Chapter 2

The New Technologies

Chapter 2

The New Technologies

Technology has made U.S. agriculture one of the most productive in the world. Some of that technology has taken the form of new products—che-rnicals to control pests, drugs to control disease, or sensors and computers that automatically measure moisture conditions and irrigate the field. Other technology has been embodied in new processes—such as the ability to use a computer, to make better economic decisions, or to apply the best combination of cultural practices. The emerging technologies encompass both products and processes, and, like their predecessors, promise to reshape the practice of agriculture.

This chapter provides a brief survey of the emerging agricultural production technologies that could have such an impact and analyzes the effect of various technology development and adoption environments on agricultural food production over the next 15 years,

SURVEY OF EMERGING TECHNOLOGIES

Before the turn of the century, cattle ranchers in Texas may be able to raise cattle as big as elephants. California dairy farmers may be able to control the sex of calves and to increase milk production by more than 10 percent without increasing feed intake. Major crops may be genetically altered to resist pests and disease, grow in salty soil and harsh climate, and provide their own fertilizer. And computers and electronics will be used to increase management efficiency. These are only a few of about 150 emerging technologies in the 28 technological areas that have been identified and evaluated for this study (table 2-1). While it may sound like science fiction, advances in biotechnology and information technology will make these technologies a reality in the next 10 to 20 years,

Table 2.1 .—Emerging Agricultural Production Technology Areas

Animal	Plant, soil, and water
Genetic engineering	Genetic engineering ‘‘
Animal reproduction	Enhancement of photosynthetic efficiency
Regulation of growth and development	Plant growth regulators
Animal nutrition	Plant disease and nematode control
Disease control	Management of insects and mites
Pest control	Weed control
Environment of animal behavior	Biological nitrogen fixation
Crop residues and animal wastes use	Chemical fertilizers
Monitoring and controlling	Water and soil-water-plant relations
Communication and information	Soil erosion, productivity, and tillage
Telecommunication	Multiple cropping
Labor-saving technologies	Organic farming
	Communication and information management
	Monitoring and controlling
	Telecommunications
	Labor-saving technologies
	Engine and fuels
	Land management
	Crop separation, cleaning, and processing

SOURCE Office of Technology Assessment

Biotechnology

Animal Agriculture

One of the major thrusts of genetic engineering in animals is the mass production in microorganisms of proteinaceous pharmaceuticals, including a number of hormones, enzymes, activating factors, amino acids, and feed supplements. Previously obtained only from animal and human organs, these biological were either unavailable in practical amounts or in short supply and costly.

Some of these biological can be used for detection, prevention, and treatment of infectious and genetic diseases; some can be used to increase production efficiency. One of the applications of these new pharmaceuticals is the injection of growth hormones into animals to increase productivity. Several firms, including Monsanto and Eli Lilly, are developing genetically engineered bovine growth hormone to stimulate lactation in cows. In trials at Cornell University, daily doses of recombinant bovine growth hormone were administered to dairy cows. The hormone, produced naturally by a cow's pituitary gland, was synthesized by Genentech for Monsanto. The results showed that each cow treated with the hormone increased milk production by at least 12 percent without increasing feed intake. Commercial introduction of the new hormone now awaits approval by the Food and Drug Administration (FDA) (Bachrach, 1984; Hansel, 1984).

Another new technique arising from the convergence of gene and embryo manipulations promises to permit genes for new traits to be inserted into the germ lines of livestock and poultry, opening a new world of improvement in animal health and productivity, Unlike genetically engineered growth hormone, which increases an animal's milk production or body weight but does not affect future generations, this technique will allow future animals to be permanently endowed with traits of other animals and humans, and probably also of plants.

I Pharmaceuticals that are proteins.
'Reproductive cells.

In this technique, genes for a desired trait, such as disease resistance and growth, are injected directly into either of the two pronuclei of a fertilized ovum (egg), Upon fusion of the pronuclei, the guest genes become a part of all of the cells of the developing animal, and the traits they determine are transmitted to succeeding generations.

In 1983, scientists at the University of Pennsylvania and University of Washington successfully inserted a human growth hormone gene, a gene that produces growth hormone in human beings, into the embryo of a mouse to produce a supermouse that was more than twice the size of a normal mouse (Palmiter, 1983). In another experiment, scientists at Ohio University inserted rabbit genes into the embryos of mice. The genetically engineered mice, which were 2.5 times larger than normal, ate as much as normal mice (Mintz, 1984).

