Appendixes

Appendix A

Animal and Plant Technology Workshop Methodology and Procedures

To assess the impacts of emerging agricultural production technologies, two workshops—one for animal technology and the other for plant, soil, anti water technology–-were conducted in April 1984. The objective of the workshops was to obtain information about the development and adoption of emerging technologies so that the information could be used to analyze the economic, social, and environmental impacts of technology adoption,

Since the information needed spanned a wide range on the spectrum of the process of technological innovation—from successful completion of research to widespread commercialization of t he technology—participants of the workshops were carefully selected to include expertise in different stages of technological innovation. Participants comprised physical and biological scientists, engineers, economists, extension specialists, agribusiness representatives, and experienced farmers.

The Delphi technique was used to obtain collective judgments from the workshop participants. To facilitate the process of obtaining consensus, an electronic Consensor was employed to tabulate the ratings assigned by each expert, In addition to registering the ratings, the device allowed each expert to weight his rating according to the degree of confidence or expertise he had in his rating. That level of confidence or expertise could be set at zero, 25, 50, 75, or 100 percent,

The Consensor provided an immediate video screen readout of the rating distribution, the weighted average rating, and the average degree of confidence, If the first vote showed a very wide distribution on ratings, those experts with ratings that were outliers were asked to explain their reasons for the ratings assigned. After additional discussion, another vote was taken. Since lack of a consensus after such discussion was, in itself, an indication of considerable uncertainty about the impacts of new tech no log y, no attempt was made to force a consensus beyond a second vote.

The principal tasks accomplished at the workshops were:

a. Estimation of the year that each technology’ was likely to be introduced for commercial adoption,
b. Estimation of the yield trends for each commodity in 1990 and 2000 under the no-new-technology environmental
c. Packaging of technologies that are likely to be introduced in the production of each commodity in 1990 and 2000,
d. Estimation of the increases in crop and livestock performance measures when the package of technologies is fully adopted by farmers.
e. Estimation of the adoption profile (i.e., the number of years it takes to reach a certain percentage of adoption and the maximum percentage of adoption) of each package of technologies applied to a particular commodity}’,
f. Discussion of major barriers to the adoption of a particular package of technologies to the production of each commodity.
g. Identification of public policy options that could remove the barriers or facilitate adoption of the packages of technologies.

Information obtained from this workshop was used to assess the economic, social, and environmental impacts of these technologies. Iowa State’s CARD econometric and hybrid models were used to simulate the impacts of these emerging technologies on plant and animal production, inventory, demand, supply, prices, gross farm income, production expenses, and net farm income in 1990 and 2000 under alternative technology environments.

Alternative Environments for the Development and Adoption of Technology

Since the information to be obtained at the workshops depended on the environment under which a new technology would be developed and adopted, it was necessary to make certain assumptions about future environments, or scenarios. Four technology environments were developed and used in the workshops: most likely, more-new-technology, less-new-technology, and no-new-technology environments.

[1] Alternative technology environments will be discussed in the next section

The most likely environment is bordered by the more-new-technology and the less-new-technology environments; both deviate from the position of the most likely environment. It is assumed in the most likely environment that the historical trends will continue into the future. Forces, such as gross national product (GNP), population growth, export demand for U.S. agricultural commodities, trade policy, inflation rates, energy prices, and research and extension expenditures, that have shaped the past would continue to evolve as they had in the past decades. Assumptions made for various economic variables under the three environments are shown in table A-1. Factors underlying the more-new-technology environment are generally more favorable for development and adoption of new technologies than those under the most likely environment, and factors underlying the less-new-technology environment are less favorable than those under the most likely environment.

The assumptions under the no-new-technology environment are the same as that of the less-new-technology environment except for new technologies. It is assumed that all emerging technologies discussed in the two workshops will not be available for commercial introduction before year 2000. Existing technologies will continue to be used. Through education and extension, farmers will learn to use the existing technologies better to increase productivity. Productivity is likely to continue to increase at a decreasing rate and will eventually level off.

