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Over the next 15 years, American farmers will be offered an extensive array of new biotechnologies and information technologies that could revolutionize animal and plant production. The adoption of these technologies will be critical for shoring up the United States' lagging ability to compete in the international marketplace. Indeed, 83 percent of the estimated 1.8-percent annual increase in agricultural production needed to meet world agricultural demand by year 2000 must come from increases in agricultural yields, yields that can only be possible through the development and adoption of emerging technologies.

Yet if current agricultural policies remain in force, this new biotechnology and information technology era will also generate marked changes in the structure of the agricultural sector and of the rural communities that support farming. Some of these changes are' already evident: Farming is becoming more centralized, more vertically integrated. Large farms, though small in number, now produce most of this country's agricultural output. Operators of small and moderate-size farms, the so-called backbone of American agriculture, are becoming increasingly less able to compete, partly because they lack access to the information and finances necessary for adopting the new technologies effectively. Many such farmers must relocate, change to other kinds of farming, or give up farming altogether. The disappearance of these farm operations is causing repercussions for other businesses in the rural community and for the labor pool in general, which must absorb all those whose livelihood once depended on agricultural production.

This report is the first step toward understanding the social and economic costs, as well as the benefits, of the emerging technologies for U.S. agriculture. It analyzes the dynamic forces influencing change in the structure of agriculture. Although technology was found to be an important force in such change, it is only one of several such forces. Public policy, institutions, and economics have had and will continue to have important roles in shaping agriculture. OTA analyzed the relationships between all these factors, focusing on the 150 production technologies that are likely to be available commercially over the next 15 years. The study results are presented in this report in four parts.

Part I identifies and analyzes the productive capacity of those emerging technologies that will help shape and define American agriculture to the year 2000. Chapters 2 and 3 describe the emerging technologies, discuss how they will be used in agriculture, and analyze the impact these technologies will have on animal and plant agriculture.

Part II traces the historical changes in agricultural structure. It provides a perspective for analyzing technology's distributional impacts on agricultural structure by surveying the characteristics of that structure and the factors that affect it.

How the emerging technologies, the policies, and structural change relate to one another is the subject of chapters 6 through 12 in part III. The chapters analyze the results of this relationship on: 1) future structure, 2) agricultural finance and credit, 3) survivability of crop and dairy farms of various sizes, 4) environment, 5) rural communities, and 6] agricultural research and extension.

Part IV draws the implications of the analysis for policy makers. It shows the direction in which agriculture is headed and concludes with congressional policy options for improving the picture of U.S. agriculture.

AGRICULTURAL DEPENDENCEY ON WORLD MARKETS

The financial condition of many American farmers in the 1980s has significantly deteriorated during a long period of surpluses. The decline in agricultural exports is largely responsible for this situation. And although exports are not this report's central focus, the future of U.S. agricultural exports loom large in the background of this report.

Agricultural exports have historically been responsible for lessening the negative trade balance caused primarily by the manufacturing and energy sectors. This importance of agriculture to the balance of trade has increased significantly over the past 30 years. However, the past several years have witnessed a drop both in the value of U.S. agricultural exports and in agriculture's share of total U.S. exports.

Several key factors are causally related to recent declines in U.S. agriculture:

1. a weak world economy,
2. the strong value of the dollar,
3. the enhanced competitiveness of other countries,
4. an increase in trade agreements, and
5. price support levels that permit other countries to undersell the United States.

Although all of the factors are important, agricultural experts are beginning to focus on the lower costs of production in other countries as the long-term primary factor in the decline of this country's competitiveness. The United States faces strong competition in wheat, corn, rice, soybeans, and cotton. Each of these major export commodities has been produced by at least one country at or below the U.S. average production costs since 1981. Estimates suggest that any historic cost advantage that the United States may have enjoyed in these commodities is now tenuous.

Future exports will depend on the ability of American farmers to use new technology to produce commodities more efficiently than competing countries can. If the United States cannot effectively compete with other countries in the export market, reduced exports will magnify the structural change and adjustment that U.S. farmers and the rural communities will face because of technological change.

EMERGING TECHNOLOGIES FOR AGRICULTURE

Technology has made U.S. agriculture one of the world's most productive and competitive industries. Americans have already witnessed the dramatic results of two major technological eras in agriculture. The mechanical era of 1920 to 1950 allowed farmers to make the transition from horsepower to mechanical power and greatly increased the productive capacity of U.S. agriculture. The chemical era of ***1950*** to ***1980*** further increased agricultural productivity by increasing the farmers' ability to control pests and disease and by increasing the use of chemical fertilizers. Now, in the 1980s, American agriculture is being propelled by a new major technological thrust—the biotechnology and information technology era. The effects of this new era on agricultural productivity may be more profound than those experienced from either the mechanical or chemical eras.

Below is a brief summary of the technologies examined for this study. A more complete description of the 150 technologies can be found in chapter 2.

BIOTECHNOLOGY

Biotechnology, broadly defined, includes any technique that uses living organisms or processes to make or modify products, to improve plants or animals, or to develop micro-organisms for specific uses. It focuses on two powerful molecular genetic techniques: recombinant deoxyribonucleic acid (rDNA) and cell fusion technologies. Using these techniques scientists can visualize the gene—to isolate, clone, and study the structure of the gene and the gene's relationships to the processes of living things. Such knowledge and skills will give scientists much greater control over biological systems, leading to significant improvements in the production of plants and animals,

Animal Agriculture

In animal agriculture, advances in protein production, gene insertion, and embryo transfer will play a major role in increasing efficiencies in animal production.

Production of Protein.—One major thrust of biotechnology in animals is the mass production in micro-organisms of protein-like pharmaceuticals, including a number of hormones, enzymes, activating factors, amino acids, and feed supplements. Previously, these biological products could be obtained only from animal and human organs and were either unavailable in sufficient amounts or were too costly.

Some of these biological products can be used for detection, prevention, and treatment of infectious and genetic diseases; some can be used to increase animal production efficiency, One of the applications of these new pharmaceuticals is the injection of growth hormones into animals to increase production efficiency. For example, several firms are developing a genetically engineered bovine growth hormone to stimulate lactation in cows. Trial results indicate that cows treated with the hormone increase milk production by 20 to 30 percent, with only a modest increase in feed intake. Commercial introduction of the new hormone awaits approval by the U.S. Food and Drug Administration, which is expected to approve the hormone within the next 3 years.

In the area of disease prevention and treatment, an immunological product currently exists on the market that prevents "scours" in calves. In addition, vaccines produced by rDNA methods are currently being tested for foot-and-mouth disease, swine dysentery and, most recently, coccidiosis in poultry.

Gene Insertion.—A new technique arising from the convergence of gene and embryo manipulations promises to permit genes for new traits to be inserted into the reproductive cells of livestock and poultry, providing major opportunities to improve animal health and productivity. Unlike the genetically engineered hormones discussed above, which cannot affect future generations, gene insertion will allow future animals to be endowed permanently with traits of other animals. In this technique, genes for a desired trait, such as disease resistance or growth, are injected directly into either of the two pronuclei of a fertilized egg. on fusion of the pronuclei, the guest genes become part of all the cells of the developing animal, and the traits they determine are transmitted to succeeding generations.

Embryo Transfer.—Embryo transfer, which is closely related to gene insertion, involves artificially inseminating a super-ovulated donor animal[1] and removing the resulting embryos nonsurgically for implantation in surrogate mothers which then carry them to term. Prior to implantation, the embryos can be treated in a number of special 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 for storage. Freezing is of great practical importance because it allows embryos to be stored until the estrus of the intended farm animal is in synchrony with that of the donor. Embryos used for gene insertions 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 stimulators), digestive enzymes, and interferon, thereby providing both growth and enhanced resistance to diseases.