Encouraged by the success of the supermouse experiments, USDA scientists at the Beltsville Agricultural Research Center are now conducting a new experiment to produce super sheep and pigs by injecting human growth hormone gene into the germ lines of sheep and pigs (Russell, 1984). In this experiment, USDA scientists provide Ralph Brinster of the University of Pennsylvania with fertilized eggs from sheep and pigs at their Beltsville farms. After injecting the eggs with the human growth hormone genes, Brinster returns the embryos to Beltsville to be inserted into the surrogate mother animals.

The experiments of crossing the genetic materials of different species in general and of using the human growth hormone in particular have prompted lawsuits from two scientific watchdog groups: the Foundation of Economic Trends, headed by Jeremy Rifkin, and the Humane Society of the United States. Both charged that such experiments are a violation of "the moral and ethical canons of civilization, " and they sought to halt the experiment. The researchers argued that they are continuing the experiment cautiously and countered that the potential scientific and practical benefits far outweigh the theoretical problems raised by the critics.

The success of the mice experiments indicates that analogous insertion into bovine germ lines of additional bovine growth hormone genes, or of growth hormone genes from larger mammals such as sperm whales or elephants, could yield larger productivity gains than would somatic injections of growth hormones. Moreover, the change in growth would remain a permanently inheritable characteristic, The expression "a whale of an animal" would no longer be just a figure of speech. Probably, however, the growth hormone gene from any animal may be used (not just hormones from very large animals) as long as enough of that hormone is injected to do the job.

Although some scientists may be too optimistic when they predict in 2 years the development of a lo, ()()()-pound cow and the growth of a pig 12 ft long and 5 ft high (Mintz, 1984), these developments are certainly within the realm of possibility in the next 10 to 20 years, However, some of these changes mayor may not be desirable due to economic, environmental, anatomical, institutional, and ethical reasons.

Another technique, embryo transfer in cows, involves artificially inseminating a superovulated donor animal[4] and removing the resulting embryos nonsurgically for implantation in and carrying to term by surrogate mothers. Prior to implantation, the embryos can be treated in a number of ways. They can be sexed, split (generally to make twins), fused with embryos of other animal species (to make chimeric animals or to permit the heterologous species to carry the embryo to term), or frozen in liquid nitrogen, Freezing is of great practical importance because it allows embryos to be stored until the estrus of the intended recipient on the farm is in synchrony with that of the donor. For gene insertions, the embryo must be in the single-cell stage, having pronuclei that can be injected with cloned foreign genes. The genes likely to be inserted into cattle maybe those for growth hormones, prolactins (lactation stimulator), digestive enzymes, and interferon, thereby providing both growth and enhanced resistance to diseases.

[3]Injections into body cells rather than into reproductive cells.
[4]An animal that has been injected with a hormone to stimulate the production of more than the normal number of eggs per ovulation,

While less than 1 percent of U.S. cattle are involved in embryo transfers, the obvious benefits will push this percentage upward rapidly, particularly as the costs of the procedure decrease (Brotman, 1983). One company, Genetic Engineering Inc. (GEI), already markets frozen cattle embryos domestically and abroad and provides an embryo sexing service for cattle breeders (Genetic Engineering News, 1983).

Plant Agriculture

The application of biotechnologies in plant agriculture could modify crops so that they would make more nutritious protein, resist insects and disease, grow in harsh environments, and provide their own nitrogen fertilizer. While the immediate impacts of biotechnology will be greater for animal agriculture, the long-term impacts may be substantially greater for plant agriculture. The potential applications of biotechnology on plant agriculture include microbial inoculums, plant propagation, and genetic modification.

Microbial Inoculums.—Rhizobium seed inoculums are widely used to improve nitrogen fixation by certain legumes. Extensive study of the structure and regulation of the genes involved in bacterial nitrogen fixation will likely lead to the development of more efficient inoculums. Research on other plant colonizing microbes has led to a much clearer understanding of their role in plant nutrition, growth stimulation, and disease prevention, and the possibility exists for their modification and use as seed inoculums,

Recently, Monsanto announced plans to field-test genetically engineered soil bacteria that produce naturally occurring insecticide capable of protecting plant roots against soil-dwelling insects (Journal of Commerce, Dec. 12, 1984). The company developed a genetic engineering technique that inserts into soil bacteria a gene from a micro-organism known as Bacillus thuringiensis, which has been registered as an insecticide for more than two decades. Plant seeds can be coated with these bacteria before planting. As the plants from these buds grow, the bacteria remain in the soil near the plant roots, generating insecticide that protects the plants.