Presentation and Discussion Of Technologies

In a plenary session, each author of a technology paper made a lo-minute presentation to give the participants essential information about a technology area so that they would be able to make intelligent projections about the development and adoption of that area. The authors' presentations focused on the following:

a. When would a significant technology emerge from each major line of research?
b. What is the output of the new technology? IS it a new product (e.g., a new vaccine for a particular disease) or a new process to produce the same product (e.g., no till)?
c. How will each technology be used by farmers? Can it be used alone or in combination with other technologies? If it has to be combined with other technologies, how will they be packaged?
d. What will it take for farmers to adopt it? Do they have to make a capital investment, such as the purchase of new chemicals, instruments, equipment, or machinery?
e. What specific crops or livestock would be affected by adoption of a specific package of technologies?
f. How would the package of technologies affect the performance of crop and livestock production?
g. How would each package of technologies affect the quality of the environment and resource use?

Table A-1.—Alternative Technology Environments

Factors	More new technology	Most likely	Less new technology
Population growth rate:			
United States	1 .0%	0.7%	0.5%
World	1.8	1.6	1,3
GNP growth rate:			
United States	4.0	3.4	3.0
World	5.0	3.5	2.0
Trade policy	Less protectionist, more favorable terms of trade	Continuation of present trends	More protectionist, less favorable terms of trade
Rate of growth of export demand:			
Grain	1.80/0	1.4%	0,80/0
Oilseeds	2.3	1.8	1.2
Red meat	2.0	1.0	0.0
Energy price growth rate (constant dollars)	5.0	3.0	1.0
Growth rate of research and extension expenditures (constant dollars)	4.0	2.0	0.0
Inflation rate	8.0	5.0	3.0

SOURCE Office of Technology Assessment

A checklist was given on the above information to the participants. Based on information obtained from the presentation and on interactions with the authors, the participants collectively packaged the technologies and estimated the impacts and the adoption profile for each package of technologies (see section "Packaging of Technologies").

Timing of Commercial Introduction

Since the impact of a new technology on agriculture at a given time depends on when the technology is introduced for commercial adoption, each author at the workshops was asked to make an initial estimate on the probable year of commercial int reduction for each technology. Following each presentation, the entire group evaluated and discussed the author's initial estimate. The entire group then collectively estimated the year of commercial introduction of each technology under the three technology environments. Table A-2 shows the probable years of commercial introduction of animal technologies, and table A-3 shows the same for plant technologies under the three alternative environments.

The years of commercial introduction estimated ranged from the present or possibly earlier—for genetically engineered pharmaceutical products; control of infectious disease in animals; superovulation, embryo transfer, and embryo manipulation of cows; and control of 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, 27 were estimated to be available for commercial introduction before 1990, and the other 30 between 1990 and 2000, under the most likely environment. In plant agriculture, 50 of the 90 technologies examined were projected to be available for commercial introduction by 1990, and the other 40 technologies between 1990 and 2000.

Packaging of Technologies

Since in practice most technologies would be used in combination with other technologies, the 28 areas of technologies were grouped into packages according to their probable impacts on particular commodities under different technology environments. Table A-4 shows different packages of technologies used in producing different commodities under the three alternative environments. In beef production, for example, 12 animal technology areas were grouped into six packages. Since more new technologies would be available for commercial adoption in later years than earliers years, each package of technologies was further categorized as a 1990 package and a 2000 package. For example, package 1990A would include all genetic engineering technologies introduced commercially by 1990, and package 2000A would include all genetic engineering technologies introduced commercially by 2000, including all package 1990A technologies. Thus, there are really a total of 12 packages of technologies for beef production.

