FORCES SHAPING THE EFFORT TO CONSERVE SOIL AND WATER: RESEARCH ISSUES FOR THE 1990'S

Proceedings of a NCR-149 Symposium
January 1988

Steven E. Kraft
Editor

Published for

North Central Regional Committee 149,
Changing Institutional Environment for the on-Farm
Adoption of Soil and Water Conservation

by the
Soil Conservation Society of America
7515 Northeast Ankeny Road
Ankeny, Iowa

Contents

Contributors ii

Introduction
Steven E. Kraft iii

Soil and Water Conservation in the Turbulent World of American Agriculture: Issues and Challenges for the 1990's--Comments
Richard T. Clark 1
Eckhart Dersch 10

Biotechnology and Its Implications for Water and Soil Conservation
Yao-chi Lu 13

Research Issues in the Arena of Soil and Water Conservation Policy
J. D. Esseks and
Steven E. Kraft 30

Changing Agricultural Property Rights in the Environmental Sector
Stephen B. Lovejoy and
Harry R. Potter 48

Economic Forces Affecting Farmers' Actions to Reduce Erosion
Lawrence W. Libby 59

Policy and Program Considerations for "A National Program for Soil and Water Conservation--The 1988-1997 Update"
James A. Maetzold 78

North Central Regional Committee 149 97

Contributors

Richard T. Clark, Associate Professor
Department of Agricultural Economics, University of Nebraska,
North Platte, Nebraska

Eckhart Dersch, Professor
Department of Resource Development, Michigan State University,
East Lansing, Michigan

J. Dixon Esseks, Associate Professor
Center for Governmental Studies, Northern Illinois University,
DeKalb, Illinois

Steven E. Kraft, Associate Professor
Department of Agribusiness Economics, Southern Illinois University,
Carbondale, Illinois

Lawrence J. Libby, Professor and Chair
Food and Resource Economics Department, University of Florida,
Gainesville, Florida

Stephen B. Lovejoy, Associate Professor
Department of Agricultural Economics, Purdue University,
West Lafayette, Indiana

Yao-chi Lu, Agricultural Economist
Agricultural Research Service, U.S. Department of Agriculture
Beltsville, Maryland

James A. Maetzold, Program Analyst
Soil Conservation Service, U.S. Department of Agriculture,
Washington, D.C.

Harry R. Potter, Associate Professor
Department of Sociology, Purdue University,
West Lafayette, Indiana

Biotechnology and Its Implications for Water and Soil Conservation

Yao-chi Lu

Abstract

Biotechnology could provide powerful tools for conserving soil and water resources, improving the quality of the environment, increasing the productivity of soil, and maintaining the productivity of land which would otherwise be taken out of production because of overuse.

However, there are some potential negative impacts. One concern is that biotechnology can be used to engineer crop and livestock varieties which can thrive in tropical wildlands and thus destroy them. Another concern is that industry, because of profit motivation, is developing applications which are not socially and environmentally desirable.

The foremost concern is with deliberate release into the environment of genetically engineered organisms. Unlike toxic chemicals, released organisms potentially have the capacity to reproduce, to spread, to transfer novel genetic information into other organisms, and to establish themselves within an ecosystem.

Since biotechnology is inchoate and so powerful, it is important that this technology be used to benefit our society, improve the quality of the environment, and conserve our natural resources.

Biotechnology promises to bring enormous benefits to agriculture and to change the ways farmers produce food and fiber. It could also

have important implications for water and soil conservation practices and land use. Biotechnology could provide the means to preserve soil and water resources, improve the quality of the environment, and change the geographical location of production. To examine its possible implications, we need to understand what biotechnology is, how it is different from previous technologies, and how it is applied to agriculture.

What Is Biotechnology?

Biotechnology has been defined as any technique using living systems to develop commercial processes or products (18). It includes recombinant DNA (deoxyribonucleic acid) techniques, gene insertion, embryo manipulation and transfer, plant regeneration, tissue culture, cell fusions and bioprocessing.

Modifying organisms to meet human needs is nothing new. The selection and breeding of plants, animals, and microbes to have desirable traits such as faster growth and pest resistance have been practiced for thousands of years. But these processes of breeding by crossing and selection are imprecise, slow, and laborious.