Plant Propagation.—Cell culture methods for regeneration of intact plants from single cells or tissue explants have been developed and are used routinely for the propagation of several vegetable, ornamental, and tree species (Murashige, 1974; Vasil, et al., 1979). These methods have been used to provide large numbers of genetically identical, disease-free plants that often exhibit superior growth and more uniformity over plants conventionally seed-grown. Such technology holds promise for important forest species whose long sexual cycles reduce the impact of traditional breeding approaches. Somatic embryoss produced in large quantities by cell culture methods can be encapsulated to create artificial seeds that may enhance propagation of certain crop species.

Genetic Modification.—Three major biotechnological approaches—cell culture selection, plant breeding, and genetic engineering—are likely to have a major impact on the production of new plant varieties. The targets of crop improvement via biotechnology manipulations are essentially the same as those of traditional breeding approaches: increased yield, improved qualitative traits, and reduced labor and production costs. However, the newer technology offers the potential to accelerate the rate and type of improvements beyond that possible by traditional breeding.

Of the various biotechnological methods that are being used in crop improvement, plant genetic engineering is the least established but the most likely to have a major impact. Using gene transfer techniques, it is possible to introduce deoxyribonucleic acid (DNA) from one plant into another plant, regardless of normal species and sexual barriers. For example, it has been possible to introduce storage protein genes from French bean plants into tobacco plants (Murai, et al., 1983) and to introduce genes encoding photosynthetic proteins from pea plants into petunia plants (Broglie, et al., 1984),

Transformation technology also allows introduction of DNA coding sequences from virtually any source into plants, providing they are engineered with the appropriate plant gene regulatory signals. Several bacterial genes have now been modified and shown to function in plants (Fraley, et al., 1983; Herrera-Estrella, et al,, 1983). By eliminating sexual barriers to gene transfer, genetic engineering will greatly inc:rease the genetic diversity of plants.

Information Technology

Animal Agriculture

The most significant changes in future livestock production due to information technology will come from the integration of computers and electronics into a modern livestock production system that will make the farmer a better manager.

Computers and electronic devices can be used efficiently in animal feeding, reproduction, disease control, and environmental control. The first step toward efficient management will be with electronic animal identification (Muehling and Jones, 1983). Positive identification of animals is necessary in all facets of management, including recordkeeping, individualized feed control, genetic improvement, and disease control. All animals could be identified soon after birth with a device that would last the life of the animal. The device would be readable with accuracy and speed from 5 to 10 ft for animals in confinement and at much greater distances for animals in feedlots or on pasture. Research on identification systems for animals has been in progress for some years, especially for dairy cows. For example, an electronic device now used on dairy cows is a transponder that is worn in the ear or on a neck chain. A feed-dispensing device identifies the animal by its transponder and feeds the animal for maximum efficiency, according to stage of production. It also permits animals in different stages of production to be penned together yet still be fed properly.

[5]Embryos reproduced asexually from body cells.

Feeding systems with sensing devices also detect outdoor temperature so that animals can be fed accordingly. Since the amount of feed-energy an animal needs under various weather situations and at each stage of growth is known, the ability to sense weather information could fine-tune diet preparation.

A rapid analysis of the feedstuff going into the ration will be available at the farm. In formulating a ration, it will be very helpful to get an instant and accurate reading on the calcium, phosphorus, and Iysine contents of the ration ingredients, This will permit a feedback control to adjust the mill and mixer automatically to provide an optimum feed.

The largest potential use of electronic devices in livestock production will be in the area of reproduction and genetic improvement. An inexpensive estrus detection device, for example, would prove profitable in several ways:

- Animals could be rebred faster after weaning and increase the number of litters per year.
- Animals that did not breed could be culled from the herd, saving on feeding and breeding space.
- Time would be saved because breeding would be done faster.
- Embryo transplants would be easier because of better estrus detection.

Another use of information technology is in disease control and prevention (Osburn, 1984). Computers and computer programs are being used at many dairies and swine production units and in the poultry industry. Herd recordkeeping systems for animal health are being developed and refined for various production units. Examples of these programs now in operation include FARMHX in Michigan and similar systems in New York and California (Mather, 1983). These recordkeeping systems may be linked with animal identification systems, including radiotransmitters, as indicated earlier. Examples of the types of information that can be recorded for each animal include production records, feed consumption, vaccination profiles, breeding records, conception dates, number of offspring, listing and dates of diseases, and costs of medicants for treatment or prevention of disease, A review of printouts will allow the manager or veterinarian to analyze quickly a health profile for each animal. Bringing all of this information together will allow the veterinarian and manager of the livestock enterprise to plan for more cost-effective disease control programs and to designate the duties, such as vaccinations and pregnancy examinations, that are to be carried out, These programs are being applied and refined on a few farms. By 1990 many of the more progressive livestock producers will be using these systems, and by 2000 these systems will be widely applied to nearly all of the cost-efficient livestock production units.