Even though less than 1 percent of U.S. cattle are involved in embryo transfers, the obvious

[1]An animal that has been injected with a hormone to stimulate the production of more than the normal number of eggs per ovulation.

benefits of this technology will push this percentage upward rapidly, particularly as the costs of the procedure decrease. Recently, a genetically superior Holstein cow and her 14 embryos were purchased for $1.3 million.

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 will be greater for animal agriculture, the long-term impacts of biotechnology may be substantially greater for plant agriculture. The potential applications of biotechnology on plant agriculture include microbial inoculums, plant propagation, and genetic modification.

Microbial Inocula.-Rhizobium seed inocula already are used widely to improve the nitrogen fixation of certain legumes. Extensive study of the structure and regulation of the genes involved in bacterial nitrogen fixation will likely lead to development of improved inocula. Moreover, research on other plant-colonizing microbes has led to a clearer understanding of the role of these microbes in plant nutrition, growth stimulation, and disease prevention, and the possibility exists for the modification and use of these microbes as seed inocula.

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

Plant Propagation.—Cell culture methods for regeneration of intact plants from single cells or tissue explants are now used routinely for propagation of several vegetable, ornamental, and tree species. These methods can 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 breeding in important forest species whose long sexual cycles reduce the impact of traditional breeding approaches. Somatic embryos' 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.—Plant genetic engineering is the least established of the various biotechnologies used in crop improvement, but the most likely to have a major impact. Using gene transfer techniques, it is possible to introduce DNA from one plant into another plant, regardless of normal species and sexual barriers. For example, it is possible to introduce storage-protein genes from French bean plants into tobacco plants and to introduce genes that encode photosynthetic proteins in pea plants into petunia plants.

Transformation technology also allows introduction of DNA coding sequences from virtually any source into plants, providing those sequences are engineered with the appropriate plant-gene regulatory signals. Several bacterial genes have now been modified and shown to function in plants. By eliminating sexual barriers to gene transfer, genetic engineering will greatly increase a plant's genetic diversity.

Information Technology

Animal Agriculture.

Information technology is the use of computer- and electronic-based technologies for the automated collection, manipulation, and processing of information for control and management of agricultural production and marketing. The most significant changes in future livestock production resulting from information technology will come from the integration of computers

[2]Embryos produced from body cells rather than reproductive cells.

and electronics into modern livestock production systems that will help make the farmer a better manager. Animal identification, animal reproduction, and disease control and prevention are some promising areas for information technology in livestock production.

Electronic Animal Identification.—Positive identification of animals is necessary in all facets of management, including recordkeeping, individualized feed control, genetic improvement, and disease control. Research on identification systems for animals has been in progress for some years. Soon, all farm animals will be "tagged" shortly after birth by an electronic device, called a transponder, that lasts the life of the animal. For example, some dairy cows now wear a transponder in the ear or on a neck chain. A feed-dispensing device identifies the animal by the transponder's signal and provides an appropriate amount of feed for the animal.

Reproduction. —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 will allow: 1) animals to be rebred faster after weaning; 2) animals that did not breed to be culled from the herd, saving on feeding and breeding space; 3) time to be saved because breeding can be done faster; and 4) easier embryo transplants because of improved estrus detection.

Disease Control and Prevention.—Herd recordkeeping systems for animal health are already being developed and refined in the dairy, swine, and poultry industries. These recordkeeping systems will eventually be linked with the animal identification systems discussed above. 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 medicines for treatment or prevention of disease. Bringing all this information together will allow the veterinarian and a manager of the livestock enterprise to analyze quickly a health profile for each animal and *to* plan for improved efficiency in disease control programs.

Plant Agriculture

Pest Management.—Information technology is already being used in plant agriculture for the management of insects and mites. Design improvements and availability of computer hardware and software will produce marked changes in insect and mite management.

Availability at the farm level of microcomputers, equipped with appropriate software and having access to larger centralized databases, will accelerate transfer of information and facilitate pest management decisionmaking. The advantages, simply in terms of information storage and retrieval, will be of major importance. 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 selection of the appropriate management unit and the design and implementation of pest management strategies for that unit.

Current software has already greatly improved the efficiency and accuracy with which pest management decisions can be made and implemented. Much effort is being devoted to the development of new software and the improvement of existing software. The resultant products, in conjunction with the rapid advances being made in computer hardware, will provide a powerful force that will lead to dramatic changes in the implementation of integrated pest management (1PM) and to increases in the level of sophistication of 1PM.

Irrigation Control Systems .—Because irrigation decisions are complex and require relatively large amounts of information, a microcomputer-based irrigation monitoring and control system is especially useful in areas with soils having variable percolation and retention rates, where rainfall is especially variable, or where the salinity of irrigation water changes unpredictably. In this system, a network of sensors, with radio links to the central processor, is buried in irrigated fields. Additional sensors may include weather station sensors to estimate crop stress and evaporation rates, salinity sensors, and runoff sensors. The central processor uses such information to allocate water automatically according to crop needs in each field, subject to considerations of cost, leaching requirements, and availability of water.

Radar, Sensors, and Computers.—Through the use of radar, sensors, and computers the correct amount of fertilizer, pesticides, and plant growth regulators can be applied to plants by integrating tractor slippage and chemical flow. The correct rate of application of most agricultural chemicals is usually within a narrow range for a given crop and field. However, application rates are often variable from area to area within a field, owing to changes in the flow rate of chemical slurries and to changes in tractor wheel slip, grading, and drawbar tension. Economic and environmental costs are associated with applications of too little or too much chemicals. Control of application rate depends on the ability to estimate rate of flow through the chemical sprayer and on the vehicle's speed over the field. The speed indicated by sensors in the tractor drivetrain is usually greater than the actual speed over the ground, owing to slippage of the drive wheels. The amount of slippage can be monitored by a doppler radar device that compares actual speed to indicated speed in the drivetrain. When all this information is available, a computer can then adjust the spray line pressure to deliver the correct amount of chemicals at varying speeds and amounts of wheel slip.

THE CHANGING STRUCTURE OF AGRICULTURE

Agriculture is entering a new technological era at a time when the character of agriculture is changing rapidly. Emerging biotechnologies and information technologies will be introduced within a socioeconomic structure that has undergone considerable change in the last 50 years and that promises to continue to change throughout the remainder of this century.

one of the best ways to look at changes in the economic structure of U.S. agriculture is in terms of value of production as measured by gross sales per year. In this way farms can be usefully classified into five categories of gross sales, as shown in table 1-1.

Small and part-time farms generally do not provide a significant source of income to their operators. Most of these farmers obtain their primary net income from off-farm sources. However, this segment is highly diverse. This class of farms is operated either by subsistence farmers or by individuals who use the farm as either a tax shelter or a source of recreation.

Moderate-size farms cover the lower end of the range in which the farm is large enough to

Table 1-1 .—Distribution of Farm Sizes, Percent of Cash Receipts, Percent of Farm Income, and Farm and Off-Farm Income per Farm by Sales Class, 1982

Sales class	Value of farm products sold	Number of farms	Percent of all farms	Percent of total cash receipts	Percent of net farm income	Average net farm income	Average off-farm income	Average total income
Small	<$20,000	1,355,344	60.6	5.5	–3.8	(615)	20,505	19,890
Part-time	*$20,000-$99,000*	*581,576*	*25.9*	*21.8*	*5.4*	**998**	*13,220*	*14,218*
Moderate.	$100,000-$199,000	180,689	8.1	19.1	14.6	17,810	11,428	29,236
Large	$200,000"$499,000	93,891	4.2	21.0	20.4	48,095	12,634	60,929
Very large	> $500,000	27,800	1.2	32.5	63.5	504,632	24,317	529,149
	All farms	2,239,300	100	100	100	$9,976	$17,601	$27,578

SOURCE: Compiled from *Economic Indicators of the Farm Sector: Income and Balance Sheet Statistics, 1983*, USDA Economic Research Service, 1984, table 59, using farm number and cash receipts distribution from the *1982 Census of Agriculture*, U.S. Department of Commerce, Bureau of the Census, 1984.

be the primary source of income. However, most families with farms in this range also rely on off-farm income.