Biotechnology enables scientists to manipulate genetic materials directly with more precision and speed. The basic technique of biotechnology is the recombinant DNA technique by which desirable genes are isolated and inserted into another organism, so that the desirable traits can be expressed in the new organism.

Unlike traditional crossing and selection, the recombinant DNA technique enables scientists to isolate and modify genes from almost any organism and insert them into almost any other organism regardless of normal species and sexual barriers. By using traditional crossing and selection, scientists can also change or induce mutations in genes and move them, but they cannot change or move a single gene or a few desirable genes. They have to move a group of genes, desirable and undesirable. To develop a new variety of crops or livestock with desirable traits, many cycles of selection are necessary. Thus traditional techniques are much less precise and controlled (19).

How Is Biotechnology Applied to Agriculture?

Animal Agriculture

Currently, there are three major applications of biotechnology to animal agriculture. One is insertion of desirable genes into microorganisms and use of the microorganisms to mass produce biologicals such as hormones, enzymes, activating factors, amino acids, and feed supplements (1). These biologicals can be used for detection, prevention, and treatment of infectious and genetic diseases or to stimulate growth. The well publicized bovine growth hormone to increase milk production is an example of an application of these biologicals. Recently, Agricultural Research Service scientists at Beltsville have derived a porcine growth hormone from the pituitary glands of pigs. Pigs injected with this hormone daily grow 10 to 20 percent faster on 30 percent less feed, and pork chops from these animals have less fat on the rim (26).

A second application arises from the convergence of gene and embryo manipulations. Genes for a desirable trait such as rapid growth or disease resistance are isolated and injected directly into either of the two pronuclei of a fertilized ovum (egg). Upon fusion of the pronuclei, the guest gene becomes a part of all the cells of the developing animals. This technique allows future animals to be permanently endowed with traits of other animals, humans, and probably plants. In 1983, scientists at the University of Pennsylvania and University of Washington successfully inserted a human growth hormone gene into the embryo of a mouse to produce a supermouse that was more than twice the size of a normal mouse (22). In another experiment, scientists at Ohio University inserted rabbit growth hormone genes into the embryos of mice. The genetically engineered mice were 2.5 times larger than normal mice (27). Using the same approach, USDA scientists at the Beltsville Agricultural Research Center are currently conducting experiments to produce sheep and pigs with desirable traits.

Another technique, embryo transfer in cows, involves artificially inseminating a super-ovulated donor animal and removing the resulting embryos nonsurgically for implantation in and carrying to term by surrogate mothers. Prior to implantation, the embryos can be sexed, split (generally to make twins), fused with embryos of other animal species (to make chimeric animals), or frozen in liquid nitrogen. Freezing is of great practical importance because it allows embryos to be stored until the intended recipient is in estrus. The genes likely to be inserted into animals are those for growth hormones, prolactins (lactation stimulator), digestive enzymes, and interferons, thereby providing both faster growth and enhanced resistance to diseases.

Plant Agriculture

Applications of biotechnology in plant agriculture could modify microorganisms to protect crops from diseases, insects, and harsh environment or modify crops themselves so that they would make more nutritious protein, resist insects and diseases, grow in harsh environments, and provide their own nitrogen fertilizer and herbicides. The potential applications include microbial inoculums, plant propagation, and genetic modification (7). Microbial Inoculums

Rhizobium seed inoculums are widely used to improve nitrogen fixation by certain legumes. Research on other plant colonizing microbes has led to a much clearer understanding of their role in plant nutrition, growth stimulation, and disease prevention. The possibility exists for the modification and use of these other microbes as seed inoculums. Recently, Monsanto genetically engineered soil bacteria that produce a naturally occurring insecticide capable of protecting plant roots against soil- dwelling insects (12). The company developed a genetic engineering technique that inserts into soil bacteria a gene from a microorganism known as Bacillus thuringiensis, which has been registered as an insecticide for more than two decades. Plant seeds can be coated with these bacteria before planting. As the plants grow, the bacteria remain in the soil near the plant roots, generating insecticide that protects the plants.