Performance Estimates Under the No-New-Technology Environment

To estimate the net impact of emerging technologies on agricultural production, the participants of the workshops were first asked to project the performance measures of crop and livestock production, such as crop yields and livestock feed efficiency, to 1990 and 2000 under the no-new-technology economic environment. Historical trend lines of performance measures of crop and livestock production were provided to the participants as a basis for their discussion, Through the Delphi process, participants collectively projected the performance measures for each of the nine commodities for 1990 and 2000 assuming that all emerging technologies identified and discussed in this study would not be available for commercial adoption by 2000. The performance measures used in this study were as follows:

- Wheat: bushels per acre, percent of planted acreage harvested.
- Corn: bushels per acre, percent of planted acreage harvested.
- Soybeans: bushels per acre, percent of planted acreage harvested.
- Cotton: pounds per acre, percent of planted acreage harvested.
- Rice: bushels per acre, percent of planted acreage harvested.
- Beef: pounds of meat produced per pound of feed, calves per cow per year.
- Swine: pounds of meat produced per pound of feed, pigs per sow per year.
- Dairy: pounds of milk produced per pound of feed, pounds of milk produced per cow per year.
- Poultry: pounds of poultry produced per pound of feed, eggs per layer per year,

The results of the estimates are shown in table A-5. If all the new technologies identified in this study do not become available for commercial adoption

Table A-2.—Timing of Commercial Introduction of Animal Technologies

Technology	Technology environments: More new technology	Most likely	Less new technology
Genetic engineering:			
Production of pharmaceuticals	1982	1982	1982
Control of infectious diseases	1983	1983	1983
Improvements in animal production	1990	2000	> 2000"
Detection and treatment of genetic abnormalities:			
Detection	1990	1995	>2000
Treatment	1990	2000	>2000
Control of cancer and leukemia	1990	1990	>2000
Animal production:			
Cycle regulation	1985	1989	1995
Superovulation, embryo transfer, and embryo manipulations	1983	1983	1983
Improvement of fertility	1990	1995	1995
Genetic engineering techniques for farm animals	1995	2000	>2000
Regulation of growth and development:			
Muscle and adipose tissue accretion	1987	1992	>2000
Hormone, serum, and tissue factors important to growth	1995	2000	>2000
Immunological attraction of animals	1990	1995	>2000
Measuring body composition and animal identification	1990	1995	>2000
Animal nutrition:			
Animal product consumption and human health	1995	2000	>2000
Alimentary tract microbiology and digestive physiology	1989	2000	>2000
Voluntary feed retake and efficiency of animal production	1989	1995	>2000
Maternal nutrition and progeny development	1984	1984	1984
Aquiculture	1984	1984	1984
Livestock pest control:			
Slow-release Insecticides	1984	1984	1984
Vaccines	1986	1986	1991
Integrated systems	1987	1989	1994
Modification of insect habitat	2000	2000	2000
Insect-resistant animals	2000	2000	2000
Utilizing Immunity systems	1990	1990	1995
Disease control:			
Data managment and systems analysis	1980	1980	1980
Diagnostic methodologies	1986	1986	1988
Selection for disease resistance	1994	1999	>2000
Genetic engineering of micro-organisms and embryos			
Embryos	1995	1999	>2000
Micro-organism	1988	1989	1999
Immunobiology	1983	1983	1983
Environment and animal behavior:			
Energy conservation			
Non-Integrated system	1985	1990	2000
Integrated system	1995	2000	>2000
Optimizing total stress	1995	2000	>2000
Stress and immunity	1995	2000	>2000
Photoregulation of physiological phenomena	1990	1990	>2000
Utilization of crop residues and animal wastes:			
Energy from manure	1985	1985	1985
Chemicals from crop residues	1990	1990	>2000
Animal feed from crop residue	1990	1990	>2000
Animal feed from manure	1990	1995	>2000
Monitoring and control technologies:			
Sensors	1985	1985	1985
Controllers	1985	1985	1985
Displayers	1985	1985	1985
Actuators	1985	1985	1985
Communication and information management:			
Local communication networks	1985	1985	1985
Data terminals	1985	1985	1985
Software and database systems	1985	1985	1985
Manufacturing management systems	1987	1990	2000
Expert systems	1992	1995	2000
Telecommunications:			
Digital communication	1990	2000	>2000
Fiber optics	1990	2000	>2000
Personal computers	1985	1985	1985
Videotex and teletext	1985	1985	1985
Value-added networks	1985	1985	1985
Integrated services digital network	1987	1990	2000
Remote sensing	1985	1985	1985
Labor-saving technologies:			
Robotic farming	1995	2000	>2000

