CHAPTER 16

Agroecosystem Quality: Policy and Management Challenges for New Technologies and Diversity

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1-56670-290-9/99/$0.00+$.50

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Biodiversity in Agroecosystems

CRC Press
Boca Raton London New York Washington, D.C.

1999

INTRODUCTION

Providing a meaningful contribution to the topic of agroecosystems, new tech-logy, and diversity poses many challenges. First, it is difficult to obtain agreed-definitions or standards for "agroecosystem quality." The second difficulty occurs ıen considering how new technologies affect agroecosystem quality, including ues related to biodiversity. These difficulties, and the management and policy ues which they raise, are illustrated by examples of technical and adaptive chal-ıges facing agricultural policy makers, managers, and end users concerned with ıintaining levels of biodiversity or enhancing agroecosystem quality.

The objectives of this chapter are to first consider the differences between these :hnical and adaptive problems, the nature of the situations they each address, and : learning required when facing an adaptive challenge. Second, agroecosystem mplexities and the difficulties in determining quality indicators are presented. ›plications of biotechnology are presented as derived from international collabo-ive research using examples compiled by the Intermediary Biotechnology Service 3S), executed by the International Service for National Agricultural Research ;NAR). Some of these examples, as used in IBS policy seminars, highlight ıerging policy and management needs which were identified and discussed. It is ped that this chapter clarifies adaptive challenges regarding agroecosystem diver-y and quality, and prepares stakeholders for the challenges and opportunities of w technologies.

CONFRONTING THE DIAGNOSTIC CHALLENGE: TECHNICAL VS. ADAPTIVE PROBLEMS

When confronting "technical problems," difficulties are faced which can be :arly defined and understood, and for which solutions are readily available. They ve become problems of a technical nature by virtue of lessons learned through periences confronted over time. The benefits derived from these accumulated periences let us know both *what to do,* through the use of knowledge (organiza-nal procedures for guiding our actions), and *who should do it,* by identifying ıoever is authorized to perform such work (Heifetz, 1996).

When facing an "adaptive problem," however, ready organizational responses : absent, the problem is difficult to define, and expertise and/or established pro-lures are lacking. Technical responses to the problem are at best only part of the ution. When facing such difficulties, time is required for learning, as this is a ıtral task of the adaptive process. Learning occurs before solutions and imple-:ntation modalities become apparent. Those holding competing values with regard the problem are identified, questions are posed to define the issues, and stake-lders are given time to adjust values to accommodate the nature of the problem. e learning phase of adaptive work diminishes the gap between the original stake-lder values, the realities they now face, and the adjustments that may be necessary adapt their values to the new realities (Heifetz, 1996).

Differences between technical and adaptive problems are used to diagnose issues presented in this chapter as related to agricultural productivity (see Table 1). Agricultural problems of a technical nature are often remedied by choosing among appropriate technologies, whether they are from conventional or nonconventional sources. One chooses between or combines various cultural, crop, or livestock options to address problems, needs, or deficiencies in productivity of agricultural ecosystems. However, when technologies are considered beyond their technical dimensions, in the broader sense of affecting agroecosystem quality, then adaptive problems may be encountered for the following reasons. First, no universal definition of quality exists, especially for the variable nature of agricultural ecosystems in the tropical climates of developing countries. Second, stakeholder opinions may vary as to utility vs. risk of new inputs or technologies. Third, values (whether cultural, economic, or health) create perceptions which must be addressed in relation to the realities of the proposed inputs and the changes they may cause. It is in this context that new technologies can raise adaptive challenges to farmers, system managers, and policy makers.

Consequently, questions regarding agroecosystem quality are "adaptive challenges." In this paper, two indicators of agroecosystem quality are proposed, one based on biodiversity and the second on the use of chemical inputs. These indicators can be affected by the introduction of new technologies, using biotechnology products as examples. Biological differences among agroecosystems and stakeholder values and perceptions will be critical to defining specific quality indicators. Policy and management challenges posed by new technologies and considerations of biodiversity and use of chemical inputs are then analyzed in relation to agroecosystem quality.