Plant Propagation. Cell culture methods for regeneration of intact plants from single cells or tissue explants have been developed and are used routinely for the propagation of several vegetable, ornamental, and tree species (7). These methods have been used to provide large numbers of genetically identical, disease-free, and superior plants.

Genetic Modification. It is possible to use gene transfer techniques to introduce DNA from one living organism into another, regardless of normal species and sexual barriers. For example, toxin genes from Bacillus thuringiensis have been engineered into plants. The bacterial toxin within the plant tissues kills insects which feed on the plants (IO). The so-called ice-minus bacteria to prevent potato plants from frost damage is another recent example of genetic modification of microorganisms.

What are the Implications for Soil and Water Conservation and Land Use?

Understanding what biotechnology is, how it works, and how it is applied to crop and livestock production, we can speculate on its potential implications for soil and water conservation and land use. Like previous technologies, the impact of biotechnology will depend upon how it is used. Used correctly, it can provide powerful tools for designing resource-conserving, sustainable agricultural systems without creating adverse effects on environmental quality. Possible implications include, but are not limited to, soil and water conservation, improved quality of the environment, changes in geographical location, and increased soil productivity.

Soil and Water Conservation

Biotechnology can be used to conserve soil and water resources through perennial cropping, development of herbicide- resistant, herbicide-producing, and drought tolerant varieties, and increasing yields. The first three developments would reduce tillage. One of the major objectives of tillage is weed control. If weeds can be controlled by non-mechanical means, frequency of tillage can be reduced and erosion decreased.

Perennial cropping. This technology proposed by Rogoff and Rawlins (24) could drastically reduce soil erosion and the need for irrigation. Instead of the conventional method of growing annual and perennial food crops, they propose growing perennial plants to produce lignocellulose, which serves as a storehouse of chemical feedstocks from which food can be produced. Through biotechnological or chemical processes, stored lignocellulose could be converted to simple sugars and then into food or feed. Since only perennial lignocellulosic plants would be grown and no tillage would be needed, soil would suffer less erosion, and both water and fossil energy would be spared by reducing the need for irrigation.

Herbicide-resistant varieties. One way to control weeds is to genetically engineer herbicide-resistant crop varieties so that an overall spray of herbicide would kill all weeds and not the crops (12). Although there are concerns about the desirability of this approach, this is the direction the industry is moving.

Herbicide-producing crop varieties. Another way to control weeds is to engineer crop varieties to produce their own herbicides. This approach could reduce cultivation and application of chemical herbicides, thereby reducing soil erosion and chemical pollution. Scientists have long known that some plants produce chemicals (allelochemicals) that affect the growth of other plants. By studying the allelopaths, scientists could engineer crop varieties that give farmers naturally weed-free crops. The potential value of this line of research is great, but the work is very complicated and significant advances are not expected soon (18).

Drought-resistant varieties. Development of drought-resistant or tolerant crop varieties could reduce water requirements. However, such development is very complex and is not likely to occur before the turn of the century (2).

Increasing yields. The primary impact of biotechnology on plant and animal production will be in increased yields. Increased yields would decrease the total amount of land needed to support a given population, thereby relieving pressure on land use and conserving soil and water resources (9).

Changes In Geographical Location Of Production. Through genetic engineering, scientists may develop new varieties of plants and animals that can thrive in harsh soil and climatic conditions. It may be possible in the near future to genetically engineer crop varieties which would tolerate salt, drought, cold and heat, and resist insects and diseases. Such development could drastically change land use patterns or maintain the productivity of land which would otherwise be taken out of production because of overuse. For example, if cold-tolerant corn varieties are developed, the corn belt could be expanded northward. Similarly, development of drought- or heat-tolerant crop varieties could change the geographical location of production.

However, the same technology can also be used to keep the production region from changing. Take salt-tolerance for example. Most commercial crops cannot survive in saline soils. Continuous irrigation in many parts of the country, especially the arid Western states, builds up salt in soil. Accumulation of salt eventually kills crops and renders the farmland useless. According to the California Department of Conservation (4), more than 1.5 million acres of highly productive farmland, mostly in the San Joaquin and Imperial Valleys, suffer reduced yields from soil salinity. About 25,000 acres of prime farmland are being taken out of production every year because of this salinity problem. Development of salt-tolerant crop varieties could maintain productivity of land with continuous irrigation.