" > = After

SOURCE Office of Technology Assessment

by 2000, the performance of crops and livestock could continue to improve through 2000 (but at slower rates), primarily because of better applications of existing technologies through education and extension. For example, corn yields are projected to increase from 115 bushels per acre in 1982 to 117 bushels per acre in 1990 and 124 bushels per acres in 2000. Wheat yields are projected to increase from 36 bushels per acre in 1982 to 38 bushels per acre in 1990 and 41 bushels per acre in 2000. And milk production could increase from 12,300 pounds per cow per year in 1982 to 13,700 pounds in 1990 and 15,700 pounds in 2000.

Table A-3.—Timing of Commercial Introduction of Plant Technologies

Technology	Technology environments: More new technology	Most likely	Less new technology
Genetic engineering:			
microbial inoculums	1990	1990	Never
Plant propagation	1983-90	1983-90	>1 990'
Genetically engineered plants			
Vegetable	1990	1990	1995
Soybeans/cotton	1990	1995	2000
Cereals	1995	2000	2010
Enhancement of photosynthetic efficiency:			
Basic process of photosynthesis	1983	1983	1983
Photosynthetic control by Internal and external factors	1983-90	1983-90	1983-2000
Photosynthetic molecular biology and genetics	1990-2000	1990-2000	1990-2000
Estimation of photosynthesis and project management needs	1983-90	1983-90	1983-90
Mechanisms of response and adaptation to stress	1990	1983-95	2000
Plant growth regulators:			
Controlling growth and development	1984	1984	1985
Resistance 10 disease and Insect pests	1986	1988	1990
Overcoming environmental stresses	1986	1988	1990
Postharvest preservation	1985	1986	1990
Plant disease and nematode control:			
Breed cultivators	1984	1984	1984
Genetic engineering	2000	2000	2025
Bacteriocides fungicides and nematicides	1988	1990	2000
Biocontrol agents	1985	1990	2010
Crop loss assessment	1985	1990	2000
Management of insects and mites,			
Chemical controls	>1995	2000	>2000
New chemicals	1984	1984	1984
Application technology	1988	1990	1995
Genetic engineering			
Pathogen/c chemicals	1995	2000	2005
Plants	2000	2005	2010
Information processing	1984	1984	1984
Weed control:			
Bioregulation through chemical and biological technology	1984-2000	1984-2000	1984-2000
Allelopathic chemicals as bioregulators	1990	1995	2000
Crop tolerance and susceptibility to control agents	1992	1998	>2000
IWMS for conservation tillage and annual multicrop production	1984-2000	1984-2000	1984-2000
Biological nitrogen fixation:			
Improved strains of rhizobia	1984	1984	1984
Stress-tolerant rhizobia	1987	1990-95	1995-2000
Legumes more active m nitrogen fixation (plant breeding)	1990-95	1990-95	1990-95
Root zone of cereals	>2000	>2000	>2000
Nitrogen-fixmg cereals	>2000	>2000	>2000
Chemical fertilizers:			
Increasing *efficiency* of nitrogen use	1990	1995	2000
Decreasing energy required	1980	1980	1980
Processing of lower quality phosphate rock into fertilizers	1990	1990	1990
Ammonia from coal	1995	2000	2000
Water and soil-water-plant relations:			
Understanding drought resistance/tolerance	2000	2020	2050
Plant breeding	1984	1984	1984
Biotechnology" recombinant DNA			
Water use efficiency	2010	2030	2050
Water management	1984	1984	1984
Photovoltaic systems	1995	1995	2010
Soil ***erosion, productivity, and tillage:***			
Conservation farming systems	1995	1995	1995
Assessing erosion and its impact	1995	1995	2000
Reclaiming lands	1995	1995	>2000
Use of public for soil conservation projects	1995	1995	1995
Multiple cropping:			
Breeding crops for intensive planting systems	1985	1985	1985
Double croppmg/intercropplng	1990	1985	1985
Competition by plant species for growth factors	1990	1995	1990**
Plant nutrition through fertilizers and microbiology	1995	2000	>2000
Mechanization for multiple cropping	1987	1990	1987'"
Organic farming:			
Reduced use of inputs			
Biocides	1984	1984	1984
Reduced soil erosion	1984	1984	1984
Self-sufficiency for nutrients	1984	1984	1984
Minimum tillage with minimal biocide use	1990	1990-95	2000
Rotations			
Use	1984	1984	1984
Knowledge	1990	1990-95	2000
Labor-saving technologies:			
Mechanized fruit and vegetable operations	1985	1985	1985
Robotic farming			
Fruit and vegetable	1995	2000	2010
Grains	1995	2000	2010
Crop separation, cleaning, and processing:			
New methods for separating and cleaning grain	1995	1995	1995
Infield or onfarm processing of forages and oilseeds:			
Vegetable	1984	1984	1984
Forage	1990	1990	2000
Oilseed	1984	1984	1984
Engine and fuels:			
Adiabatic compression ignition engines with turbocompounding	1990	1990	1990
Electronic engine controls	1985-86	1986	1986
Alternative fuels			
Grams	1984	1984	1984
Cellulose	1995	2000	2010
Land management:			
Conservation tillage	1984	1984	1984
Controlled traffic farming	1987	1990	1995
Customed-prescribed tillage	2000	2005	2020
Multicropplng	1984	1984	1984
Organic farming			