INTRODUCING AGROECOSYSTEMS AND INDICATORS OF QUALITY

Defining Agroecosystems

Agroecosystems include highly managed, productivity-oriented systems which vary widely in their dependence on chemical, energy, and management inputs, and are one conservation tactic identified to protect extant diversity (Soule, 1993). Defining "quality indicators" associated with agroecosystems relies on concepts *not* inherent in the system itself, just as do efforts to define sustainability. Rather, concepts such as sustainability or "quality" imply values derived from a human or cultural perspective for a particular management system (J. Tait, personal communication). These perspectives help determine whether a particular agricultural input enhances agroecosystem quality or not.

Four major components of agricultural systems have been proposed by Antle (1994) in studies on pollution and agriculture. His work highlighted relations among (1) agricultural production, (2) the broader agroecosystem, (3) human health considerations, and (4) valuation and social welfare, with each possessing characteristics

Table 1 Summarizing the Technical and Adaptive Problems, Solutions, and Questions Related to Agroecosystem Quality, Biodiversity, and New Technologies

.A	Technical problems characterized by:	• Clear problem definition • Clear problem solution • Able to identify relevant authority/developer for solution	
.B	Technical problems and solutions posed:	Problem 1:	Is durable resistance available for rice blast in farmer's fields?
		Technical Solution:	Improved varieties, with new sources of genetic resistance
		Problem 2:	Is insect resistance using B.t. available in tropical maize?
		Technical Solution:	Improved varieties, with new sources of genetic resistance
I.A	Adaptive problems characterized by:	• Organizational responses are absent, • The problem is difficult to define, • Expertise and/or established procedures are lacking • Technical responses are at best only part of the solution • Time required for learning	
I.B	Adaptive problem posed in this paper:	Does the introduction and use of described products require changes in stakeholder values, perceptions, or attitudes with regard to agroecosystem quality?	Two indicators of quality selected in this paper: • Biodiversity, conservation and use • Minimize use of chemical inputs
II	Answers depend on ability to address questions, such as:	In the view of the stakeholders: • Have new sources of resistance affected the composition of extant biodiversity, including possibility for horizontal gene transfer? • Have the new varieties diminished the need for chemical insecticides or fungicides? • Have new varieties included management packages for gene deployment, and extending or guarding the length of time available for resistance? • Are clear understandings available for current chemical input levels? • Are measures of productivity or other economic gains available? • Was the technical problem solved?	

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valued by society. By using the divisions presented by Antle, the introduction of novel sources of genetic diversity would occur in the agricultural production. Coupling the introduction of biotechnology with the management of biodiversity and agroecosystem quality would influence a range of perspectives regarding overall quality of the agroecosystem component (2) and, often, values of human health and welfare (3 and 4).

Factors Affecting Quality Indicators

Determining practices to enhance the sustainability of a given agricultural system, as presented by Tait (personal communication), and the components used by Antle (1994) in his pollution study are also useful for this discussion. Here, these two concepts (dependence on human values and four components depicting introductions to agricultural systems) are used in the context of managing agroecosystems in developing countries. They provide a foundation for understanding the interrelations between quality indicators, inputs derived from biotechnology, and agroecosystem biodiversity. Examples of inputs are given, using cultivars as technical solutions to specific environmental and productivity problems, but which can also be valued in the context of the ecosystem.

QUALITY INDICATORS — LINKING BIODIVERSITY WITH NEW TECHNOLOGIES

Relevant agroecosystem quality indicators, which could be applied to products derived from new technologies, now need to be selected. Examples of products, like virus resistance and applications of B.t. (see section on Examples from IBS Seminars, later), illustrate both technical and adaptive challenges when considered in relation to agroecosystem quality. With such examples in mind, two indicators were selected which would relate them to agroecosystems: (1) biodiversity and (2) diminishing use of chemical inputs.