Large and very large farms include a diverse range of farms. The great majority of these farms are family owned and operated. Most require one or more full-time operators, and many depend on hired labor full time. The degree of contracting (monitoring and controlling production to produce a specified quantity of homogeneous products for a buyer) and vertical integration is much higher in this class.

To appreciate how agriculture has changed just between 1969 and 1982, consider the following:

- The number of small farms declined 39 percent, while the number of very large farms increased by 100 percent.
- The share of cash receipts from very large farms increased slightly, from 29 to 33 percent, while cash receipts declined from 40 to 25 percent for small and part-time farms.
- The share of net farm income declined significantly (from 36 to 5 percent) for small and part-time farms, and increased from 36 to 64 percent for very large farms.

These trends indicate that small and part-time farms no longer can depend on the farm to provide an adequate income. Large-scale farms dominate agriculture. Moderate-size farms have a small share of the market and a stagnant share of net farm income. The agricultural sector can be described as a bipolar, or dual sector: As the moderate-size farm disappears, it leaves small and part-time farms clustered at one end of the farming spectrum and large farms clustered at the other, in terms of their importance to agriculture.

If present trends continue to the end of this century, the total number of farms will continue to decline from 2.2 million in 1982 to 1.2 million in 2000 (table 1-2). The number of small and part-time farms will continue to decline, but will still make up about 80 percent of total farms. The large and very large farms will increase substantially in number. Approximately 50,000 of these largest farms will account for 75 percent of the agricultural production by year 2000. The trend toward concentration of agricultural resources into fewer but larger farms will continue, although the degree of concentration will vary by region and commodity.

Moderate-size farms will decline in number and in proportion of total farms, have a small share of the market and a declining share of net farm income. These farms comprise most of the farms that depend on agriculture for the majority of their income. Traditionally, the moderate-size farm has been viewed as the backbone of American agriculture. These farms are failing in their efforts to compete for their historical share of farm income.

Table 1-2.—Most Likely Projection of Total Number of U.S. Farms in Year 2000, by Sales Class

	1982		2000	
Sales class	Number of farms (thousands)	Percent of all farms	Number of farms (thousands)	Percent of all farms
Small and part-time	1,936.9	86.0	1,000.2	80.0
Moderate	180.7	10.0	75.0	6.0
Large and very large	121.7	4.0	175.0	14.0
Total	2,239.3	100.0	1,250.2	100.0

SOURCE: Office of Technology Assessment.

MAJOR FINDINGS

Emerging Technologies and Future Agricultural Production

Like the eras that preceded it, the biotechnology and information technology era will bring technologies that can significantly increase agricultural yields. The immediate impacts of these technologies will be felt first in animal production. Through embryo transfers, gene insertion, growth hormones, and other genetic engineering techniques, dairy cows will produce more milk per cow, and cattle, swine, sheep, and poultry will produce more meat per pound of feed.

Impacts on plant production will take longer, almost the remainder of the century. By that time, however, technical advances will allow some major crops to be altered genetically for disease and insect resistance, higher production of protein, and self-production of fertilizer and herbicide.

In both plant and animal production, information technologies will be widely used on farms to increase management efficiency. Introducing to the marketplace these and the rest of the 150 emerging technologies forecasted in this study raises questions about the effects these technologies will have on crop yield, livestock feed efficiency, reproductive efficiency, and future food production.

Many people are concerned that the trends of major crop yields are leveling off and that the world may not be able to continue to produce enough food to meet the demand of a growing population. OTA analyses indicate that the emerging technologies, if fully adopted, will produce significant beneficial impacts on the performance of plant and animal agriculture. The most dramatic impacts will be felt first in the dairy industry, where new genetically engineered pharmaceuticals (such as bovine growth hormone and feed additives) and information management systems will soon be introduced commercially. New technologies adopted by the dairy industry will increase milk production far beyond the 2.6-percent annual growth rate of the past 20 years (table 1-3). Under OTA's most likely conditions, milk production per cow is expected to increase from the 12,000 pounds in 1982 to at least 24,000 pounds by 2000, an annual growth rate of 3.9 percent. Applications of new technologies also will increase the feed and reproductive efficiency of other farm animals.

Table 1=3.—Impact of Emerging Technology on Animal Production Efficiency in Year 2000

	Actual 1982	Most likely 2000	Annual growth rate[a] (percent)
Beef:			
Pounds meat per lb feed	0.07	0.072	0.2
Calves per cow	0.88	1.000	0.7
Dairy:			
Pounds milk per lb feed	0.99	1.03	0.2
Milk per cow per year (1,000 lb).	12.30	24.70	3.9
Poultry:			
Pounds meat per lb feed	0.40	0.57	2.0
Eggs per layer per year.	243.00	275.00	0.7
Swine:			
Pounds meat per lb feed	0.157	0.176	0.6
Pigs per sow per year	14.400	17.400	1.1

[a]Some of these figures differ from those in table 2-2 of the first report from this study, because actual 1982 figures were preliminary.

SOURCE: Office of Technology Assessment.

Because development of biotechnology for plant agriculture is lagging behind that for animal agriculture, equally significant impacts from biotechnology will not be felt in plant agriculture before the turn of the century. Development and adoption of the new technologies under the most likely conditions will, in the short run, increase the rates of growth of major crop yields at about the level of historical rates of growth (table 1-4). However, the impacts of these technologies will be substantially greater for plant agriculture after 2000.

Any conclusion about the balance of global supply and demand requires many assumptions about the quantity and quality of resources available to agriculture in the future. Land, water, and technology will 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 re-

Table I-4.—Impact of Emerging Technology on Crop Yields in Year *2000*

	Actual 1982	Most likely 2000	Annual growth rate[a] (percent)
Corn—bu/acre	113	139	1.2
Cotton—lb/acre	481	554	0.7
Rice—bu/acre.	105	124	0.9
Soy bean—bu/acre	30	37	1.2
Wheat—bu/acre	36	45	1,3

[a]Some of these figures differ from those in table 2-2 of the first report from this study, because actual 1982 figures were preliminary.

SOURCE: Office of Technology Assessment

source. 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 increase in the quantity of land used in production. 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.

Table 1-5 shows the projections to year 2000 of increased production for some of the major U.S. commodities, based on the above yield projections, land availability, world demand, public policy, and other factors. OTA analyses 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 products for the rest of this century.

Under the most likely environments the aggregate growth rate in production of these commodities, which includes inputs of additional land resources and new technology, will be adequate to meet the 1.8 percent growth rate needed to balance world supply and demand in 2000. Under the more-new-technology environment,[4] production could increase at 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 environments the production of major crops in 2000 would drop to 1.6 percent per year, a growth rate that would not allow the United States to meet world demand.

[3]Assumes to year 2000: 1) a real rate of growth in research and extension expenditures of 2 percent per year, and 2) the continuation of all other forces that have shaped past development and adoption of technology.

[4]Assumes to year *2000:* 1) a real rate of growth in research and extension expenditures of **4** percent, and 2) all other factors more favorable than those of the most likely environment.

‘Assumes to year 2000: 1) no real rate of growth in research and extension expenditures, and 2) all other factors less favorable than those of the most likely environment,

Table 1.5.—Projections of Major Crop Production

Crop	Unit	1984	2000 No-new-technology environment	2000 Most likely environment	2000 More-new-technology environment
Corn:					
Production	Billion bu	7.7	8.6	9.3	9.7
Growth rate.	Percent		0.7	1,2	1.5
Soybean:					
Production	Billion bu	1.9	3.0	***3.2***	***3.3***
Growth rate.	Percent		3.1	3.4	3.6
Wheat:					
Production	Billion bu	2.6	3.3	3.5	3.5
Growth rate.	Percent		1.5	1.9	2.0

[a]The projections shown in this table differ from those in table 2-3 of the first report from this study, because the previous figures were preliminary,

SOURCE: Office of Technology Assessment,

Emerging Technologies and the Future Structure of Agriculture

New technologies have historically had significant impacts on structural change. New disease control technologies gave poultry and livestock farmers unprecedented opportunities to specialize and vertically integrate. Improvements in farm machinery fostered large-scale, specialized farm units.