Table A-3.—Timing of Commercial Introduction of Plant Technologies—Continued

Technology	Technology environments: More new technology	Most likely	Less new technology
Communication and information management:			
Local communication networks	1985	***1985***	***1985***
Data terminals	1985	1985	1985
Software and database systems	1985	1985	1985
Manufacturing management systems	1987	1990	2000
Expert systems	1990	1992	1997
Monitoring and control:			
Sensors	1984	1984	1984
Controllers	1984	1984	1984
Displayers	1984	1984	1984
Actuators	1984	1984	1984
Telecommunications:			
Digital communication	1995	2000	2010
Fiber optics	1990	2000	2010
Personal computers	1985	1985	1985
Videotex and teletext	1985	1985	1985
Value-added networks	1985	1985	1985
Integrated services digital network	1990	1990	>2000
Remote sensing	1985	1985	1985

•> = After
● *May actually accelerate development m this area if there is increased Interest m resource efficient/sustainable cropping systems

SOURCE Off Ice of Technology Assessment

Table A-4.—Packages of Technologies

Beef:

- Package A: Genetic engineering
- Package B: Animal reproduction
  - Regulation of growth and development
  - Animal nutrition
  - Crop residue and animal waste
- Package C: Pest control
  - Disease control
- Package D: Environment and animal behavior
- Package E: Monitoring and control
  - Communication and information management
  - Telecommunications
- Package F: Labor saving

Swine:

- Package A: Genetic engineering
  - Animal reproduction
  - Regulation of growth and development
  - Animal nutrition
  - Pest control
  - Disease control
- Package B: Environment and animal behavior
  - Monitoring and control
  - Communication and information management
  - Telecommunications
- Package C: Crop residue and animal waste
- Package D: Labor saving