Conserving, Maintaining, and Using Biodiversity

Many traditional agroecosystems are undergoing some process of modernization (Altieri and Merrick, 1988). This process of modernization and its relation to the use of high-yielding varieties can threaten indigenous diversity or other repositories of crop germplasm. Pressures to modernize can have a drastic effect on the conservation of diversity, and indicators of quality will depend on our knowledge of natural populations in each ecosystem. In many agroecosystems, premiums are placed on maintaining and conserving sources of biodiversity. Different and often competing values exist for what constitutes an ecologically correct mix or use of diversity within a given agroecosystem. Whether this diversity can be increased or decreased reflects values attributed to ecosystem quality. Placing premiums on maintaining diversity recognizes the importance of multiple-crop agroecosystems which make use of indigenous as well as introduced sources of diversity (Gliessman, 1993). Complex crop mixtures, rotations, and practices developed by local farmers can protect the environment under tropical conditions and provide an array of products for harvest.

Several case study examples illustrate the importance of using and conserving xtant biodiversity within managed agricultural and forest ecosystems (Potter et al., 1993). An important, if not essential, element of these systems is the involvement of native peoples in these managed areas, and their application of the knowledge gained over time for the care and management of such areas (Padoch and Peters, 1993). In addition, it has been argued that maintaining traditional agroecosystems s an important strategy for preserving *in situ* repositories of crop germplasm (Altieri and Merrick, 1988). For example, Latin American farming systems studied demonstrate a high degree of plant diversity (Altieri and Montecinos, 1993). The authors also recognize the importance of small farmer holdings in these ecologically diverse systems.

Minimizing Chemical Inputs

Biotechnology and sustainable agricultural systems are often portrayed as antagonistic ends of a continuum. However, this portrayal lacks evidence, especially given hat the use of biotechnology-derived agricultural products within either production systems or agroecosystems is still largely an unknown factor. In fact, there are many applications of biotechnology which seek to minimize the use of chemical inputs as pest, weed, or disease control strategies in developing country agriculture. The elation between these applications and broader concerns of sustainability have been ecognized (Hauptli et al., 1990). In this regard, technical solutions to pressing pest or weed management problems are becoming available from biotechnology. For this eason, minimizing chemical inputs to agroecosystems was selected as the second potential quality factor to be presented.

Both of these indicators will rely on mobilizing, understanding, and taking into account stakeholder values and perceptions. Management of agricultural systems will be complicated by the fact that indicators of quality are difficult to measure, highly location specific, and reflect "value judgments." Such indicators will by necessity incorporate values held or determined by the stakeholders of each system, and will reflect values that are not part of the biological system being considered J. Tait, personal communication). Solutions to stakeholder problems, such as the need to combat pests or minimize chemical applications, can take the form of echnical solutions by using new inputs. However, adaptive problems may also occur after interventions are identified and new technical solutions are employed. Here, takeholder opinions may differ with the claims made by or for technical solutions, uch as can occur with new products from agricultural biotechnology, or when levels of extant diversity are threatened.

It is necessary to identify the real stakeholders, to learn their expectations egarding the issue, and to gain an understanding of their opinions regarding these options to the problem at hand. Mobilizing stakeholder response is a key facet of adaptive problems, and a major task for those managing such situations (Heifetz, 996). Constituents of specific agroecosystems will help determine quality indicators and work with those advocating new inputs, or cultural options which may affect

levels of diversity. Introducing new sources of diversity raises further complications in agreeing whether such additions reflect an improvement in overall quality. These complications are expected, based on the increases in stakeholder involvement regarding the question of genetically engineered crops and introductions to areas rich in extant or indigenous biodiversity.

INTERNATIONAL COLLABORATION IN BIOTECHNOLOGY RESEARCH

With the two indicators of agroecosystem quality determined, attention is now placed on examples of new technologies. Examples have been selected that take into account the emerging needs of developing countries regarding biotechnology and their ability to collaborate with international research programs. These examples are taken from information collected from IBS policy seminars and its Registry of Expertise. IBS began to collect, analyze, and discuss with client countries its information on international collaboration in biotechnology by organizing a meeting held at ISNAR in 1993 (Cohen and Komen, 1994).

Information was collected through survey forms from some 40 international biotechnology programs. Taken together, this material clearly demonstrated that international collaboration in agricultural biotechnology offers developing countries access to a range of specific technologies, and unique opportunities for developing improved crop plants, livestock, vaccines, and diagnostic probes. An aggregate analysis of this information was made, as described below, for which specific conclusions are most relevant for a discussion on new technologies and agroecosystem quality.

