Issues in Agricultural Biotechnology and Biodiversity for Sustainable Agroecosystems

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Agriculture and Agri-Food Canada's *Strategy for Environmentally Sustainable Agriculture* (1997) defines an "agroecosystem" as an "ecosystem under agricultural management — an open dynamic system connected to other ecosystems through the transfer of energy and materials." While the importance for agriculture of such natural resources as soil, water, and air has long been recognized, the agroecosystem approach puts biological resources at the center of agricultural concerns. Our objective will be to identify some issues related to biological diversity in sustainable agroecosystems and to trace some of their implications, with a particular focus on the impact of biotechnologies.

Because the agroecosystem approach is defined by human management, these issues need to be addressed in a political and social context. The *Convention on Biological Diversity* (1992) is the first and foremost legal and conceptual framework for the consideration of agricultural biodiversity on the global level. This legally binding international treaty was presented for signature in June 1992 at the United Nations Conference on Environment and Development, also known as the Earth Summit. It entered into force in December 1993 and has been ratified by more than 120 countries, unfortunately not yet including the United States, although President Bill Clinton did sign it in 1993. The Convention addresses all life forms on earth, except for humans. Agricultural biological resources such as crops, farm animals, and microbial organisms important to agriculture are clearly within its scope. The objectives of the

convention, as stated in its first article, are "the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over these resources and to technologies, and by appropriate funding." Article 2 specifies that "technology" includes biotechnology, defined as any technological application that uses biological systems, living organisms, or derivatives thereof to make or modify products or processes for specific uses. This is a very wide definition, conceivably including every agricultural activity from hand-milking to the most sophisticated genetic engineering. Subsequent articles of the Convention expand upon the role of biotechnology in relation to biological diversity. We shall briefly consider the contribution of advanced biotechnologies to the conservation and sustainable use of biodiversity of importance to agriculture and then attempt to identify wider issues in an agroecosystem and global context.

Contribution of Advanced Biotechnologies to Biodiversity Conservation and Use

The use of advanced biotechnologies for the conservation of agricultural biodiversity has been described often and in depth over the past decade, in particular by Day (1989), by Towill (1989), who provided an extensive bibliography, and by the U.S. National Research Council's Board on Agriculture (1993). These authors inventoried and reviewed alternatives to conserving whole plants and animals such as *in vitro* culture (meristems or slow-growth techniques), propagules such as somatic embryos and synthetic seeds, and cryopreservation of cells, gametes, organs, and embryos. Advanced biotechnologies are also used to assist the transfer of genetic resources such as pollen collecting and conservation and *in vitro* techniques for collecting and shipping samples of germplasm. The U.S. Board on Agriculture recommended that research is needed to apply *in vitro* culture and cryogenic storage methods to a broad range of plant and animal germplasm.

The three papers cited above also documented the use of advanced biotechnologies to analyze the nature and extent of the biosystematic and genetic diversity of crop plants and their gene pools, including gene bank collections. Isoenzyme analysis was often used for this purpose in the 1980s. Newer techniques analyze diversity more directly at the level of DNA, such as restriction fragment length polymorphism (RFLPs), polymerase chain reaction (PCR), randomly amplified polymorphic DNA markers (RAPD), and DNA sequencing. These techniques are often applied to study specific genes or to distinguish between species but are not as frequently used to survey the diversity within a crop gene pool. We do not know nearly enough about intraspecies diversity in gene bank collections or in agroecosystems.

A huge amount of literature has been published on the application of advanced biotechnologies to the sustainable use of genetic resources for food and agriculture because these technologies have become a vital part of plant and animal breeding. A review of these methods, or even a listing of them, is beyond the scope of this paper. They have provided breeders with a new set of tools to complement the earlier contributions of population genetics and plant and animal physiology. These new tools include improved disease evaluation techniques; *in vitro* manipulation of cells, organs, and organelles, and the regeneration of whole organisms; genetic maps and markers; and genetic transformation. It is clear that the application of advanced biotechnological methods significantly increases the potential for wider use of genetic resources and will continue to do so.

Some authors question whether advanced biotechnological methods will soon replace gene banks or indeed make the conservation of the biodiversity of living organisms important to agriculture entirely unnecessary. In 1989, Day questioned whether in the future this technology will eventually replace conventional germplasm collection and plant exploration by providing a database that is sufficiently complete that not only existing DNA sequences could be stored and synthesized but new ones could be synthesized as well. In his view, this possibility was remote. He felt that for the foreseeable future we will continue to rely on the existing system. The U.S. Board on Agriculture (1993), began its chapter "Biotechnology and Germplasm Conservation" with the remark that biotechnology requires germplasm as both raw material and as a source of natural variation. It added that for economic and technical reasons it is unlikely, in the foreseeable future, that gene synthesis will make the physical storage of germplasm in the form of seeds, whole plants, or tissue cultures obsolete because they are not coordinated in a genome. We concur with this view.

