THE FOURTH CRITERION
SOCIAL AND ECONOMIC IMPACTS OF AGRICULTURAL BIOTECHNOLOGY

The world economy is currently undergoing major structural changes. A central factor in these changes has been the development and diffusion of fundamentally new technologies, in particular computers and the "new biotechnologies." Social and economic changes that result from these profoundly enhanced capacities in science and technology are visible in every sphere of human life from health, transportation and communication, to agriculture and the food supply. However, each change is associated not only with new benefits but also with new risks, latent complications and long term consequences which are often poorly understood.

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Commercial applications of biotechnology to agriculture are still in their infancy. Despite enormous optimism in the scientific community, in national and state governments, and in the private sector, most of the products, processes, and impacts of biotechnology, particu - larly in agriculture, remain promises for the future. jhe applications of biotechnology are fraught with concern and controversy within both the scientific community and the broader public.

Often public concerns have centered on health and environmental safety issues. Similarly in Europe, the three standard criteria, human safety, animal safety, and efficacy, have been utilized to evaluate and approve new products and processes. Currently, a fourth criterion, the social and economic effects of the product or technology is being proposed. This criterion has been employed for such actions as the European Common Market's ban on growth hormones in food products. Recently, the Advocate General of the Court of Justice in the European Communities released his opinion on the legality of the hormone ban stating that "It was appropriate and justifiable to prohibit the administration of the five substances for fattening purposes, even in the absence of scientific evidence showing that they were harmful. A total prohibition was the only solution which could bring an end to the distortions of competition and barriers to intra-Community trade in meat, eliminate risk to public health, even if they were purely hypothetical ones, and avoid a further reduction in consumption." (Weber, 1990:1)

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Similar efforts are underway to utilize this approach as a precedent to alter the product approval process in the United States. Scientists, regulators, industry representatives, and the public in general have all voiced concern that all technologies, including genetically engineered organisms and products, could have adverse impacts. As a result of these concerns and experiences with previous technologies, an increasingly accepted position among technology assessment professionals is that: 1 - all technologies have multiple effects; 2 - many of these effects are potentially harmful and thus require conscious decisions; and 3 - these critical decisions entail moral as well scientific analysis.

Although introduced as the fourth criterion, it may be more appropriate in evaluating research agendas and new products and processes to consider the broad socioeconomic effects as the first criterion. As most scientists and policy analysts acknowledge, biotechnologies are the tools and means to achieve particular socioeconomic goals. As such they should be framed and evaluated in terms of those social goals and values.

In a democracy, the public has an obligation and a right to shape the developments of technology in terms of the broad social and economic values of their respective society. In the case of biotechnology, as we have seen, the public is increasingly exercising that obligation and right. Therefore, it is important for scientists, regulators, and policy-makers to understand and evaluate not only elements of human safety, animal safety, environmental risk, and efficacy, but also the range of socioeconomic impacts and concerns.

The potential social and economic impacts of biotechnology on the food and fiber system and society are just emerging. Consequently, the proposed implications of biotechnology for the system represent only possible scenarios. The socioeconomic effects may include impacts on: 1 - science, 2 - farmers and rural communities, 3 - consumers, 4 - the structure of agribusiness and industry, and 5 - the global market and developing countries.

The knowledge and tools generated by molecular biology and biotechnology have stimulated a great deal of enthusiasm and redirected large sums of money in an effort to pursue knowledge in this area.

IMPACT ON SCIENCE

Perhaps the most dramatic immediate impact of the new biotechnologies has been on science itself. While some argue that biotechnology is a continuation of the application of biological techniques to improve plants, animal, and microorganisms, molecular biologists contend that "biotechnology has revolutionized biology and is destined to have even greater impact than the industrial revolution on agriculture and the food system in this country" (Harlander, *etal,* 1991).

The knowledge and tools generated by molecular biology and biotechnology have stimulated a great deal of enthusiasm and redirected large sums of money in an effort to pursue knowledge in this area. At the federal level, financial support for biotechnology has grown steadily since the mid 1980s, reaching $3.8 billion in 1991. The President's budget for 1992 calls for an 11 percent increase to $4.1 billion. While 80 percent of the federal budget has been devoted to the National Institutes of Health program, support for agricultural biotechnology has been relatively meager, constituting less than three percent of federal expenditures for biotechnology. There is, however, significant optimism that agricultural biotechnology will receive substantial increases at the federal level through the National Research Initiatives Program. In addition, industrial expenditures for biotechnology research and development had grown to $2 billion by 1990, with a large portion of the expenditures devoted to agricultural biotechnology (Metheny and Monahan, 1991).