Findings

Among the international programs studied by IBS, most research is undertaken on essential commodities, or foods on which significant numbers of people depend, often with regional significance (Brenner and Komen, 1994; Cohen and Komen, 1994; IBS, 1994). Analysis of the 22 international crop biotechnology research programs indicates that they address five broad research objectives, containing 126 separate activities. These primary objectives, crops, and research activities are shown in Table 2. As such, they represent solutions to many technical situations facing farmers and growers in developing countries.

With regard to crop transformation, research supported by the international programs concentrates primarily on resistance to viruses and insects, and improving quality factors (IBS, 1994). In Table 3, general categories and specific examples of transformation are shown for agriculture in industrialized countries, using examples from Day (1993). The third column summarizes research being conducted specifically for developing country agriculture with illustrations of specific applications.

These data indicate a strong commitment to improving crop plants through biotechnology by addressing agricultural needs and objectives for developing countries. Approximately 50% of the expenditures in these international biotechnology programs are devoted to research needed to develop these modified crops (Cohen,

Table 2 Number of Research Activities Undertaken by International Biotechnology Projects as Shown for Five General Research Objectives and for Crops of Major Importance to Developing Countries

	Objectives					
Crops	Disease Resistance	Insect Resistance	Virus Resistance	Quality Traits	Micropropagation	All
Cereals	**9**	**13**	**8**	**12**		**42**
Rice	5	4	6	6		21
Maize	1	6	2	3		12
Sorghum	1	3		2		6
Other	2			1		3
Root Crops	**4**	**5**	**7**	**2**	**1**	**19**
Potato	1	3	2			6
Cassava	1		3	2		6
Yam	2		1		1	4
Sweet potato		2	1			3
Legumes	**4**	**6**	**4**	**6**		**20**
Bean	1	2	1	2		6
Groundnut	1	1	3	1		6
Chickpea	1	1		2		4
Other	1	2		1		4
Horticulture	**2**		**3**		**1**	**6**
Perennial	**2**	**1**	**2**	**2**	**15**	**22**
Banana/plantain	2		1		5	8
Industrial crops				1	4	5
Coffee			1		4	5
Sugarcane			1	1	1	3
Cocoa					1	1
Forestry Species				**2**	**5**	**7**
Miscellaneous	**3**	**3**		**2**	**2**	**10**
All	**24**	**28**	**24**	**26**	**24**	**126**

Note: Figures are based on information gathered from 22 international research programs that include activities in crop research. For this table, we used those research activities with a specific applied objective, excluding research activities aimed toward general technology development.

From IBS *BioServe* Database, 1997.

1994). This percentage of available resources increases their ability to solve technical problems, as defined in this chapter, and as shown in the examples below. However, this also means that a much smaller amount of resources is available to address questions of a more adaptive nature arising as their products move from research into agricultural production, and then enter the broader agroecosystem, confronting human health or valuation considerations (Antle, 1994).

Anticipating Adaptive Challenges for Developing Countries

Over the past 4 years, IBS has organized a series of Agricultural Biotechnology Policy Seminars, held regionally for collaborating countries. In these seminars, attention is given to examples of biotechnology providing solutions to technical problems faced by farmers in developing countries. These same examples are

Table 3 Cloned Genes of Interest for Crop Plant Improvement and Related Applications of the International Biotechnology Programs