Like their predecessors, the emerging technologies examined in this study will make a considerable impact on farm structure, especially by 2000. Biotechnologies will have the greatest impact because they will enable agricultural production to become more centralized and vertically integrated. Although in the long run the use of new technologies will not increase the farmer's overall need for capital, there will be trade-offs: biotechnology will require less capital; information technology will require more.

The new technologies will allow increased control over end-product characteristics, for example less fat per unit of lean in meat animals or a specific color characteristic in corn. This implies that increased homogeneity within an agricultural product may result and that there will be a growing number of end products with engineered characteristics. This would require less sorting or grading to achieve increased homogeneity and a shift toward having more control over the production process so as to achieve homogeneity during production.

An anticipated economic consequence of this increased control over production is an increase in the practice of contracting. Contracting allows husbandry and cultural practices to be monitored and controlled closely during the production process. This greater process control leads to uniform product differentiation.

Biotechnologies will have relatively more important effects on resource concentration than will other technological developments. Even though mechanical technologies will continue to be important, they are not expected to have as important an impact on future structure. In particular, biotechnologies are expected to encourage closer coordination and greater process control in livestock production, permitting more contract livestock production. One example is the potential from these technologies for modifying milk at the farm rather than at the processing plant. This technology holds promise for producing more highly unsaturated fats in milk. If adopted, it would entail close coordination at the producer/first-handler markets and additional process control at the production level.

The biological technologies will encourage coordination in crop production, as well. However, the magnitude of change in this area is expected to be relatively less for crops than livestock. Part of the reason is that biotechnologies for livestock production are further advanced. The biotechnology era is expected to encourage closer vertical coordination, with a slight reduction in market access as a consequence. This situation would subsequently lead to fewer but larger farms.

The information technologies are expected to reduce barriers to entry and to increase market access without any significant change in vertical coordination or control at the producer/first-handler level-especially for crop agriculture. Information technologies hold the potential for significantly increasing the amount of information across markets. This impact would be attributable to improved communication of buyers' needs to production-level managers, which should result in more equality between buyers and sellers.

The largest farms are expected to adopt the greatest amount of the new technologies. Generally, 70 percent or more of the largest farms are expected to adopt some of the biotechnologies and information technologies. This contrasts with only 40 percent for moderate-size farms and about 10 percent for the small farms. The economic advantages from the technologies are expected to accrue to early adopters, a large proportion of which will probably be operators of large farms.

Impacts of Agricultural Finance and Credit

The severe financial stress of a large proportion of farmers and the recent regulatory and competitive changes in financial markets have combined to change significantly the financial framework of farming. The farm of the future will be treated financially like any other business—it will have to demonstrate profitability before a bank will finance its operation. Managing a farm efficiently and profitably, which will necessitate keeping up-to-date technologically, will be the key to access to credit.

The cost of credit, however, will be higher and more volatile. Interest on loans may be variable rather than fixed. Moreover, given the concentration in the banking industry, decisions about extending credit more likely will be made at large, centralized banking headquarters far removed from a loan applicant's farm. Loan decisions will thus be less influenced by the considerations of neighborly good will that frequently shaded decisions of local farm banks.

Congress will have to consider all these factors because the availability of capital will continue to be an important factor in agricultural production in general and in the adoption of agricultural technologies in particular. Readily available capital at reasonable rates and terms, plus technologies that aid profitability, provide a favorable environment for technology adoption. Emerging technologies, for the most part, will pass the test for economic feasibility.

The financing consequences of new technologies in agricultural production will probably depend on the relationships between three important factors: 1) the financing characteristics of the new technologies, 2) the creditworthiness of individual borrowers, and 3) the changing forces in financial markets that affect the cost and availability of financial capital. The financing characteristics suggest that most of the new technologies should be financed largely with short- and intermediate-term loans that are part of the normal financing procedures for agricultural businesses. However, the technical characteristics of the technologies, together with the factors constituting the creditworthiness of individual borrowers, suggest that increased emphasis in credit evaluations will be placed on the farmers' management capacity, on their ability to demonstrate appropriate technical competence in using the new technologies, and on building human capital, where appropriate. In some cases—particularly for Farmers Home Administration borrowers—significant investments inhuman capital, with related financing requirements, may accompany new technology adoption. This is consistent with the more conservative responses by lenders to the agricultural stress conditions of the early 1980s. Lending institutions themselves, in turn, must have sufficient technical knowledge and expertise to evaluate these management and credit factors along with other sources of business and financial risks in agriculture. Finally, some forms of new technology involving large investments and having long-run uncertain returns will probably rely more on equity capital for financing.

The changing regulatory and competitive forces in financial markets, including the preference for greater privatization of some credit institutions, means that the cost of borrowing for agricultural producers will likely remain higher and more volatile than before 1980 times and will follow market interest rates much more closely. Similarly, the continued geographic liberalization of banking and the emergence of more complex financial systems mean that the functions of marketing financial services, loan servicing, and credit decisions will become more distinct, with an increasing proportion of credit control and loan authority occurring subregionally and with regional money centers being located away from the rural areas. This will continue to fragment and dichotomize the farm-credit market so that commercial-scale agricultural borrowers will be treated as part of a financial institution's commercial lending activities and small, part-time farmers will be treated as part of consumer lending programs.

The competitive pressures on financial institutions and the risks involved will bring more emphasis on analyzing the profitability y of various banking functions, including loan performance at the department level and individual customer level. Innovative lenders will strive more vigorously to differentiate their loan products and financial services, especially for more profitable borrowers, and will tailor financing programs more precisely to the specific needs of creditworthy borrowers. In turn, however, to compete for credit services these agricultural borrowers must be highly skilled in the technical aspects of agricultural production and marketing as well as in financial accounting, financial management, and risk analysis.

In general, most forms of new technology in agricultural production should meet the tests of both economic and financial feasibility, although the structural characteristics of the adopting farm units will continue to evolve in response to managerial, economic, and market factors. The structural consequences of these factors are severalfold:

1. a continuing push toward larger commercial-scale farm businesses, with greater skills in all aspects of business management;
2. continuing evolution in the methods of entry into agriculture by young or new farmers, with greater emphasis on management skills and resource control and less emphasis on land ownership;
3. the continuing development of a marketing systems approach toward financing agriculture, with more sophisticated skills in marketing analysis by farmers and higher degrees of coordination with commodity and resource markets;
4. more formal management of financial leverage and credit by farmers, with greater diversity of funding sources by farmers and better developed markets for obtaining outside equity capital;
5. further development in financial leasing and greater stability in leasing arrangements for real estate and other assets; and
6. more complex business arrangements in production agriculture that accommodate various ways to package effectively debt and equity financing, leasing, management, accounting, and legal services for the future farm business.

Emerging *Technologies, Policy* and Survival of Various Size Farms

The size and, therefore, the survival of farms is affected by several factors. Clearly, there are economies of size in many commodity areas covered by farm policy. These economies motivate further concentration of resources. In addition, present farm policy, more than any other policy tool, makes major impacts on farm size and survival. Although very large farms can survive without these programs, moderate-size farms depend on them for their survival.