The techniques and tools of biotechnology are facilitating basic research efforts to understand the intricate, complex, functioning of living organisms at their molecular and cellular level. Molecular biology in conjunction with other basic research is accelerating the accumulation of knowledge in traditional disciplines such as biology, genetics, plant physiology, and biochemistry. Moreover, biotechnology, particularly in agriculture, may truncate both the time and space required to develop new plant, animal, and food products. Finally, it may complement and extend

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traditional methods used to enhance agricultural productivity and nutritional quality.

Still, several potential negative impacts of molecular biology on science may exist. Biotechnology and molecular biology continue and extend the basic methods and approaches of modern science. Their perspective, often called "logical positivism," attempts to reduce nature to small, definable pieces, subject to human manipulation and separated from broader questions of value. From this perspective, scientists control, measure, reduce, and divide nature in order to generate knowledge.

One concern is that this approach, while providing only partial knowledge, has become the dominant epistemology, often to the exclusion of other important alternative ways of knowing. As a consequence, whole plant and animal level research, such as traditional plant breeding, and systems level research programs such as agroecology, farming systems, and social assessments, which should be important complements to a comprehensive biotechnology research agenda, receive inadequate support. In U.S. colleges of agriculture, for example, employment opportunities in agricultural biotechnology and molecular genetics are growing, while employment in plant and animal breeding is declining. Between 1982 and 1988 full time equivalent (FTE) scientists conducting agricultural biotechnology research in the state agricultural experiment stations increased by 259 percent (273 to 682). In addition, staff working in this area rose from 472 in 1982 to 1131 in 1988. At the same time, overall FTE faculty positions in the state agricultural experiment stations increased by only 65 (National Association of State Universities and Land Grant Colleges, NASULGC, 1989). Therefore, much of the increase in the FTE's for biotechnology research represented a reallocation of existing positions. Interviews with state agricultural experiment station directors confirmed this conclusion. They indicated that many of these molecular biology positions had been created by reducing the scope of conventional breeding programs (Busch, *et al,* 1991).

Another impact on science is the increase in the concentration of research funds and scientific talent at a small number of public and private institutions. For example, in the public sector, every U.S. state could afford and has had a conventional breeding program. Every state cannot afford and will not be able to have a comprehensive agricultural biotechnology program. Instrumentation and annual funding costs are particularly expensive, with start-up funds and operating costs two to three times that of other agricultural sciences (NASULGC, 1989). Concentration of public sector and scientific talent in a few states is already occurring. While 33 states are actively engaged in some promotion of biotechnology research and development, three states account for more than half the investment in biotechnology (Office of Technology Assessment, OTA, 1988). In agricultural biotechnology eight states account for over half of the state experiment station expenditures and nearly half of all science years for biotechnology research (NASULGC, 1989).

The new biotechnologies are also changing the division of labor between universities and industries with concomitant impacts.

The new biotechnologies are also changing the division of labor between universities and industries with concomitant impacts. While partnerships between universities and industries have existed for several decades, the new types of university and industry relationships in biotechnology (e.g., centers, institutes, research parks, public corporations) are more varied, more aggressive, and more experimental. They include: large grants and contracts between companies and universities in exchange for patent rights and exclusive licenses to discoveries; programs and centers, organized at major universities with industrial funds, that give participating private firms privileged access to university resources and a role in shaping research agendas; professors, particularly in the biomedical sciences, serving in extensive consulting capacities on scientific advisory boards or in managerial positions of biotechnology firms; and faculty receiving research funding from private corporations in which they hold significant equity. In a recent survey of biotechnology researchers at 40 major universities, 47 percent of these faculty consulted with outside corporations and eight percent held equity in a firm whose products or services were directly related to their own university research (Blumenthal, *etal.,* 1986).