General Category[a]	Specific Examples[a]	International Biotechnology Program Applications[b]
Disease resistance: viruses	Virus coat protein subunits (TMV, cucumber mosaic, potato virus X) Potato leaf roll virus Potato virus S Soilborne wheat mosaic virus Plum pox virus Tomato spotted wilt virus Viral replicase gene (PVX)	African cassava mosaic virus, common cassava mosaic virus Bean gemini viruses Rice stripe virus, yellow mottle virus, tungo virus, ragged stunt Potato virus X and Y Tomato yellow leaf curl virus Sweet potato feathery mottle virus Groundnut stripe virus, Rosette virus, and clump virus
Fungal diseases	Chitinase gene, H1 gene for resistance to *H. carbonum* from maize, systemin gene — a peptide signal molecule which controls wound response in plants, infectious viral CDNA	Potato late blight Rice blast
Insect resistance	B.t. genes, cowpea trypsin inhibitor, wheat agglutinin gene for resistance to European corn borer	B.t. toxin genes applied to borers in maize, rice, sugarcane, potato, coffee Potato glandular trichomes Sweet potato weevil Pigonpea: *Helicoverpa* and podfly
Storage protein genes	Wheat low-molecular-weight glutenin gene, maize storage protein	No applications reported
Carbohydrate products	Polyhydroxybutyrate as an alternative to starch for the production of biodegradable plastics	No applications reported
Ripening	Antisense polygalaturonase in tomato, regulation of ACC synthase gene	No applications reported
Breeding systems	Self-incompatibility genes from *Brassica*, anther specific genes used for male sterility with a ribonuclease gene	Male sterility in rice
Flower color	Petunia, *Antirrhinum*	No applications reported
Herbicide resistance	Glyphosate, bialaphos, and imidazolinone resistance	No applications reported

[a] General categories and specific examples from Day, 1993.

[b] Examples from IBS (1994) *BioServe* database of international agricultural biotechnology programs.

explored with regard to the adaptive challenges posed when new technologies enter agricultural systems. As in many complex social situations, agricultural managers and policy makers can face substantially more complex adaptive challenges from situations originally perceived as technical in nature. Often, the problem itself is unclear because of divergent opinions regarding the nature of the problem and its possible solutions (Heifetz, 1996). One stakeholder's technical solution is another stakeholder's adaptive challenge. In these cases, there is also often disagreement among scientific experts, particularly at early stages of problem definition, hence the time needed for learning.

In the seminars, technical examples are explored from the perspective of multidisciplinary and diverse national delegations. In facilitating these delegations, IBS ensures involvement of individuals with responsibility for, or vested interest in, the design, implementation, and use of agricultural biotechnology. This range of stakeholder interests enriches the debates which occur within each delegation as the delegates identify needs for services to help with the learning phase of adaptive work, often taking the form of policy dialogues, management recommendations, or responses needed for various international agreements. As such, IBS builds on scientific data and available understanding to expand discussions to address the broader needs of stakeholders, including policy makers, managers, and researchers, and farmers, end users or non-governmental organizations (Komen et al., 1996).

Seminar Findings

Participant action planning methodology, carried out by the 17 attending countries, identified needs and/or constraints. In total, 227 needs were identified from the delegations. These needs were systematically analyzed, identifying nine general policy issues, their relative degree of emphasis, and whether or not there was a convergence of these needs (Table 4). In addition, seven implementation issues and three issues related to priority setting have been summarized. Most relevant to a discussion on new technologies and agroecosystem diversity are the needs identified for biosafety, socioeconomics, and priority setting. Here, the specific needs related very clearly to the adaptive policy challenges facing developing countries, particularly those located in centers of diversity. These issues will be presented later, in the section on Quality Indicators and New Technologies.

EXAMPLES FROM IBS SEMINARS: THE TECHNICAL AND ADAPTIVE CHALLENGES

In the most recent policy seminar for selected countries of Latin America, three case studies were presented on issues related to biotechnology, productivity, and the environment. These case examples are most relevant to the discussion above. They illustrate solutions to agricultural problems having, to a greater or lesser extent, an adaptive and technical component (Roca et al., 1998; Serratos, 1998; Whalon and Norris, 1998).