This study finds that substantial economies of size exist for several major commodities (table 1-6). The commodities include dairy, corn, cotton, wheat, and soybeans. With the exception of corn, economies of size do not exist uniformly in all the production areas studied for these commodities. Table 1-6 shows the areas in which economies of size do exist. It should be noted that the analysis considered only technical economies of size. If it had also included pecuniary economies, additional production areas would have been found to have economies of size.

Table 1-6 also shows commodities in which there will be significant gains in yield based on emerging technologies. All of the commodity areas except rice will experience substantial gains in yield as well *as* significant economies of size. (No economies of size were found for

Table 1.6.—Comparison of Commodities With Current Economies of Size and Future Technological Gains

Current economies of size (in descending order)	Greatest yield increases for the future (in descending order)
Dairy	Dairy
Arizona	
California	Wheat
New Mexico	
Corn	Soybeans
Illinois	
Indiana	Corn
Iowa	
Nebraska	Rice
Cotton	Cotton
Alabama	
Texas	
Wheat	
Kansas	
Montana	
Soybeans	
Iowa	

SOURCE Office of Technology Assessment,

rice.) Dairy, in particular, leads all commodities in economies of size and production increases from new technologies. These forces will combine to shift overtime the comparative advantage in dairy production from the smaller dairies in the Great Lake States and Northeast to the larger dairies in the Southwest and West.

Overall, the combination of future yield increases from new technology and current economies of size in these commodities means that there will be substantial incentives for farms to grow in size. These powerful forces will continue, and may even speed up resource concentration in U.S. agriculture.

This study finds that farm programs, which include Commodity Credit Corporation (CCC) purchases and price and income supports, have major impacts on rates of growth in farm size, wealth, and incomes of commercial farmers. Large farms increase their net worth significantly more than moderate-size farms under current farm programs and large farms account for a significantly large share of farm program payments. In particular, price supports provide most of the wealth and growth benefits to large farms.

Removing farm programs reduces the probability of survival more for moderate-size farms than for large farms. OTA's analyses find that large farms can survive and prosper without farm programs. And, because these farms account for the vast majority of farm program benefits, significant savings in Government expenditures could be realized if large farms were ineligible to receive program payments.

On the other hand, this study finds that moderate farms need farm programs to survive and be successful. Income supports, in particular, provide significant benefits to moderate farms, and the targeting of income supports to moderate farms is an effective policy tool for prolonging these farms' survival.

Those changes in tax policy that would be more restrictive have little impact on farm survival. Increasing the Federal tax burden on farmers reduces the average annual rate of growth in farm size uniformly for all farm sizes.

Currently the financial position of many farmers is under severe stress. The situation is serious and may not improve for some time. Two alternatives most discussed by policymakers are interest subsidy and debt restructuring programs. OTA finds that restructuring debt for highly leveraged farms does not appreciably increase their probability for survival. The interest rate subsidy substantially increases average net income more than debt restructuring. It is the more effective strategy to ease financial stress. In addition, large farms with high debts are not as dependent on these financial programs for survival as moderate farms are.

impacts on the Environment and Natural Resources

In general, with a few notable exceptions, most emerging technologies are expected to reduce substantially the land and water requirements for meeting future agricultural needs. Consequently, these technologies are expected to reduce certain environmental problems associated with the use of land and water. The technologies are thought to have beneficial effects relative to soil erosion, to reduce threats to wildlife habitat, and to reduce dangers associated with the use of agricultural chemicals. New tillage technologies, however, may reduce erosion and threats to wildlife while increasing the dangers from the use of agricultural chemicals.

The new technologies are most likely to receive first adoption by farmers who are well financed and are capable of providing the sophisticated management required to make profitable use of the technologies. Most of these farmers will be associated with relatively large operations. Hence, the technologies will tend to give additional economic advantages to large farm firms relative to moderate and smaller farms, accentuating the trend toward a dual farm structure in the United States.

In addition, since many of the new technologies tend to be environmentally enhancing, public interest exists in research and education that can lead to the rapid development and widespread adoption of the technologies. That conelusion becomes even stronger if public policy is aimed at maintenance of the moderate-size farm. Larger farms, with their own access to research results and scientific expertise, may be able to advance the new technologies with relatively little publicly sponsored research. But moderate and small farms will have to depend on publicly sponsored research and extension education to gain access to the new technologies and to adapt them to their individual needs.

The new technologies will entail more stringent environmental regulations and stronger enforcement of regulations than at present. The complexities of some of the emerging technologies will pose significant challenges for those promulgating wise environmental regulations. The economic benefits of the technologies will be inviting, but users may have little incentive to use the technologies in ways that avoid unnecessary, adverse, third-party effects. Economic incentives or disincentives, including the use of excise taxes to discourage overuse of potentially threatening materials, represent a promising approach to the protection of environmental values than do direct regulation. Additional efforts to enforce existing regulations would hasten the adoption of the new technologies that seem less environmentally threatening. New regulations will be required, however, for dealing with some aspects of the emerging technologies.

Perhaps the most revolutionary of the new technologies are those associated with rDNA. While the specific applications of such technologies appear likely to reduce resource needs and threats to the environment that arise from agricultural activities, dangers may accompany the deliberate release of genetically altered micro-organisms. The revolutionary nature of the new biotechnologies and the lack of a scientifically accepted predictive ecology prevent specific evaluation of resource/environmental impacts associated with the deliberate release of new forms of life at this time.

Many scientists see little danger in the applications of rDNA technology in laboratory experiments. The proponents of biotechnology argue that genetic engineering has been used in plant breeding and animal husbandry for centuries and that genetically engineered micro-organisms are no more dangerous than micro-organisms already in commercial use or that might be used in nature. However, the opponents of deliberate release argue that the new products of genetic engineering are different from the old ones. Scientists do not know how these new micro-organisms will behave in the environment and fear adverse consequences to the ecosystem. Both sides agree that more research should be conducted to assess the potential benefits and risks. Recently, the Environmental Protection Agency approved the first two field tests of genetically altered organisms.

Impacts on Rural communities

The impacts of technological and structural change in agriculture do not end with the individuals who live and work on farms. A variety of additional consequences are expected at the level of rural communities, consequences that directly or indirectly affect farms and farmers. As with individual farmers, some communities are likely to benefit from change, while others are likely to be affected adversely. Much depends on the type of overall labor force in the community and on the opportunities for labor to move to other employment areas.

Hard-hit communities may need technical assistance to attract new businesses to their areas, to develop labor retraining programs, and to alter community infrastructure to attract new inhabitants. To accomplish these goals, Federal policy will have to be complemented by regional and local policies.

Those rural communities that benefit from changes in agricultural technology and structure may do so in several ways. For example, as agriculture becomes more concentrated, some communities will emerge as areawide centers for the provision of new, high-value technical services and products. Likewise, some communities will emerge as centers for high-volume food packaging, processing, and distribution. In both cases, the economic base of these communities is likely to expand. However, unless total demand for agricultural commodities increases substantially, centralization of services, marketing, and processing will be like a zero-sum game in many areas. The market centers will benefit at the expense of other communities. Many of the communities that are bypassed will decline as a result of the process of centralization.

Communities also may benefit in those parts of the country in which the number of small and part-time farms is increasing. This phenomenon results in an increase in population in many rural areas and an increase in total income and spending in some of these areas. The increase in small farms may sustain additional retail establishments than would otherwise be the case, since purchases by small farmers may tend to be more from local sources than those by larger farmers. The operators of these farms in many cases subsidize their own production from off-farm income.

A wide range of diversity is evident in the character, agricultural structure, patterns of change, and patterns of impact on rural communities in the five different regions of the United States studied for this report:

1. the CATF (California, Arizona, Texas, and Florida) region;
2. the South;
3. the Northeast;
4. the Midwest; and
5. the Great Plains and the West.