The consequences of these collaborations may be both positive and negative. First, these university and industry collaborations may bring useful products to market more rapidly and may promote U.S. technological leadership in a changing world economy. This has been a major motivation behind a number of recent funding policies and laws of the federal government requiring this collaboration for federally funded research. Second, in light of funding stagnation at both the federal and state levels, *Even some scientists with public funding feel inhibited about discussing their work...*

the collaborations are a means of raising new funds for university research. Third, these joint efforts may expand the scientific network, increasing communication between some industry and university scientists.

A number of concerns, however, have been raised regarding these new relationships. First, long term research, previously a major emphasis of the public sector, may decline. The private sector has short term proprietary goals, and, as a consequence, funding for research is also generally short term. A study in the mid-1980s of biotechnology firms revealed that nearly half funded research in universities. Of those funding research, 50 percent reported that projects spanned one year or less, while only 25 percent reported funding projects lasting more than two years (Blumenthal, *etal,* 1986). In contrast, nearly all of the NIH extramurally funded programs and the USDA Hatch formula funded projects are for three years or more.

A second issue is a potential restriction of communication. Proprietary agendas have begun to inhibit the flow of information among biotechnology scientists and have raised concern about access to information. This is particularly true of university scientists with private sector grants, who often must delay public discussion of work, or its results, pending review by the sponsoring company. In one study 25 percent of industry sponsored biotechnology faculty, reported conducting research that belonged to the firm and could not be published without prior consent, while 40 percent reported that their collaboration resulted in unreasonable delays in publishing (Blumenthal, *etal.,* 1986). Even some scientists with public funding feel inhibited about discussing their work, for fear that some private company with the money, equipment, and time will utilize their ideas and perform the experimental work before they can. The net effect of these various developments appears to be a reduction of the free flow of information. Open communication is fundamental to public sector science, and indeed, one industry scientist remarked that more knowledge is generated by keeping an open environment for scientists (personal interview, 1987). Most breakthroughs do not come from just one laboratory; instead there is need for more information from a number of different laboratories. Communication among the scientists is crucial (OTA, 1986).

A third concern is a potential for conflict of interest or scientific misconduct. In interviews both public and private sector scientists stressed the potentially detrimental effects of granting private patents for work done in the public sector. These effects include potential favoritism, unwarranted financial advantage through privileged use of information or technology partly derived from publicly funded research, constraints on sharing of germplasm, and shelving of research which may be of interest to the public but not to the corporation (Lacy, *et al,* 1988).

Recently, Derek Bok in his final President's report to Harvard University's Board of Overseers warned that the commercialization of universities may be the most severe threat facing higher education. Mr. Bok noted that as universities become "more entrepreneurial they appear less and less as charitable institutions seeking truth and serving students and more and more as huge commercial operations that differ from corporations only because there are no shareholders and no dividends." He concluded by saying that "it will take very strong leadership to keep the profit motive from gradually eroding the values on which the welfare and reputation of universities ultimately depend" (McMillen, 199KA31).

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IMPACTS ON FARMERS AND RURAL COMMUNITIES

The impact of agricultural change on rural communities is to a high degree proportional to the level of local dependence on agriculture. Today, nationwide, fewer than 40 congressional districts have more than 20 percent of their population living on farms (Sundquist and Molnar, 1991). The overwhelming majority of farms that once existed in the United States no longer exist and production is highly concentrated among the remaining farms. The largest 13 percent of farms now produce over 75 percent of the value of total production. In addition, the vast majority of small farms are now buffered from the effects of technological change, since the farm is no longer the primary source of income for their owners. Consequently, biotechnology will probably have less impact on the total number of farms than previous mechanical and chemical technologies adopted by farmers during the last 50 years. Moreover, it is likely biotechnology will not greatly exacerbate the decline in the number of farms, although it will certainly maintain present trends which indicate that farming will continue to be one of the fastest declining occupations in the next decade (Bureau of Labor Statistics estimates 28 percent decline between 1990-2000).