Environmental control of livestock facilities is another area where electronic devices can be used. Microprocessors will be used to alleviate odorous gases and airborne dust in ventilation systems.

Plant Agriculture

One of the applications of information technology in plant agriculture is in the management of insects and mites (Kennedy, 1984), Improvements in the design and availability of computer hardware and software will produce tremendous changes in insect and mite management at all levels (research, extension, pest management, personnel, and farmer). To be implemented efficiently, as measured by its contribution to crop profitability, insect and mite management requires the processing of voluminous quantities of information, including: 1) condition and phonological stage of the crop, 2) status of the various insect and mite pests and their natural enemies present in the crop, 3) production inputs into the crop, 4) incidence of plant diseases and weed pests and the measures used in their control, 5) weather conditions, and 6) insect and mite management options. Further, this information must be updated and reviewed at regular intervals, Computers can help superbly in the effective and efficient processing of this information as well as in the design, direction, and analysis of pest management-related research.

The availability at the farm level of microcomputers equipped with appropriate software and having access to larger centralized data bases will greatly speed the transfer of information and facilitate pest management decisionmaking. The advantages, simply in terms of information storage and retrieval, will be tremendous, The ready storage of and access to current and historical information on pest biology, incidence, and abundance; pesticide use; cropping histories; weather; and the like at the regional, farm, and even field level will facilitate the selection of the appropriate management unit and the design and implementation of pest management strategies for that unit.

Centralized, computer-based, data management systems for crop, pest, and environmental monitoring information have been developed and are being evaluated for use on a regional scale by a USDA / Animal and Plant Health Inspection Service regional program. Such systems will provide rapid analysis, summarization and access to general crop summaries, observer reports, pesticide and field management information, reports of new or unknown pests, general pest survey information, and specified field locations with pest severities.

Other software systems designed to facilitate directly the implementation of pest management programs are in use and are continually being improved. The Prediction Extension Timing Estimator (PETE) model (Welch, et al., 1978) is a generalized model for the prediction of arthropod phonological events. PETE is sufficiently flexible to be used for management in many agricultural and nonagricultural systems, For example, it is used as a part of the broader biological monitoring scheduling system (BIOSHED) developed in Michigan by Gage and others (1982) for a large number of pests on a wide variety of crops (Croft and Knight, 1983).

Experiences with these and other software systems have demonstrated their great value and identified areas where improvements are needed. It has also pointed out that the data base from which biological models are developed is limited, Since all biological models are only as good as the biological information upon which they are based, the continued development and improvement of such models for use in integrated pest management (1PM) is contingent on continued high-quality research on the appropriate aspects of plant and pest biology and ecology,

The advantages provided by computer software are tremendous, in terms of improved efficiency and accuracy with which pest management decisions can be made and implemented. There is a great deal of effort currently being devoted to the development of new software and the improvement of existing software. This, in conjunction with the rapid advances being made in computer hardware, provides a powerful force that will lead to dramatic changes in the implementation of 1PM and to increases in the level of sophistication of 1PM, where such increases are desirable.

A detailed description of all technologies examined in this study will be presented in OTA'S full report later this year,

IMPACT OF EMERGING TECHNOLOGIES ON PRODUCTION

To help analyze the impact of emerging technologies on agricultural productivity, OTA commissioned leading scientists in each of the 28 technology areas studied to prepare papers on the state of the art. The papers were valuable resources for workshops conducted to assess the impacts of emerging production technologies. Participants in the workshops—on animal and plant agriculture—provided data on: *1)* the timing of commercial introduction of each technology area, 2) the number of years needed to adopt the technology (by commodity), and 3) yield increases (by commodity) expected from the technology. Workshop participants included physical and biological scientists, engineers, commodity extension specialists, economists, agribusiness representatives, and experienced farmers.