A clear picture of adverse relationships between agricultural structure and the welfare of rural communities is evident in the industrial-agricultural counties of the CATF region. Large-scale and very large-scale industrialized agriculture in these communities is strongly associated with high rates of poverty, substandard housing, and exploitative labor practices in the rural communities that provide hired labor for these farms. Very large-scale agriculture has been a strong source of employment in the CATF region for many years, although at very low wage rates. Emerging technologies may reduce the labor requirements throughout much of the CATF region by 2000. Increased unemployment will greatly increase the strain on these communities. A potential exists for the CATF region to increase its share of national agricultural production, which would mitigate the trend toward increasing unemployment. However, increased agricultural production in this region will tend to be constrained by the cost of irrigation water and the need to control environmental impacts.

The coastal zone of the South also has a substantial potential for structural change similar to that of the CATF region. Topography and climate favor large-scale, labor-intensive production of fruits, vegetables, and dairy products. The area also has a segmented, relatively unskilled labor force that could provide a source of low-cost labor similar to that of the CATF region. It is difficult to generalize about the rest of the South, owing to the diversity of agricultural structure and production. Evidence exists of a relatively strong association between rates of unemployment and agricultural structure. Unemployment rates tend to be lowest in counties with a predominance of moderate farms.

In the Northeast, dairy products are the single most important agricultural commodity group. Because dairy farms are likely to experience widespread failure as a consequence of the combination of technological change and public policies, the structure of agriculture in the Northeast is likely to change substantially during the next 10 to 15 years. However, rural communities in the Northeast have a low overall dependence on income from agriculture. Most productive agricultural counties in the Northeast are adjacent to metropolitan areas where greater employment opportunities and services are available. The most rural counties sometimes are not the most agricultural. Therefore, rural communities in the Northeast generally are not likely to experience adverse consequences from structural change, with the exception of a few localities with especially high dependence on dairy production.

No clear-cut evidence exists that rural communities in the Midwest were adversely affected by structural change during the 1970s. In general, alternative sources of employment in the manufacturing and service sectors were relatively prevalent and are expected to continue to be relatively good in the Midwest. Indicators of social welfare, in general, tended to improve as farm structure moved from small and part-time farms toward moderate to large farms during the 1970s. However, there was a tendency for population to decline in counties where the share of part-ownership of farms increased. As with the Northeast region, there is a reasonable expectation that technological change in the dairy industry will result in a mass exodus of small to moderate dairy farms during the next 5 to 15 years. Rural communities in dairy counties may not be adversely affected because off-farm employment is quite high in these counties. Those mixed agricultural counties on the western edge of the Midwest that are relatively dependent on agriculture are the most likely to suffer adverse consequences from structural change. If the percent of part-ownership increases as agriculture becomes more concentrated, population, median income, and retail sales may decline in these counties.

Strong potential exists for development of a high concentration of agricultural production in the Great Plains and the West, especially in terms of farm size, if not gross sales per farm. In turn, the number and percent of hired managers in this region is likely to increase. Unlike the South, there is a low potential for development of an industrialized agriculture with large numbers of hired field workers. The most likely adverse impact will be the loss of population and small retail firms in the region. In general, fewer alternate employment options will be likely in manufacturing and the service industries in this region than in the other regions of the country.

This study shows clearly that policies designed to prevent or ameliorate adverse impacts and promote beneficial impacts need to be crafted with consideration for regional structural/technological differences. Generalizing about the impacts of changing agricultural technology and structure on rural communities across regions of the United States is difficult.

Impacts on Agricultural Research and Extension

U.S. agriculture has been very successful to an important extent because of technological advances. However, agriculture's adoption of biotechnology and information technology raises several questions about the impact of technical advances on the performance of the research and extension system and about how that performance will ultimately affect the structure of agriculture.

Public research in the past was the driving force for agricultural production. Now, with the private sector becoming more involved in certain aspects of applied research, the public sector is emphasizing increased basic research. This situation leaves open the question of who will do applied research in the public sector. Although the public sector has allocated resources to research in biotechnology and information technology, extension has done little to make information about these technologies available to farmers. The extension service must thus decide what its mission will be, for extension policy will determine how effective moderate farm operators will be in gaining access to new technology. Without such access moderate-size farms will disappear even faster.

Consideration of specific changes in research and extension policy may be justified. The following areas have been identified as meriting consideration for policy changes:

- The social contract on which the agricultural research and extension system was created needs reevaluation. This issue should not be left for resolution by the courts. Specific guidelines must be developed that allow the system to compete while protecting the public interest and investment in the agricultural research and extension functions. Both Congress and the U.S. Department of Agriculture (USDA) should have a voice in this type of policy development.
- Some experts believe that increased private sector support for agricultural research sig-

nals less need for public support. Even though private sector support complements public support, basic biotechnology and information technology research is very costly. A reduced role for public research and extension would result in a slower rate of technological progress and a lower level of protection for the public. In addition, the public has a strong interest in maintaining an agricultural research component in each State to serve the problem-solving needs of that State's agriculture.

- Many agricultural problems are local or regional in scope. The applied nature of the system, having an agricultural experiment station and extension service in each State, has provided a unique capacity to identify and solve local or regional problems. Reality suggests that only certain universities have sufficient resources to compete for private sector support in biotechnology and information technology. The result is a confluence of forces that is creating a dichotomy of "have" and "have not" universities. There is, however, still an important role for even the smallest, poorest funded land-grant university. It plays an important part in a national system designed to deal with thousands of agro-ecosystems and to the existence of a decentralized system with nationwide capability. Because of these inequalities, there is concern that the traditional extension-research interaction and feedback mechanisms could break down, particularly in States that are not in a position to command a major biotechnology component.
- The role of extension is even more important than it has been in the past. New, more complex products require evaluation and explanation. In States where experiment stations have attracted substantial private sector support, the product testing function can be most objectively performed by extension. The recently passed 1985 farm bill gives explicit authority for extension to engage in applied research functions such as product testing and evaluation.
- While most agricultural research is not inherently biased toward large-scale farms, lags in adoption by small and moderate farms have the effect of such a bias. Unless special attention is given to technology generation and transfer to moderate farms, major structural changes could result, leading to the eventual demise of a decentralized structure that includes moderate farms. To the extent that preservation of these farms is a policy objective, special funding for and emphasis on the problems of technology generation and the transfer of that technology to moderate farms is warranted.
- Although the agricultural research system has received the benefits of increased funding from both private and public sources, extension funding has not materially increased. As a result, extension staff at the county and specialist levels are being caught up in a whirlwind of technological change. The result is a need for the injection of substantial staff development funding into the extension system.
- Basic organizational issues must be addressed by the Extension Service. The premise on which extension was developed was that of research scientists conveying the knowledge of discoveries to the extension specialist who, in turn, supplied information to the county agent who then taught the farmer. Over time, this concept has gradually but persistently broken down as agricultural technology has become more complex and insufficient resources have been devoted to staff development. Consequently, more emphasis has been placed on direct specialist-to-farmer education. More specialists have been placed in the field to be closer to their clientele, but at the cost of less contact with research scientists. As these changes have occurred, the role of the county agent has become increasingly unclear. Appreciation for and use of county agents as educators and technology transfer agents has declined. As a result of these changes, a basic structural reevaluation of the organization of the extension function of the agricultural research system is needed.