Impact of Biotechnologies on Agroecosystems

These new scientific tools have profound effects on agroecosystems. On the one hand, genetic engineering is improving the resistance of crops and farm animals to pests and to abiotic stresses, thereby reducing the need to use chemical inputs such as pesticides, fertilizers, and antibiotics. In Canada, pesticide use has decreased steadily over the past few years, partly as a result of new crop cultivars such as herbicide-resistant canola and partly because of the increased use of conservation tillage to combat soil erosion. Implicit in this trend is the conclusion that less use of chemical inputs will correlate positively with reduction in misuse of them, thereby reducing the pressure on biodiversity, both in agroecosystems and in marginal or nonagricultural habitats, and improving their sustainability.

On the other hand, some authors have promoted the idea that the use of advanced biotechnologies contributes to genetic erosion. The reasoning appears

to be that one of the main causes of the loss of biological diversity in farmers' fields is the replacement of older varieties and landraces by newer cultivars and the replacement of small, diverse farms by more specialized operations. Thus any factor or technology that accelerates the development of better adapted, more productive cultivars would result in a higher rate of genetic erosion. In our opinion, this logic takes little account of the need for food security or of the role of *ex situ* conservation measures. Proponents sometimes simultaneously call for more on-farm diversity, less farming on marginal land, and increased food production. It is true, however, that unless genetic resource conservation measures are effective, potentially useful genetic diversity will be lost forever.

Are people part of the agroecosystem? One would think so, according to Agriculture and Agri-Food Canada's definition. In that case, social factors also enter the equation. The Biodiversity Convention defines sustainable use as "the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations." If biotechnology results in enhanced food production, then one should expect attendant benefits such as greater food security and a greater role for agriculture as a motor of sustainable development, a line of thought that has been eloquently described in publications of the International Food Policy Research Institute.

With particular reference to developing countries, some authors consider that agricultural biodiversity is best conserved and more sustainably used in a system of traditional agriculture. Such management is subject to farmers' decisions about which crops to plant or which livestock to raise, and the reasons behind these decisions are not well known. *The Global Plan of Action for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture* (1996), adopted by representatives of 148 states, recognized the need for a better understanding of the effectiveness of such biotechnologies as on-farm conservation, management, and improvement. As a result, some country representatives have called for an examination of the relationship between trade liberalization and agricultural biodiversity. They apparently expect that the results would legitimize the use of trade measures to protect traditional farming systems. These calls have been referred to the World Trade Organization's Committee on Trade and Environment by both the U.N. Food and Agriculture Organization's *Global Plan of Action for World Food Security* and the Conference of Parties of the Convention on Biological Diversity in Decision III/11 taken at their third meeting in November 1996 (UNEP 1994).

Cultural aspects of agricultural biodiversity have inspired other authors. Many people consider crop varieties and races of livestock to be part of their cultural heritage. Who doesn't have a favorite variety of baking apple or potato? This tendency is even stronger among indigenous peoples. The Convention addresses this concern in the context of *in situ* conservation, stating in Article

8(j), “Each Contracting Party shall, as far as possible and as appropriate . . . Subject to its national legislation, respect, preserve, and maintain knowledge, innovations, and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity, and promote their wider application with the approval and involvement of the holders of such knowledge, innovations, and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations, and practices.” Indigenous people are rarely static preservers of ancestral biotechnologies but tend to generate their own innovations and adopt others that suit their purposes, so the practical implications of this provision are far from clear.

Concern is also being expressed about the potential social effects of the replacement of traditional crops by new products. This issue is likely to take a progressively higher profile in coming years as new products are put on the market much more quickly than traditional farming societies are capable of adapting to the socioeconomic consequences. We can probably expect increasing calls for international measures to compensate for or to mitigate these effects.

The jury will likely be out for a long while concerning the overall sustainability of agroecosystems based on increasingly advanced biotechnologies. It is important to remember that biotechnologies are tools, and what counts is the uses to which they are put.

Intergovernmental Negotiations Regarding a Biosafety Protocol

Faced with the ever-changing environment created by new technological advances and by the globalization of agricultural markets, all countries are realizing that they must harmonize the need to benefit from these technologies with the need to protect the biological safety of the environment. Many developing countries are finding it particularly difficult to reconcile these two complementary goals. This dichotomy was played out during the negotiation of the segments of the Convention on Biological Diversity that pertain to the relationship between biotechnology and biodiversity, and it is reflected in their final form. Two articles are particularly relevant — Article 16, “Access and Transfer of Technology,” and Article 19, “Handling of Biotechnology and Distribution of Its Benefits.”