Improvement In the Quality Of the Environment

Biotechnology provides powerful tools to improve the quality of the environment. Through genetic engineering, scientists could develop crop varieties which fix their own nitrogen fertilizer, resist insects and diseases, and control weeds, thereby reducing dependence on hazardous chemicals and improving the quality of the environment.

Nitrogen fixation. Development of nitrogen-fixation technology could not only conserve soil and water resources, it could also have significant and positive impacts on the environment. This technology could reduce substantially the use of chemical fertilizers. As a result, less nitrogen would run off into surface waters and percolate into groundwater and thus water quality would be improved. With less nitrogen being manufactured and used, fewer people would be exposed to health risks in fertilizer manufacturing plants and on the farm. Reduced fertilizer manufacturing could improve air quality and reduction of nitrogen runoff into surface waters would benefit wildlife, especially aquatic life (13).

Biological pest control. Using toxin genes from bacteria to control pests could decrease applications of chemical protectants and improve the quality of the environment. For example, Bacillus thuringiensis produces a toxin that has been used as an insecticide. There are two new ways to use this bacterium as a natural insecticide to protect crops (12).

One way is to insert toxin genes from Bacillus thuringiensis into other bacteria so that the new bacteria will produce toxin. These bacteria can then be delivered to places, such as roots, that are not accessible for spraying with Bacillus thurinqiensis. As indicated earlier, scientists at Monsanto have inserted Bacillus thuringiensis toxin genes into microorganisms that are normally associated with the roots of corn plants so that the toxin is present at the site of feeding of the corn rootworm.

Another approach is to engineer crops to produce toxin for their own protection. This approach is especially useful in cases where insects inhabit and feed on parts of plants such as roots or cotton bolls that are difficult to reach with sprays. Recently, Plant Genetic Systems had isolated the gene for Bacillus thuringiensis and inserted it into tobacco plants (17). Field trials confirmed the ability of these plants to resist attack by caterpillars and the trait has been shown to be stably inherited by subsequent generations.

Alleochemical. As indicated earlier, engineering crop plants with their own ability to control weeds could reduce mechanical cultivation and thus reduce erosion. It also could reduce applications of chemical herbicides, thereby reducing chemical pollution and benefiting wildlife.

Increased Soil Productivity

Biotechnology could increase soil productivity by conferring nitrogen-fixing ability on nonlegumes and by increasing the nitrogen-fixing ability of certain soil microbes (15). It is well known that legumes have the ability to fix nitrogen from the atmosphere and transform it into a form that plants can use but major cereal crops lack this ability. Developing cereal plants with nitrogen fixing abilities has long been a goal of agricultural geneticists, but many difficult problems have been encountered. Advances in genetic engineering have opened up new avenues for scientists to develop cereal plants with nitrogen fixing capabilities (13). While the possibilities for significant breakthroughs prior to the end of the century are considered remote according to a recent report by the Office of Technology Assessment (21), some incremental advances are expected.

What Are the Risks?

So far we have discussed the potential positive implications. However, like any technology, biotechnology can also have negative impacts. For example, the recombinant DNA techniques can be used to develop two different kinds of crop varieties to control weeds:

herbicide-resistant crop varieties and herbicide-producing varieties. Even though herbicide producing crop varieties are socially and environmentally more desirable, big chemical companies, motivated by profit, are moving to producing herbicide-resistant varieties. They can sell more seeds (many seed companies are now owned by chemical companies) and herbicides. Although industry claims that herbicides such as Roundup by Calgene are environmentally safe and herbicides-resistant varieties allow farmers to make more effective use of a single herbicide by reducing the number of different chemicals or applications (12), the public is concerned about possible overuse of chemicals. It is ironic that recombinant DNA techniques are being used to encourage more use of chemicals when the public is concerned about toxic chemical residues in foodstuff (5).