The extent of biotechnology's influence on the trend towards fewer and larger farms depends, in part, on how adoption affects the cost structure of

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farms. If biotechnology developments significantly alter costs, returns, competitive positions, and the special location of production, and if certain trade and farm policies are implemented, the potential impact of biotechnology could be relatively important. The Office of Technology Assessment (1986) has argued that these new technologies will be adopted by well financed, innovative farmers who are presumed to run the comparatively large farms. However, others have argued that biotechnology innovations will provide widespread benefits to the full range of farmers because new technologies will be used in traditional ways. Regardless of which farmers are likely to benefit, however, biotechnology will probably increase the value added off-farm at the expense of value added on-farm (Goodman, *et al*,, 1987).

Other significant changes in the farming community may result if the information and products of this technology bypass the Extension Service and agricultural cooperatives. Previous products and information of biological research have been disseminated through the Extension Service. However, the development of new seed-chemical packages through biotechnology will emerge from private research, and public sector scientists will have limited knowledge with which to support extension programs. As a consequence, extension, and potentially agricultural cooperatives, may gradually be reduced to playing a secondary role in farm change. Moreover, many agriculturally based rural communities will continue the ongoing process of shrinkage and consolidation, as producers, and local supply and marketing firms continue to decline in numbers.

Biotechnology may also accelerate the trend toward contract integration, already common in the U.S., where commodities such as poultry and most processed vegetables are produced on contract. Such contracts specify the seeds, chemicals, planting and harvesting times and other aspects of farm production. These arrangements will further reduce the autonomy of farmers and will certainly reduce their contact with and need for extension services, agricultural cooperatives and local farm suppliers. The new biotechnologies may also restructure the relationship between farmers and researchers. Until very recently farmers were seen as the primary clientele of public sector research. However, the entry of molecular biology into agricultural research has increasingly been accompanied by the insertion of the agribusiness sector between farmers and researchers.

As a result it is quite possible that only problems of interest to the agribusiness sector will be the subject of public research agendas.

Another impact of biotechnology has been the stimulation of new moral and ethical debates regarding the limits of science.

IMPACT ON CONSUMERS

The new biotechnologies expand and extend researchers' ability to improve plants, animals, and microorganisms. For consumers this could mean dramatic improvements in the productivity and efficiency of food production and processing and the expansion and extension of food and nonfood uses of raw agricultural commodities. Consumers could benefit in the form of reduced prices, increased food safety and more nutritional foods. The new technologies also have the potential to change the very nature of food itself and to expand the range of possible food products. With molecular biology it is possible to move genetic material among plants and between plants, animals, and microorganisms. It is now possible to consider the production of new fabricated foods in which basic foods are broken down into their component parts (e.g., starch, fat, and sugar) and recombined into wholly new types of food. Such new forms of food may not be desirable to consumers and may make it far more difficult in the future for the consumer to determine the composition of the food and to maintain a balanced diet.

Another impact of biotechnology has been the stimulation of new moral and ethical debates regarding the limits of science. Public concern about a range of scientific developments including biotechnology, are resulting in a decline in public confidence in science and an increasing public perception of a likelihood of environmental risks from genetically-altered bacteria, plants and animals. The development of biotechnology is stimulating a wider range of concerns about science which extend beyond human health, environmental risk, food safety, and animal health issues and include such concerns as negative socioeconomic consequences and the morality of tampering with nature and life itself (Lacy, *etal.,* 1991).

IMPACT ON AGRIBUSINESS

John Hardinger, Director of Biotechnology at Dupont's Agricultural Products department, views biotechnology as a force to not only restructure farming but also to catalyze a major change in the structure of worldwide agribusiness. He notes that the application of molecular biology permits the various segments of the world's largest industrial sector to form logical linkages to other economic sectors that were never before practical. This 1.3 trillion dollar agribusiness sector (not counting feed and fiber) consists of the four basic elements: input suppliers, growers, processors and consumers. This system has experienced mechanical and chemical eras which contributed to increased productivity and efficiency. According to Hardinger the new biological and biotechnology era will further increase both efficiency and productivity, as well as provide the ability to change the quality of food and feed. Furthermore, it will lead to consolidation and new forms of vertical integration of the food industry (Busch, *et al.,* 1991).