Dairy:

- Package A: Genetic engineering
  - Animal reproduction
  - Pest control
  - Disease control
- Package B: Regulation of growth and development
  - Animal nutrition
  - Environment and animal behavior
  - Crop residue and animal waste
- Package C: Monitoring and control
  - Communication and information management
  - Telecommunications
  - Labor saving
- Package D: Bovine growth hormone

Poultry:

- Package A: Genetic engineering
  - Animal reproduction
  - Regulation of growth and development
  - Animal nutrition
- Package B: Pest control
  - Disease control
  - Environment and animal behavior
  - Crop residue and animal waste
- Package C: Monitoring and control
  - Communication and information management
  - Telecommunications
  - Labor saving

Wheat:

- Package A: Plant growth regulators
  - Plant disease and nematode control
  - Management of insects and mites
  - Weed control
  - Chemical fertilizers
  - Water and soil-water-plant relations
  - Soil erosion, productivity, and tillage
  - Multiple cropping
  - Organic farming
  - Land management
- Package B: Labor saving
  - Crop separation, cleaning, and processing
  - Engines and fuels
- Package C: Communication and information management
  - Monitoring and control
  - Telecommunications

Corn:

- Package A: Genetic engineering
  - Plant disease and nematode control
  - Management of insects and mites
  - Water and soil-water-plant relations
  - Communication and information management
  - Monitoring and control
  - Telecommunications
- Package B: Weed control
  - Chemical fertilizers
  - Soil erosion, productivity, and tillage
  - Multiple cropping
  - Land management
- Package C: Organic farming

Soybean:

- Package A: Genetic engineering
  - Enhancement of photosynthetic efficiency
  - Plant growth regulators
  - Plant disease and nematode control
  - Multiple cropping
- Package B: Management of insects and mites
  - Weed control
  - Biological nitrogen fixation
  - Chemical fertilizers
  - Water and soil-water-plant relations
  - Soil erosion, productivity, and tillage
  - Organic farming
  - Labor saving
  - Crop separation, cleaning, and processing
- Package C: Communication and information management
  - Monitoring and control
  - Telecommunications

Rice:

- Package A: Genetic engineering
  - Enhancement of photosynthetic efficiency
  - Plant growth regulators
  - Plant disease and nematode control
- Package B: Management of insects and mites
  - Weed control

Table A-4.—Packages of Technologies—Continued

	Chemical fertilizers Water and soil-water-plant relations Multiple cropping Crop separation, cleaning, and procesing Communication and information management Monitoring and control Telecommunications
Cotton:	
Package A:	Genetic engineering Enhancement of photosynthetic efficiency Plant growth regulators Plant disease and nematode control Management of insects and mites Weed control Chemical fertilizers Water and soil-water-plant relations Soil erosion, productivity, and tillage Multiple cropping Labor saving Engines and fuels Land management
Package B:	Communication and information management Monitoring and control Telecommunications
Package C:	Biological nitrogen fixation Organic farming Crop separation, cleaning, and processing

SOURCE: Office of Technology Assessment

Table A.5.—Performance Projections Under No. New-Technology Environment

Commodity	Unit	1990	2000
Beef	lb. meat per lb. feed	0.071	0.066
	calves per cow	0.940	0.950
Dairy.	lb. milk per lb. feed	0.938	0.952
	milk per cow per year (thousand lb)	13.7	15.7
Poultry , ...	lb. meat per lb. feed	0.52	0.53
	eggs per layer per year	255.0	260.0
Swine	lb. meat per lb. feed	0.167	0.17
	pigs per sow per year	14.8	15.7
Corn	bushels/acre	116.5	123.5
Cotton	pounds/acre	502.0	511.0
Rice	bushels/acre	108.6	111,9
Soybean.	bushels/acre	32.2	34.8
Wheat	bushels/acre	37.8	40.8

SOURCE: Office of Technology Assessment