Biotechnology can also be used to destroy our natural resources and environment. This is the concern expressed by Jenzen (14). He argues that "tropical wildlands and most of the earth's contemporary species still exist because humanity has not had organisms capable of converting all tropical land surface to profitable agriculture and animal husbandry." He fears that when biotechnology can engineer crop and livestock varieties which can thrive in tropical wildlands and be profitable, the wildlands will be destroyed.

The foremost concern about the risk of biotechnology is with the deliberate release of genetically engineered organisms. Unlike toxic chemicals, released organisms potentially have the capacity to reproduce, to spread, to transfer novel genetic information into other organisms, and to establish themselves within an ecosystem. Yet little is known about the potential consequences of releasing modified organisms into the environment. For example, Steven Lindow and Nicholas Panopoulos of the University of California, Berkeley, have genetically engineered ice-nucleation bacteria which inhibit frost formation in potato plants. To form ice, there must be nucleation sites around which water molecules can form ice crystals. In the ecosphere, this role is performed by bacteria called Pseudomonas syringae which contain a specific protein that acts as the nucleation centers for the growth of ice crystals (5). Lindow and Panopoulos constructed a new strain of bacteria in which the nucleation protein is absent so that the bacteria no longer act as nucleation centers. If the new strain of bacteria will outcompete the normal strains in the field, the new bacteria will prevent crops from frost damage and millions of dollars in lost crops will be saved.

However, scientists know little about these new strains of bacteria once they are released to the environment. Several questions have been raised. What if the new strains outcompete and replace most of the normal strains which may play a role in the moisture nucleation in clouds and consequently rain or snow fall? What if they allowed clouds to hold much more moisture before precipitation occurred? If any of these problems occur, they could have tremendous implications for reallocation of our water resources.

Currently, the Agricultural Research Service at Beltsville, Maryland, is drafting a project to develop sound and complete methodologies for assessing potential risks of the deliberate release into the environment of genetically engineered organisms including microorganisms, plants, and animals. This project will identify possible damage and estimate the likelihood and magnitude of the impacts of released organisms on human and animal health and on the environment. The results will help regulatory agencies make sound decisions while obviating unnecessary regulations and increasing public acceptance of the technology by allaying fears about biotechnology.

Summary and Conclusions

Biotechnology could provide powerful tools for sustaining agricultural systems without adverse impacts on the environment. If used correctly, this technology could conserve soil and water resources, maintain the productivity of land which would otherwise be taken out of production because of overuse, improve the quality of the environment, and increase the productivity of soil.

However, there are some potential negative impacts. Biotechnology can be used to destroy our natural resources and environment. One concern is that biotechnology can be used to engineer crop and livestock varieties which can thrive in tropical wildlands and thus destroy them. Another concern is that industry, motivated by profit, is developing applications which are not socially and environmentally desirable. Development of herbicide-resistant varieties is an example.

The foremost concern is with deliberate release into the environment of genetically engineered organisms. Unlike toxic chemicals, released organisms potentially have the capacity to reproduce, to spread, to transfer novel genetic information into other organisms, and to establish themselves within an ecosystem. Yet little is known about the potential consequences of releasing modified organisms into the environment. Currently, scientists have insufficient information to predict the fate of the organisms after they are released and the hazards they might pose if they become established. It is difficult not only to quantify the probability of such occurrence but also to predict the type of damage that might occur.

Since biotechnology is inchoate and it can provide very powerful tools to change our lives and our environment, it is important that this technology be used to benefit our society, improve the quality of the environment, and conserve our natural resources. Currently, the

Agricultural Research Service at Beltsville is planning research to assess the risks of biotechnology products. The results will help regulatory agencies make sound decisions about biotechnology products to safeguard the public while obviating unnecessary regulations so that this new industry will flourish.

References

1. Bachrach, Howard. 1986. "Animal Genetic Engineering." In Technology, Public Policy, and Changing Structure of American Agriculture, Vol. II--Background Papers, Office of Technology Assessment, U.S. Congress.

2. Boersma, Larry and E. L. McCoy. 1986. "Water and Soil-Water-Plant Relations." In Technology, Public Policy, and Changing Structure of American Agriculture, Vol. II--Background Papers, Office of Technology Assessment, U.S. Congress.