The formation of new biotechnology companies increased dramatically from 1979 to 1983, with more than 250 small venture capital biotechnology firms founded in the U.S. Proliferation of these risk-taking companies helped raise billions of dollars from private investors and gave the U.S. a competitive lead in the early stages of biotechnology commercialization. By the late 1980s the number of these firms had grown to over 600. However, consolidation has begun in the industry with mergers, bankruptcies and major multinational corporation investments. Indeed, 80 percent of the funds in venture-capital firms have been invested in just ten companies (OTA, 1988).

In the early 1980s, multi-national corporations began to recognize the potential of biotechnology and to develop their own research and development capacities. These corporations began diversifying into every field or specialty that used living organisms as a means of production. The new biotechnologies appeared to further reduce the distinctions among the traditional industrial sectors, rendering corporate boundaries virtually unlimited. Those large multinational corporations specializing in oil, chemicals, food, and pharmaceuticals have taken the leadership in agricultural biotechnology research and development (e.g., American Cyanamid, Campbell Soup, Ciba Geigy, Dupont, Eli Lily, Monsanto, Rhone-Poulenc, R. J. R. Nabisco, Shell, Sandoz and Standard Oil). These corporations have also established research contracts, joint projects, exclusive licensing and marketing, equity positions, and control or ownership in the venture capital firms. By the late 1980s a small number of large multi-national corporations had significant positions in all the major biotechnology firms and provided over half of total funds being invested in developing this new technology (Busch, *etal.,* 1991).

This concentration, accompanied by horizontal and vertical integration across industrial sectors, reflects the mergers, acquisitions and concentration in the food processing industries as traditionally nonfood industries dramatically expand their investments. This trend is also apparent in the input industries. Of the top seven pesticide corporations, five ranked among the world's largest twenty seed companies with only Bayer and Dupont having marginal seed interests. Moreover, of the ten top seed companies, eight have significant interest in crop chemicals. Most analysts predict biotechnology will continue and accelerate this trend towards increasing concentration of power in the hands of a small number of large multinational corporations.

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Consequently, development and commercial control will be in the hands of corporations that transcend geographic boundaries and hold limited national allegiance. Within this context, people question how we can ensure that democratic participation will occur in the decision-making processes surrounding the development and commercialization of biotechnology. This is difficult within national boundaries and generally prohibitive internationally, given current governmental structures.

INTERNATIONAL IMPACTS

The new technologies offer the hope of increasing crop yields where population growth is outstripping the food supply. In a recent parliament meeting in India, biotechnology was acknowledged as the lifeline for the whole of Indian agriculture, offering opportunities for increased sustainability, profitability and international competitiveness (Ministry of Foreign Affairs, The Netherlands and the University of Amsterdam, 1990). Other nations have been equally optimistic regarding the prospects of agricultural biotechnology (Deo, *et al,* 1989).

It has been proposed that the direct use of molecular biology in conjunction with plant propagation and breeding could dramatically increase crop productivity and overall food production in developing countries. Tissue culture techniques are already creating more drought and disease resistant varieties of cassava, oil palms, and groundnuts. Embryo transfer may raise the reproductive capacity of livestock. In Africa genetically engi -

neered vaccines and drugs may cure fatal or debilitating diseases (e.g., onchoceriasis-river blindness, Guinea worm disease, schistosomiasis and trypanosomiasis) thus opening up new agricultural and grazing areas (Gibbons, 1990; Barker and Plucknett, 1991).

Yet despite biotechnology's great promise for feeding the world's rapidly growing population, particularly in developing nations, science and policy-makers admit it will not be easy to ensure that this technology has the desired positive effects. First, there is legitimate concern that the developed nations will use their technology to undercut traditional Third World exports, such as sugar, vanilla, cocoa butter, and other important cash crops. Genetic engineering is already being applied to bacteria, yeast and fungi to produce starter cultures with specific metabolic capabilities in food fermentation. These processes, combined with the new cell culture techniques, are being used to transform the production of certain agricultural commodities into industrial processes. In principle, any commodity that is consumed in an undifferentiated or highly processed form could be produced in this manner and product substitutions could be easily introduced. Similarly, although with greater difficulty, tissue culture techniques could be used to produce edible plant parts *in vitro*. In short, agricultural production in the field could be supplanted by cell and tissue culture factories (Busch, *et al.,* 1991).