Transfer of technologies was very much part of the benefit-sharing agenda of the Convention. The first paragraph of Article 16 states, “Each Contracting Party, recognizing that technology includes biotechnology, and that both access to and transfer of technology among Contracting Parties are essential elements for the attainment of the objectives of this Convention, undertakes . . . to provide and/or facilitate access for and transfer to other Contracting Parties of technologies that are relevant to the conservation and sustainable use of

biological diversity or make use of genetic resources." Terms of technology transfer were the object of lengthy negotiation; many developing countries held out for concessional transfers. Most developed countries, however, emphasized the role of intellectual property rights to stimulate innovation. The second paragraph of the article specifies that "access to and transfer of technology . . . to developing countries shall be provided and/or facilitated under fair and most favorable terms, including on concessional and preferential terms where mutually agreed . . . In the case of technology subject to patents and other intellectual property rights, such access and transfer shall be provided on terms which recognize and are consistent with the adequate and effective protection of intellectual property rights."

Acting under the assumption that developing countries would be the major providers of genetic resources, their representatives also wanted to tie access to technology to the provision of genetic resources. The third paragraph of Article 16 states, "Contracting Parties, in particular those that are developing countries, which provide genetic resources, are provided access to and transfer of technology which makes use of those resources, on mutually agreed terms, including technology protected by patents and other intellectual property rights . . ." The fourth paragraph addresses private sector innovation. It reads that "Each Contracting Party shall take . . . measures . . . with the aim that the private sector facilitates access to, joint development and transfer of technology . . . for the benefit of both governmental institutions and the private sector of developing countries."

Article 19, "Handling of Biotechnology and Distribution of its Benefits," considers other aspects of sharing the benefits arising from the use of genetic resources. Its first paragraph provides for "participation in biotechnological research activities by those Contracting Parties, especially developing countries, which provide the genetic resources for such research," and the second paragraph promotes "advance priority access . . . to the results and benefits arising from biotechnologies based upon genetic resources provided by those Contracting Parties."

It is important to understand, however, that all of these provisions are to be implemented subject to mutually agreed terms and in respect of property rights. In addition to the provisions of the second paragraph, the fifth paragraph of Article 16 states, "The Contracting Parties, recognizing that patents and other intellectual property rights may have an influence on the implementation of this Convention, shall cooperate in this regard subject to national legislation and international law in order to ensure that such rights are supportive of and do not run counter to its objectives."

These articles do not amount to a radical shift in terms of technology transfer. They illustrate the great interest of developing countries in developing better international cooperation in this field and reflect their great thirst for new technology, in spite of the best efforts of some green nongovernmental

organizations to persuade them of the unmitigated evils of modern technology. Under these circumstances, any institution that establishes a mutually satisfactory partnership with a technology-hungry developing country can likely expect a long and profitable association.

The concern for biosafety emerges in Article 19 of the Convention. Paragraph three states, "The Parties shall consider the need for and modalities of a protocol setting out appropriate procedures, including, in particular, advance informed agreement, in the field of the safe transfer, handling and use of any living modified organism resulting from biotechnology that may have adverse effect on the conservation and sustainable use of biological diversity." The next paragraph calls upon "Parties to provide any available information about the use and safety regulations . . . in handling such organisms, as well as any available information on the potential adverse impact of the specific organisms." After much debate extending over several meetings, in November 1995 the Conference of the Parties to the Convention set in motion a negotiation process to develop a protocol on Biosafety, and established an Open-ended *ad hoc* Group on Biosafety, composed of government representatives, to elaborate it.

The second meeting of the Open-ended *ad hoc* Group on Biosafety took place May 12-16, 1997, in Montreal, Canada. According to the *Earth Negotiations Bulletin* (May 19, 1997), delegates discussed provisions regarding procedures for transfers of living modified organisms (LMOs); competent authorities or focal points; information-sharing provisions; capacity-building; public participation and awareness; risk assessment and management; unintentional transboundary movements; handling, transport, packaging, and transit; and monitoring and compliance. Many of these provisions were discussed in great detail. Participating countries fleshed out their preliminary positions on various areas of the protocol. In some less contentious areas, consensus was close to being reached, for example, on information sharing. For each specific area discussed, text elements were generated that expressed the range of views expressed.

Developing countries raised the issue of including the assessment of socioeconomic factors in the future protocol, which resulted in a call for a workshop at the next negotiating session in October 1997. The inclusion of socioeconomic issues, in particular potential effects on traditional farming systems, as a criterion for assessing LMOs before importing them, could have significant effects on international trade. Canada helped in raising awareness about how a future protocol could affect commodities, for example, whether requirements of the future protocol might impede shipments of grain that may or may not contain LMOs. In general, Canada has taken the approach of regulating products, not processes so that identical commodities would be regulated (or not) in the same way, independent of which biotechnology was used to develop them. Canada is expected to lead a workshop on this topic at

the October negotiating session. The OECD's Expert Group on Harmonization of Regulatory Oversight in Biotechnology has suggested that it will give priority to discussing this workshop at its next meeting in Paris, France, June 26-27, 1997. The Biodiversity Convention Secretariat has proposed a fourth negotiating session for February 1998 and a final session in November 1998 to complete the protocol.

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