3. Buttel, Frederick H. 1986. "Biotechnology and Alternative Agriculture: An Overview of Major Issues and Concerns." In Proceedings of the Institute for Alternative Agriculture. Third Scientific Symposium, Washington, DC, March 1987.

4. California Agricultural Lands Project. 1982. Genetic Engineering of Plants. San Francisco, California.

5. Feldberg, Ross. 1985. "Framing the Issue: The Social Implications of Biotechnology." Science for the People 17:3.

6. Fiksel, Joseph and Vincent T. Covello. 1986. Biotechnology Risk Assessment: Issues and Methods for Environmental Introductions. Pergamon Press, New York.

7. Fraley, Robert, T. 1986. "Genetic Engineering in Plants." In Technology, Public Policy, and Changing Structure of American Agriculture, Vol. II--Background Papers, Office of Technology Assessment, U.S. Congress.

8. Gillett, James W., ed. 1986. "Potential Impacts of Environmental Release of Biotechnology Products: Assessment, Regulation, and Research Needs." Environment Management. 10(4).

9. Goodman, Robert M. "Conservation and Agricultural Economics: Responses." Science 236: 1159.

10. Goodman, Robert M., Holly Hauptli, Anne Crossway, and Vic C. Knauf. 1987a. "Gene Transfer in Crop Improvement." Science 236: 48-54.

11. Goodman, Robert M., Holly Hauptli, Anne Crossway, and Vic C. Knauf. 1987b. "Conservation and Agricultural Economics: Reply." Science 236: 48-54.

12. Hauptli, Holly and Robert M. Goodman. 1987. "Commercial Priorities of Small Companies in Agricultural Biotechnology: Relevance to Alternative Agriculture." In Proceedings of the Institute for Alternative Agriculture, Third Scientific Symposium. Washington, DC.

13. Hite, James. 1986. "Environmental and Natural Resource Impacts of Emerging Technologies in American Agriculture." In Technology, Public Policy, and Changing Structure of American Agriculture, Vol. II--Background Papers, Office of Technology Assessment, U.S. Congress.

14. Janzen, Daniel H. 1987. "Conservation and Agricultural Economics." Science 236: 1159.

15. Levin, Moriris A., George H. Kidd, Tobert H. Zaugg, and Jeffrey R. Swarz. 1983. Applied Genetic Engineering: Future Trends and Problems. Noyes Publication, New Jersey.

16. Marx, Jean L. 1977. "Assessing the Risks of Microbial Release." Research News, September 18.

17. Meeusen, Ronald L. 1988. "Status and Future of Insect Resistant Crops Research." In Proceedings of AgBiotech,88: International Conference and Exposition. Washington, DC.

18. National Academy of Sciences. 1987a. Agricultural Biotechnology: Strategies for National Competitiveness. National Academy Press, Washington, DC.

19. National Academy of Sciences. 1987b. "Introduction of Recombinant DNA-Engineered Organisms into the Environment: Key Issues." National Academy Press, Washington, DC.

20. Office of Technology Assessment, U.S. Congress. 1981. Impacts of Technology on U.A. Cropland and Rangeland Productivity. Washington, DC.

21. Office of Technology Assessment, U.S. Congress. 1986. Technology, Public Policy, and Changing Structure of American Agriculture. Washington, DC.

22. Palmiter, R.D., et al. 1983. "Metallathionein-Human GH Fusion Genes Stimulate Growth of Mice." Science, 222:809-814.

23. Perpich, Joseph G. 1986. Biotechnology in Society. Pergamon Press. New York.

24. Rogoff, Martin H. and Stephen L. Rawlins. 1987. "Food Security: A Technological Alternative." Bioscience 37(11):800-807.

25. Schneiderman, Howard A. "An Innovative Edge Through Biotechnology. Agricultural Engineering. July/August.

26. Steele, Norman C. 1987. "Update of Porcine Growth Hormone Research: Practical and Biological Implications." Cornell Nutrition Conference. Cornell University, Ithaca, New York.

27. Wagner, Thomas E. 1985. "Gene Introduction and Regulation in Transgenic Animals." Paper presented at the Conference on Genetic Engineering of Animals: An Agricultural Perspective, University of California, Davis, Sept. 9-12.