Several companies are now capable of phytoproduction of a natural vanilla product in the laboratory. A genetic modification of oilseed plants to convert cheap oils (e.g. palm or soybean oil) into high quality cocoa butter is well advanced. Biotechnology is also being used to produce substitutes for sugar as an industrial sweetener. Several major corporations in the U.S. and Europe, (e.g., Unilever and Ingene) are attempting to use recombinant DNA technology to produce the thaumatin protein, one of the sweetest known substances. Successful development of a thaumatin product through genetic engineering may continue a transition to alternative sweeteners, eliminating the market for beet and cane sugar and capturing the valuable sweetener market. Even moderate success in realizing these product substitutions would have profound effects around the world, most immediate and important would be the restructuring of global markets (Persley, 1990).

Another issue focuses on environmental risks. Because the environmental release of genetically modified organisms may have hazardous effects on the ecosystem, in many of the industrialized countries the public has pressed for the adoption of safety regulations. These regulations, however, may restrict biotechnology experiments. As a consequence, researchers and biotechnology companies are attempting to relocate their experiments to countries with limited or no safety regulations. This may result in the movement of possibly hazardous biotechnology experiments to Third World countries.

A further concern is that biotechnology will increase the disparities between the developed and developing nations. With the shift in applied research and associated product development from the public to the private sector, the benefits from the new biotechnologies may become less widely available. Moreover, the products developed are unlikely to be ones which are important to the poor developing countries, particularly in the tropics. Biotechnology research has emphasized temperate zone animal reproduction, breeding, veterinary health care and animal nutrition, and temperate zone plant improvement. Little or no work is currently being directed at transformation of tropical crops important to developing countries. This could further widen the gap between the agriculture production methods in the North and the less advanced practices in the South (Deo, *etal,* 1989).

The Third World might be able to counter these technological developments by enhancing its own scientific capabilities. But this is unlikely to occur. Many developing countries have no basic research capacity, limited capabilities to adapt biotechnological advances to local conditions, and few resources to attract transnational corporations.

In conclusion, agricultural biotechnology may shift the geographic location of agricultural production from one Third World country to another or from the Third World to the First World. For many Third World countries, dependent on one or two agricultural commodities for their continued viability, this production and market restructuring and increased productivity gaps could result in a collapse in existing markets. Significant numbers of farmers and farm workers could find themselves with no products to sell. This could increase the already high Third World debt and exacerbate the deficit in balance of payments in Third World

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countries. Political instability, already a problem in the developing world, would doubtless increase.

The effects of these possible changes in the patterns of world trade are also likely to be felt in the West. With developing countries experiencing economic deterioration they could no longer serve as a main market for developed country exports, creating economic and social stress in the developed nations as well. For the continued well-being of an increasingly global economy, a conscientious effort must be made to help developing nations acquire the appropriate technology, establish and maintain an infrastructure for support of applied research, and improve their capacity to evaluate this new technology in terms of their own public good.

CONCLUSION

Addressing issues relative to the new biotechnologies at this early stage offer us an opportunity to assess these technologies before they actually exist and to examine the alternative paths for their development. Although changes and developments are proceeding rapidly, they are neither inevitable nor totally shaped. As Winner (1986:29) observed "By far the greatest latitude of choice exists the very first time a particular instrument, system or technique is introduced." The ultimate direction this technology takes will be determined by the actors who participate in its development.

This paper has discussed a number of both positive and negative social and economic impacts biotechnology may have on science, farms and rural communities, consumers, agribusiness, global markets and the international community. We suggest that biotechnology may increase inequities not only among various groups in our society, but also between developed and developing countries and among the more and less advanced developing countries. These potential impacts raise complex ethical and policy questions. A more careful review and monitoring of the scientific developments is essential, and a more detailed assessment of the fourth criterion, the social and economic impacts of particular technological changes, is needed. Further, we need to incorporate the fourth criterion into our decision-making and develop policies and long-range planning capacities to address the potential scenarios. Finally, we need to balance research programs, nationally and globally, in terms of time frame, proprietary nature and level of analysis (molecular, cellular, species and system) to ensure an agenda that is environmentally sound, enhances our health and focuses on building sustainability in both our fields and communities. Whose needs and goals will be served and whose neglected are perhaps the most important agricultural and social questions of the coming decade.

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