Since the impact of a new technology on agriculture at a given time depends in part on when the technology is available for commercial introduction, workshop participants were asked to estimate the probable year of commercial introduction of each technology under four alternative environments:

1. Baseline environment—assumes to 2000: a) a real rate of growth in research and extension expenditures of 2 percent per year, and b) the continuation of all other forces that have shaped past development and adoption of technology.
2. No-new-technology environment—assumes that none of the technologies identified in the study will be available for commercial introduction by 2000.
3. Less-new-technology environment—assumes to 2000: a) no real rate of growth in research and extension expenditures, and b) all other factors less favorable than those of the baseline scenario.
4. More-new-technology environment—assumes to 2000: a) a real rate of growth in research and extension expenditures of 4 percent, and b) all other factors more favorable than those of the baseline scenario.

The year of commercial introduction ranged from now—for genetically engineered pharmaceutical products; control of infectious disease in animals; superovulation, embryo transfer, and embryo manipulation of cows; and controlling plant growth and development—to 2000 and beyond—for genetic engineering techniques for farm animals and cereal crops. Of the 57 potentially available animal technologies, it was estimated that 27 would be available for commercial introduction before 1990, and the other 30 between 1990 and 2000, under the baseline environment. In plant agriculture, 50 out of 90 technologies examined were projected to be available for commercial introduction by *1990,* and the other 40 technologies between *1990* and 2000.

Historical trend lines of efficiency measurements of crop and livestock production were provided to the participants as a starting point for their assessment of impact on productivity. Through the Delphi process, participants collectively projected the primary impacts of the technologies on each of the nine commodities for 1990 and 2000 under the different environments. Based on the information obtained from the workshops on the year of commercial introduction, the adoption profile, and the primary impacts, OTA computed crop yields and production efficiencies for the nine commodities for 1990 and 2000 (table 2-2).

Projections of Agricultural yield

Under the baseline environment, major crop yields are estimated to increase from now until 2000 at a rate ranging from 0.8 percent per year, for soybeans and cotton, to 1.3 percent per year, for wheat. Wheat yield, for example, is projected to increase from 35.6 bushels per acre in 1982 to 44.8 bushels per acre in 2000 at the rate of 1.3 percent per year under the baseline environment. However, under the no-new-technology environment, wheat yield would increase to 40,8 bushels per acre in 2000 at the rate of 0.8 percent a year. The difference in wheat yield between the two environments, 4 bushels per acre, represents the impact of new technologies.

Under the baseline environment, feed efficiency in animal agriculture would increase at a rate of from 0.4 percent per year for beef to 0.8 percent for poultry, In addition, the reproduction efficiency would also increase, at an annual rate ranging from 0.5 percent, for beef cattle, to 0.9 percent, for swine. Milk production per cow per year would increase from 12,300 pounds (lbs) to 17,563 Ibs per cow in the period 1982-2000. Without new technologies, milk production per cow per year would increase to only 13,700 lbs in 2000; under the

Table 2-2.—Estimates of Crop Yields and Animal Production Efficiency

		No-new-technology environment		Baseline environment		More-new-technology environment	
	1982	1990	2000	1990	2000	1990	2000
Corn bu per acre	115	117	124	119	139	121	150
Cotton lb per acre	481	502	511	514	554	518	571
Rice bu per acre	105	105	109	111	124	115	134
Soybean bu per acre	30	32	35	32	37	33	37
Wheat bu per acre	36	38	41	39	45	40	46
Beef							
Pounds meat per lb feed	0.070	0.071	0.066	0.072	0.072	0.072	0.073
Calves per cow	0.90	0.94	0.96	0.95	1.0	0.95	1.04
Dairy							
Pounds milk per lb feed	0.94	0.94	0.95	0.95	1.03	0.96	1.11
Milk per cow per year (thousand lb)	12.3	13.7	15.7	14.0	17.6	14.2	19.3
Poultry							
Pounds meat per lb feed	0.44	0.52	0.53	0.53	0.57	0.53	0.58
Eggs per layer per year	245	255	260	258	275	257	281
Swine							
Pounds meat per lb feed[a]	0.165	0.167	0.17	0.17	0.176	0.17	0.18
Pigs per sow per year	14.4	14.8	15.7	15.2	17.4	15.5	17.8

[a]The value shown fo,swine feed efficiency for 1982 is the average of national feed efficiencies for the 10 Years Prior to 1982 The national aggregate linear trend of swine feed efficiency is slightly negative and gives a value of ,157 in 1982.

SOURCE. Office of Technology Assessment

more-new-technology environment, production could reach *19,300* lbs.