Table 4 **Number of Policy Needs Identified by Members of 17 National Delegations Attending Policy Seminars for Africa, Asia, and Latin America**

General Policy Issues	No. of Countries Responding	No. of Needs Identified	No. of Convergent Needs
1 Biosafety	14	19	4
2 Socioeconomic assessment	12	19	3
3 Integration	9	11	2
4 Policy development/coordination	9	9	2
5 End user/beneficiary linkages	9	10	2
6 Technology transfer system	8	8	2
7 Intellectual Property Rights (IPR)	7	8	3
8 Biodiversity	6	7	3
9 Public awareness	5	5	1

The first example uses the introduction of improved rice varieties with the potential to curtail use of toxic and expensive fungicides. This case is primarily technical, as the products and techniques used have not posed adaptive challenges. In this case, the new varieties are not products of transgenic technologies. Rather, biotechnology tools have been used after varietal development to understand sources of resistance and to type resistance against lineages of the pathogen. For the second case, the introduction of maize containing novel sources of resistance to insect pests is considered. In the case of maize, insect resistance is derived from transgenic technologies allowing for the insertion of genes encoding a pesticide from bacteria. In the third case, broader implications of managing and deploying transgenic crops using *Bacillus thuringiensis* (B.t.) technologies are considered. As can be seen from the maize and the B.t. examples, complex situations can be anticipated when introducing new inputs into traditional agroecosystems.

The Case of Durable Resistance to Rice Blast Fungus

Blast is the most widespread and damaging disease of rice. When control is needed, and is not present in the form of cultivar resistance, then fungicide treatments are applied which may not be effective, economically sound, or desirable from an environmental perspective. Conventional resistance has been made available genetically, but it has traditionally been weakened or lost after 3 years. However, durable resistance has been achieved in rice cultivars using conventional breeding, resulting in Oryzica Llanos 5, developed as a resistant variety by Centro International de Agricultura Tropical (CIAT), the National Federation of Rice Growers, and the National Research Institute of Colombia (F. Correa-Victoria, personal communication).

The variety was introduced to tropical agroecosystems in Colombia and represented a technical solution to the problem of blast, as well as the potential to improve system quality by reducing the unwise or ineffective use of fungicides. The cultivar was adopted across Colombia in the season following its release, and has been planted in at least 50,000 ha/year until 1996. Since then, newer high-yielding cultivars were released and widely adopted by farmers (F. Correa-Victoria, personal communication).

More recently, techniques derived from biotechnology have been coupled to these applied breeding strategies (Tohme et al., 1992; Roca et al., 1998). These molecular tools are helping to understand the mechanisms controlling durable resistance in Oryzica Llanos 5 by typing resistance genes to different genetic families of blast, identifying molecular markers associated with resistance genes in other highly resistant cultivars, and guiding rice breeders in selection of potential parents leading to lines with durable blast resistance. Genes are being identified that express resistance to six pathotype lineages of the blast pathogen. This analysis depended on the use of DNA probes containing cloned fragments of the blast fungus genome which could then be used to construct DNA fingerprints of the fungus. Molecular markers were then used by breeders to confirm the manipulation and selection of various sources of resistance to these six lineages of the blast fungus. This resistance will bring a reduction in the use of fungicides by farmers as in the case of the cultivar Oryzica Llanos 5 (Tohme et al., 1992).

Decreases in the use of fungicides as a result of farmers growing these new varieties have been reported. Unfortunately, it has not been possible to review these data at this time. Measures of declining use of fungicides in agroecosystems of Colombia can be estimated, in that farmers' expenditures on these chemicals range from 6 to 50% of total crop protection costs. Actual estimates of how much farmers have saved over this period of time and how much the use of fungicides has been reduced as a result of resistance will be obtained later (F. Correa-Victoria, personal communication).

The Case of *Bacillus thuringiensis* and Transgenic Crops

By using genetic engineering, it is possible to introduce novel sources of insect resistance to crop plants. In this case, resistance comes from genes encoding the production of various endotoxins, which is being done by some of the international programs as shown in Tables 2 and 3, including work on maize. Engineered varieties would eventually be suitably adapted for growth in areas of Latin America, some areas of which are associated with centers of diversity for maize. It is essential to prepare Latin American countries for the advent of transgenic maize containing genes for insect resistance, for which it is claimed that dependence on pesticides would be eliminated, thereby enhancing the quality of the agroecosystem.

Studies on the introduction of transgenic maize in Mexico were one of the cases selected by IBS for the Latin American seminar. Serratos (1998) stated that research criteria for transgenic corn to be introduced in Mexico should be based on characterization of agroecological, social, and economic aspects of the area where it is to be grown. The introduction of transgenic cultivars seems inevitable to developing countries. Thus, it is important to consider the impact of transgenic cultivars on the agroecosystems of countries with extensive diversity of native germplasm.

