real price of broilers has fallen even more dramatically.

Improvement in the efficiency of broiler production owes much to public-supported research and to the employment of university-trained geneticists by breeders. In addition to genetic improvement in feed conversion efficiency and quality of meat, there were accompanying changes in housing, feed and waste handling systems, and disease control methods. Over the past 30 years the structure of the industry also has changed significantly. The size of broiler farms has increased while the total number dramatically declined. These larger units employ forward contracting and obtain large scale infusions of credit from feed suppliers.

Farm Management. Farm management specialists devote the great bulk of their farm-oriented research toward developing information and guides for farmers choosing enterprises and methods of production. The largest single group of studies deals with enterprise costs and returns. Production studies are devoted to providing

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Farm management specialists are providing producers with information and alternatives for producing crops and livestock using cost-effective methods, materials, and new technologies. (Colorado, computer specialist and farmer—controlling an irrigation system.)

cost information on alternative ways of producing crops and livestock using alternative irrigation systems, fertilizer combinations, fertilizer and seed, labor-machinery-equipment combinations, alternative rations, and dryland versus irrigation farming. Given this nation's economy, rich in alternative farm technologies and highly dynamic in developing new technologies, it is not surprising that a great deal of effort is devoted to providing guidance in choice of production methods. Nor is it surprising that the choice of enterprise is regarded as the most important decision problem, because comparative advantage shifts as technologies, prices, and institutions change.

The impact of farm management research cannot be measured as easily as the results of biological and physical sciences, but anyone having knowledge of the farm enterprise realizes its importance. In contrast to farmers in controlled economies, U.S. farmers operate as free, independent business managers, controlling their means of production, making their own decisions, and receiving the results of their own labor and management abilities. Helping these independent farmers make the best decisions possible, given the circumstances facing them, has been a major factor in the success story of U.S. agriculture.

Need for Improved Technologies

The urgency of short-term needs of the agricultural sector, such as credit, should not obscure the continuing need of producers and the agricultural support system for scientific knowledge. Continued vigor of the food and fiber industry calls for improved productivity and higher quality goods and services—including more value-added products for the export market. The combination of traditional research methods and the new biotechnology techniques offers tremendous potential for improving the competitive position of U.S. agriculture.

Animal Technologies. New and improved animal technologies point to faster growth rates, less feed per unit of output, increased disease resistance, and more offspring per animal. Animal diets can consist of more forages and crop byproducts, and be supplemented with minerals, vitamins, amino acids, and other nutrients.

Plant Technologies. Using biotechnology techniques and conventional plant breeding, crops will have increased resistance to disease, insects and nematodes. Variation in temperature, water availability, and competition from weeds will have less effect on new, more resistant varieties of tree crops, potatoes, corn, soybeans, and grain sorghum. Genetic engineering can alter plant structures and shapes to improve harvesting and maturing processes with a potential reduction in production costs and improvement in quality.

Nutrition. Plant and animal scientists need a better understanding of the results of human nutrition studies, and nutritionists should become more aware of the realities of agricultural production. Producers need help in adjusting to changing markets. They have made large investments and will resist changes until they can see reasonable options. Scientists and educators are in a good position to provide this help. Nutritious food cannot be provided without the cooperation of the farmer and other performers in the food system.

Future Challenges

Forces creating a need for improved technologies include the following:

- Concerns are increasing about the continued availability of the natural resource base. Improved resource-saving technologies need to be incorporated into current production practices. What resource use patterns are consistent with sustained agricultural uses over time?
- During the past century, converging scientific, economic, and technological developments have led to growing public concern over the effects of these developments on human health and quality of life. Such changes have prompted vigorous debate over the enforcement and adequacy of our laws and regulations. How can the wholesomeness and safety of the nation's food supply be effectively monitored? How can the safety of genetically engineered microbes which may be used in food processing or production be properly evaluated? And how do we evaluate low-level carcinogenic risks from multiple sources?
- The United States has extensive acreages of forest and range resources (71 percent of total land area). These resources provide jobs, wood, wildlife, water, forage, and en-

ergy—and a varied array of recreation opportunities. As with annual crops and domestic farm animals, improved forest and range technologies can increase yields, better protect the resource, reduce input costs, and enhance quality of outputs—all to meet changing demands of domestic and foreign customers.

- The United States is still competitive in world markets for most of its agricultural and forest exports, but its future position and comparative advantage are in question. Comparative advantage is affected by investments in human and natural resources and in research and development of technology as well as by policy and the marketing and transportation system. Understanding the interactions and trends of these variables and then acting on that knowledge is critical for the future of U.S. agriculture.

To meet these challenges, the agricultural science and education system must attract and train scientists and specialists with needed skills in molecular genetics, human nutrition, soil and water sciences, international marketing, systems analysis, agricultural engineering and other specialties.

Some other concerns are: 1) Low salary levels and lack of promotion opportunities in the USDA/State system, which make it difficult to retain highly qualified people in the high-tech fields; 2) Graduate and undergraduate education programs that are not attracting enough students in critical fields; and 3) Obsolete scientific equipment.

The technology development process must continue to consider the incentives of final users. Before new or existing techniques are adopted by an owner, manager, or consumer, many questions need answers. Will an alternative approach be more cost-effective? Can the farmer afford the additional cost when the prices of wheat, corn, or stumpage are so variable? What financial plan best fits a given farm or household? USDA's Cooperative Extension Service has a primary responsibility in this area, but it needs help—especially in the more advanced technical areas such as integrated management systems and technologies resulting from biotechnology. The private sector is becoming more active in the technology transfer process, but scientists also will need to provide more assistance.