IMPLICATIONS AND POLICY OPTIONS FOR AGRICULTURE

The Issue of Farm Structure

This study indicates that the process of structural change in agriculture has already begun. Based on a continuation of current policies, past trends, and future technological expectations, the net result of this structural change could be the development of a farm structure composed of three agricultural classes:

1. The *large-scale farm segment* would be composed of a relatively small number of farms that produce the bulk of U.S. production. By year 2000 there could be as few as 50,000 large-scale farms producing as much as three-fourths of the agricultural production. This large-scale farm segment would be highly efficient in the performance of production, marketing, financial, and business management functions. Such farms would be run by full-time, highly educated business managers. Barring unforeseen acts of nature, farm operators would be able to predict their chances of making a profit before planting or breeding.
2. The struggling *moderate-size farm segment* would be trying to find a niche in the market and survive in an industrialized agricultural setting. The potential for the moderate farm finding that niche is rapidly becoming the center of the farm policy debate. Traditionally highly productive, efficient, moderate-size, full-time farms have been the backbone of American agriculture. It is still true that a moderate, technologically up-to-date, and well-managed farm with good yields is highly resilient. One key to the success of these farms clearly lies in the management factor. But more often than not, management has to be willing to accept a relatively low return on invested capital, time, and effort. With ever-increasing educational requirements associated with farming, there will likely be less willingness by successful managers of moderate farms to accept a lower return for their services and for invested capital. Another key to the survival of moderate farms lies in access to state-of-the-art technologies at competitive prices. Cooperatives traditionally have performed that role. But cooperatives by and large are not conducting or funding basic or applied research in biotechnology and information technology. Also, like their predominantly moderate-size farmer members, cooperatives, too, have encountered financial difficulty.
3. The *small, predominantly part-time farm segment* tends to obtain most of its net income from off-farm sources. However, this segment is highly diverse. It includes wealthy urban investors and professionals who use agriculture primarily as a tax shelter and/or country home. It also includes would-be moderate farm operators who are attempting to use off-farm income as a means of entering agriculture on a full-time basis. Finally, this segment includes a number of poor, essentially subsistence, farmers who are vestiges of the war on poverty in the 1960s. Such farmers remain a significant social concern that must be dealt with from a policy perspective, although traditional farm price and income policy hold no hope for solving their problems.

Contemporary farm programs have fostered this trend toward three farm-size classes. payments to farmers on a per-unit-of-production basis concentrate most of the benefits in large farms that produce most of the output. Large farms have been in the best position to take advantage of new technologies arising out of the public sector agricultural research system.

Without substantial changes in the nature and objectives of farm policy, the three classes of farms will soon become two-the moderate-size farm will largely be eliminated as a viable force in American agriculture. In addition, the problems of the small subsistence farm will continue to fester as an unaddressed social concern.

This section sets forth the policy changes that would be required if it were decided by Congress that overt steps should be taken to foster a diverse, decentralized structure of farming where all sizes of farms had an opportunity to compete and survive in a time of rapidly changing technology. The objective of giving every farm the opportunity to compete and survive does not imply an unchanging and stagnant farm structure. It does imply a political and social sensitivity y both to the impact of current farm programs on farm structure and to the different needs of large, moderate, and small farms for Government assistance. It can be expected that regardless of what Government does fewer commercial farms will exist in year 2000. However, Government can do much to ease the pain of adjustment.

Required Policy Adjustments

Substantive changes in policy direction are needed to address the structure issue. Specifically, separate policies and programs must be pursued with respect to each of the three farm segments—large farms, moderate farms, and small farms. The choice of any one set of policies to the exclusion of the other policy sets would imply that Congress desired to selectively enhance the status of one farm segment.

Policy for all farmers implies two basic policy goals:

- All farmers need to operate in a relatively stable economic environment where they have an opportunity to sell what they produce.
- All farmers need a base of public research and extension support whereby they can maintain their competitiveness in the markets in which they deal.

The needs of large farms can be met by addressing just these goals. The needs of moderate and small farms are more complex, however. Policy to address the needs of moderate and small farms must include the elements of large farm policy as well as additional elements,

Policy for Large Commercial Farms

A basic conclusion of this study is that large-scale farmers do not need direct Government payments and/or subsidies to compete and survive. However, this does not preclude the need for a commercial farm policy.

The criteria for determining what constitutes a large-scale farm is important but also somewhat arbitrary. The dividing line developed from this study is about $250,000 in sales for a crop or dairy farm unit under single ownership or control. This level of sales is generally required to achieve most of the economies of size found to exist in agricultural production.[6] Over time, this optimum size has had, and will continue to have, a tendency to increase. As this occurs, the farm size criteria for limiting program benefits would likewise have to increase.

Creating a Stable Economic Environment.— The policy goal of creating a relatively stable economic environment where farmers have an opportunity to sell what they Produce implies the following major farm program initiatives:

- Direct Government payments to all farms having over $250,000 in sales would be eliminated. This implies the elimination of the target-price concept for this sales class. Elimination of payments to those farms would significantly reduce Government expenditures in agriculture.
- The nonrecourse loan would be converted to a recourse loan. The nonrecourse feature has resulted in the accumulation of large Government commodity stocks. The recourse feature would provide a continuing base of support for the orderly marketing of farm products.
- Aside from the recourse price support loan, Government credit to farms having over ***$250,000*** in sales would not be available.
- An expanded international development assistance program would be established. Such a program would have to include an optimum balance of commodity aid and economic development aid. Its primary objective would be to help developing countries improve economic growth, thus becoming better future customers of American agriculture.
- A balanced macroeconomic policy that facilitates growth of export markets and

[6] The $250,000 figure is based on census data and the economies of size analysis discussed previously.

maintains a relatively low real rate of interest would have to be maintained.

Maintaining Technological Competitiveness.—The technological competitiveness of American farmers would be aided by continuing a policy that encourages public and private investment in agricultural research. The major thrust of the research and extension programs as they affect larger scale commercial farms would be as follows:

- The trend toward increased public sector emphasis on basic research would be continued. Increased reliance would be placed on the private sector for applied research in the development of new products.
- Even though public sector research would be aimed more toward basic research, an important problem-solving component would be maintained to adopt new technologies to various agro-ecosystems and to maintain newly achieved productivity from the evolution of pests and disease, decline in soil fertility, and other factors.
- Extension's role in direct education of, or consultation with, large-scale farmers would be deemphasized. Private consultants could play an increased role in technology transfer to the large-scale farm segment.

Policy for Moderate-Size Farms

Policy for moderate farms includes the aforementioned options as well as additional options tailored specifically to the needs of moderate farms. OTA finds, for example, that moderate farms having $100,000 to $250,000 in gross sales face major problems of competing and surviving in the biotechnology and information technology era. Some moderate farms will survive and some will not. This latter group should be assisted in their move to other occupations.

Policy for moderate farms requires the same stable economic environment and base of support for agricultural research and extension as for large farms. But, in addition, the following specific policy goals for moderate farms can be specified:

- The risk of moderate farmers operating in an open market environment would be reduced.
- New technologies that have the potential for adoption would be available to moderate farmers.
- Opportunities for employment outside agriculture would be created for those farmers who are unable to compete.

Diligent enforcement would be needed to assure that the benefits of programs established to favor moderate farms are limited to those farmers for whom they are intended.

Reducing Risks to Moderate-Size Farms.-The most difficult obstacle to survival facing the moderate farm is that of managing risk. Three options, that are not necessarily mutually exclusive, could reduce the risks confronting moderate farms.

1. Income protection could be provided through either a continuation of the current target-price concept for moderate farms only or through a device known as the marketing loan. Like the current nonrecourse loan, the marketing loan is a loan from the Government on commodities in storage. If the commodity is sold for less than the loan value, the farmer pays back only those receipts to the Government in full payment of the loan. The marketing loan, in essence, becomes a guaranteed price to the producer. The level of the marketing loan should be no greater than the average cost of production for moderate farmers.
2. The nonrecourse loan concept could be continued for moderate farms. However, the nonrecourse loan level should not be set any higher than the recourse loan suggested previously for large farms, or else the Government could end up acquiring most of the production from moderate farms.
3. Sharply increased assistance could be provided by the public sector to reduce the risk to moderate farms. Such assistance could be in the form of educational programs for example, on risk management, futures markets, contracting, and cooperative marketing.

Technology Availability and Transfer to Moderate-size Farms.— OTA finds that agricultural research, as a general rule, is not inherently biased against moderate farms. Rather, moderate farms may be seriously disadvantaged either by lags in adoption or by lack of access to competitive markets for the products produced by new technology. The following initiatives could help curtail such problems of technology availability and transfer.