Projections of food Production

The data obtained from the two technology workshops were used in an econometric model developed by the Center for Agricultural and Rural Development at Iowa State University to assess the collective impact of the 28 areas of emerging technologies on the production of various crop and livestock products.

Table 2-3 shows projections to 2000 of increased production for three major U.S. export commodities (which comprise 60 percent of U.S. agricultural food production exports). Under the baseline environment, corn production is projected to increase at the rate of 1.8 percent per year from 1981 to 2000. However, without the new technologies examined in this study, the rate of growth would be only 1.2 percent. Under the more-new-technology environment, corn production would increase at a much faster rate—2.2 percent per year,

About the same growth rates were obtained for wheat production, which would increase at *1.8* percent per year from 1981 to 2000 under the baseline environment. Under the no-new-technology environment, wheat production would increase at only 1 percent per year,

A more drastic increase in soybean production is projected from now until *2000* regardless of the environment considered. The annual production of soybeans is projected to increase under the baseline environment at an annual rate of *2.8* percent from 1981 to 2000. Without new technologies, the production is still expected to increase at *2,4* percent a year. Under the more-new-technology environment, soybean production would increase at *2.9* percent per year.

In the world marketplace available information points to a series of periodic surpluses and deficits in agriculture over the next two decades (Mellor, 1983; Resources for the Future, *1983).* A Resources for the Future (RFF) study indicates that global balance between cereal production and population will remain quite close to *2000,* indicating vulnerability to annual shortfalls resulting from weather, wars, or mistakes in policy. Over the next *20* years the world will become even more dependent on

Table 2-3.—Projection of Major Crop Production

Crop	Unit	1981	2000 No-new-technology environment	2000 Baseline environment	2000 More-new-technology environment
Corn					
Production	Million bushels	8,136	10,289.0	11,499.0	12,394,0
Growth rate	Percent		1.2	1.8	2,2
Wheat					
Production	Million bushels	2,704	3,273.0	3,825.0	4,063.0
Growth rate	Percent		1.0	1.8	2.2
Soybean					
Production	Million bushels	1,953	3,067.0	3,311.0	3,351.0
Growth rate	Percent		2.4	2.8	2.9

SOURCE Off Ice of Technology Assessment

trade. There will be increasing competition for U.S. farmers in international markets. Much of this increased competition will come from developing countries selling farm commodities as a source of exchange to pay for imports such as oil. Despite this increased competition, exports of grain from North America are projected to nearly double by 2000.

On the other hand, there is another school of thought that believes current studies such as that by RFF have not properly assessed the magnitude and impact of emerging technologies on farm production. Technologies such as genetic engineering and electronic information technology that are available in various forms could mean rapid increases in yields and productivity. While such changes may improve the competitive position of American agriculture, they have the potential for creating surpluses and major structural change—favoring, for example, larger more industrialized farms.

Any conclusion regarding the balance of global supply and demand requires many assumptions regarding the quantity and quality of resources available to agriculture in the future. Land, water, and technology are likely to be the limiting factors as far as agriculture's future productivity is concerned.

Agricultural land that does not require irrigation is becoming an increasingly limited resource. In the next 20 years, out of a predicted 1,8 percent annual increase in production to meet world demand, only 0.3 percent will come from an increased quantity of land used in production (RFF, 1983), The other 1.5 percent will have to come from increases in yields—mainly from new technology, Thus, to a very large extent, research that produces new technologies will determine the future world supply—demand balance and the amount of pressure placed on the world's limited resources.

The OTA results indicate that with continuous inflow of new technologies into the agricultural production system, U.S. agriculture will be able not only to meet domestic demand but also to contribute significantly to meeting world demand in the next 20 years, This does not necessarily mean that the United States will be competitive or have the economic incentive to produce. It means only that the United States will have the technology available to provide the production increases needed to export for the rest of this century.

Under the baseline environment, growth rates in production, which include additional land resources and new technology, will be adequate to meet the 1.8 percent needed to balance world supply and demand in 2000. Under the more-new-technology environment, production could increase at 2,2 percent per year, which would be more than enough to meet world demand. This increased production could, however, point to a future of surplus production. On the other hand, under the less-new-technology environment the production of major crops in 2000 would drop to 1.6 percent per year, a growth rate that would not be able to meet the demand. Under the no-new-technology environment, the annual rate of production growth would be reduced further to 1.1 percent. It should be noted that if the current administration proposal to reduce the agricultural research budget is accepted by Congress, the rate of production growth would be somewhere between 1.1 to 1.6 percent.