- Extension's evaluation of the increasing number of new products entering the market would be intensified. This increased effort would play the dual role of: 1) providing a check on the efficacy and efficiency of new products in biotechnology and information technology, and 2) eliminating the costs associated with individual farmer experimentation with those new products.
- Extension technology transfer services would be aimed specifically at moderate-size farms. The primary goal of such programs would be to ensure the same schedule of adoption of technologies for moderate-size as well as large farms.
- The development of cooperatives that emphasize technology supply and transfer services to moderate farms would have to be undertaken.
- Ample credit would have to be made available to moderate-size farms that have the potential to survive and grow. Government credit in concert with cooperative credit could be aimed specifically toward filling the needs of moderate-size farms. Emphasis should be placed on credit required to keep moderate farms technologically up-to-date.

Transition Policy to Other Agricultural Enterprises or Nonfarm Employment.—Regardless of the effectiveness of the initiatives discussed above, an accelerated need exists to assist farm families to either move to other agricultural enterprises or out of agriculture into other occupations. The need arises, therefore, for specific public action to facilitate the farmer's transition from the current farm operation into gainful, productive employment elsewhere, Specific initiatives to ease this process include the following:

- New opportunities for employment of displaced farmers need to be explored and developed within agriculture as the industry continues to evolve.
- To facilitate the transition to nonfarm jobs, special skills training programs aimed at those areas where significant employment opportunities exist must be considered. Jobs in rapidly growing service, health care, or care-for-the-aged industries provide contemporary examples.
- Financial assistance, similar to the famous G.I. bill, might be established to assist displaced farmers or rural residents during the period of transition while skills training is being received.
- In areas of severe financial stress, assistance may be provided in the form of Government purchase of land or production rights from displaced farmers at its "long-term fair market value. " The returns from the land could be used by the displaced farmer for relocation and retraining. The Government could retain the land in conservation reserve status until it is needed for future production,

Policy for Small/Part-Time Farms

Policy for small / part-time farms includes several elements in addition to those mentioned under large farm policy.

With few exceptions, small farms, those having less than $100,000 in sales, are not viable economic entities in the mainstream of commercial agriculture—nor can they be made so, However, even a small increase in their farm income could have a significant multiplier effect on the local economy because of the large number of small farms. These farms survive because their operators have substantial outside income (part-time farmers), or because they have found themselves a niche in marketing a unique product with special services attached (often direct to consumers), and / or because they are willing to accept a very low return on resources contributed to the farming operation.

For the small farmers who have substantial outside income or who have found a niche in the market, Government's role would be severely restricted. They are as much able to take care of themselves as owners of large farms.

However, small subsistence farmers who have limited resources, and often limited revealed abilities, represent a genuine problem for which public concern is warranted—these indeed are the rural people left behind. Price and income support programs have done and can do little to solve their problems. These impoverished individuals are a social and economic problem. The following suggestions are made for dealing with the problems of subsistence farmers:

- Initiate a special study to identify those individuals and their specific statuses and needs. Develop social programs to meet those needs.
- USDA and the land-grant university bear a special burden of responsibility y for serving the needs of these subsistence farmers. This responsibility has not generally been realized and, therefore has not been fulfilled. In the South, this responsibility falls particularly heavily on the 1890 land-grant universities in concert with the statewide extension education programs and the 1862 land-grant universities. In the North, the responsibility for serving the agricultural educational and research needs of subsistence farmers falls exclusively on the 1862 land-grant universities.
- USDA and these land-grant universities could be directed to develop jointly a plan for serving the agricultural research and educational needs of these farmers. Such a plan could include the delivery of farming, credit, and marketing systems designed to maximize the small farm's agricultural production and earning capacity.
- Specific farming systems must be developed to serve specifically the needs of small subsistence farms. Such systems should, to the extent practicable, encompass the use of new technologies.
- Credit delivery systems for small subsistence farmers could be developed specifically by USDA through the Farmers Home Administration. Such systems should consider the unique capital and cash flow-limiting factors associated with subsistence farmers who are often not in a position to take advantage of other farm programs such as price and income supports.
- Marketing programs geared to subsistence agriculture-are essential for providing hope for this farm segment. The difficulty lies in the inability of these farmers to obtain access to the mass markets through which most agricultural production moves.

Policy for Rural Communities

The impact of adjustment in agriculture to changing technology will by no means be limited to the farm sector. Rural communities will beat least equally affected by increasing farm size, integration, and moderate farm displacement. Although, these effects will be felt initially by implement dealers, farm supply and marketing firms, or bankers, the reverberations will extend throughout the community in terms of employment levels, tax receipts, and required services. Rural communities should assess these impacts and prepare to make needed adjustments. To ease the pain of adjustment the following actions are suggested:

- Comprehensive programs for community redevelopment and change need to be initiated throughout rural America. Such development plans should be fostered and facilitated by Federal and State government agencies.
- Increased employment opportunities in rural areas could be fostered by aggressively attracting new business activities in rural communities. Particular emphasis would be placed on attracting those businesses that develop technologies and serve the needs of high-technology agriculture in rural areas.
- Rural communities could be assisted in developing and modernizing the infrastructure needed to be a socially and economically attractive place to live. Some rural communities can serve as an attractive retirement residence for an aging population. But this would require that a higher level of social services be developed.
- Rural communities need to play a vital role in skills training for displaced farmers and

rural community employees. School and university outreach programs could be modified to serve this important role.

Policy for Technology and Environmental Resource Adjustment

One of the major reasons that American agriculture has been so productive is because technological change has been fostered by the public sector and nurtured by a profit-seeking private sector. As a result, American consumers have enjoyed a plentiful supply of low-cost food and natural fiber. In addition, agricultural exports have made a major contribution to the overall development of export markets, to the benefit of the general economy. Biotechnology and information technology promise to offer more of the same, with the added bonus of less chemicals used in the production of food—whether for the control of pests, disease, and weeds, or for the production of commercial fertilizer.

Maintaining the productivity and competitiveness of U.S. agriculture in the public interest requires a balance between public and private sector support for technological change. Yet it would be wrong to imply that there are no risks. The conferring of property rights on discoveries of the agricultural research system has shifted the agricultural research balance between the public and private sectors toward the private sector. While the effects of this shift appear to be positive, concerns exist that a substantial portion of the benefits of even public research could be captured by private firm interests. Distribution of these benefits maybe so unequally distributed that competitive performance is impaired. In addition, no scientifically acceptable methodology exists for weighing the risks or hazards of biotechnology research. To deal with such issues, the following policy suggestions are made:

- Steps should be taken to secure the public interest on which the USDA and land-grant university agricultural research system has been based. Assurance must be provided that the benefits of publicly supported research and extension are not captured in the form of excess profits by the private sector based on research property rights and increased private sector funding of public research. The effect would be to stifle the process of discovery and the dissemination of new knowledge.
- Major investments must be made to foster the development of human capital that is in a position to cope with the process of rapidly changing agricultural technology. This need extends from the training and development of the most basic biological research scientists, through the extension specialist and county agent, to the farmer who adopts the new technology and the banker who supplies the loan for its purchase.
- Little is known about the adverse impacts of potential biotechnology developments on the ecosystem. These risks must be carefully assessed, monitored, and where necessary, regulated. Care must be taken, however, not to overregulate and thereby stifle the potential competitiveness and productivity of U.S. agriculture.

SUMMARY CONCLUSIONS

The biotechnology and information technology revolution in agricultural production has the potential for creating a larger, safer, less expensive, more stable, and more nutritious food supply. Yet it will exact substantial costs in potential adjustment problems in the agricultural sector and in rural communities. Those costs can be minimized by careful analysis, planning, and implementation, This study is only the first step in that direction,