Research on the use of endotoxins in maize is also being done on tropical maize at CIMMYT's (Centro Internacional de Mejoramiento de Maiz y Trigo) Applied Biotechnology Center. These activities include screening of cloned B.t. genes for toxicity against *Heliothis zea* and other tropical maize pests. They are also working on the transformation of tropical maize inbreds containing *cry* gene constructs and greenhouse evaluations of acquired transgenic germplasm containing *cry* gene(s) and introgression of *cry* gene(s) into tropical germplasm (IBS, 1994).

Research at CIMMYT and by commercial companies on hybrid maize suitable for growth in tropical climates suggests the need for further study of their potential effects on these complex agroecosystems. Thus, it is important to study, as a multi-institutional task, gene flow and biological risks which may be associated with transgenic maize in Mexico (Serratos, 1998). This could include genetic flux, hybridization, and introgression among the transgenic cultivators, native cultivators, and wild parents. Addressing factors such as these would contribute to an analysis of benefits from the transgenic maize in relation to potential environmental concerns.

In the final case (Whalon and Norris, 1998), the role of resistance management when deploying transgenic B.t. plants is discussed within a resistance management framework. Here, it was noted first that transgenic technology will help reduce reliance on chemicals, reduce environmental contamination, and reduce human health impacts by conventional pesticides. Second, this technology appeals to developing countries lacking effective pesticide safety regulations because transgenic plants do not carry the human and environmental risks that conventional pesticides do.

However, it was argued that some type of management is needed to sustain the effectiveness of these pest control tactics by managing the factors that may contribute to resistance development. This may require commitment and participation by farmers, pesticide or seed suppliers, and regulators to help prevent insect resistance through detection and proactive management. The preservation and management of genetic resources, i.e., susceptible genes, is the key goal of resistance management (Whalon and Norris, 1998).

The authors recommend that, as regards a specific group of technologies, the decision to deploy transgenic crop plants should be based on an assessment of indigenous ecological, environmental, socioeconomic, and agricultural conditions. Criteria to consider include the risk of gene transfer from transgenic plants to related species, availability of refugia to counteract resistance development, economic importance of the target pests, and the level of cooperation among growers and industry in the management of transgenic resources. The assessment should include input from scientists, policy makers, agricultural specialists, public and private institutions, and local farmers.

QUALITY INDICATORS AND NEW TECHNOLOGIES — SYNTHESIS OF ABOVE DISCUSSION

Concerns regarding the use of crops modified by new technologies vary, as shown by the case of rice and for B.t. technologies. Clearly, more issues are expected for the use of products containing B.t.-derived genes. These differences point to the need for some of the international crop biotechnology programs (see Table 2) to consider their research, testing, and use of products in the context of integrated pest or resistance management can be anticipated. It may also require more-detailed consideration of the two indicators of agroecosystem quality presented in the section on Quality Indicators — Linking Biodiversity with New Technologies, above.

The need for such approaches is often discussed in reports and workshops enumerating biosafety considerations for the introduction of transgenes into tropical agroecosystems. By summarizing these reports (see World Bank, 1993; Frederick et al., 1995; Frederiksen et al., 1995; Beachy et al., 1997; Hruska and Pavon, 1997; Serratos 1998; Whalon and Norris, 1998), the more specific considerations regarding biosafety can be covered by the following categories:

- Transgene flow in centers of diversity: crops becoming weeds, transgenes moving to wild plants, or erosion of genetic diversity
- Development of new viruses
- Resistance developed rapidly to the transgenes
- Affects on unintended targets
- Other ecosystem damage

Addressing these concerns begins with technical solutions, including data collection and experimentation. However, there is also a more adaptive component found in biosafety considerations, indicating agroecosystem complexities, the stakeholders involved, and the need for information addressing the two quality indicators selected. Generally, the more adaptive components of these concerns are voiced in terms of educating policy makers and public regarding consequences of use and deregulation, developing educational materials, and providing cost/benefit analysis reflecting the needs or priorities of each country. These points are often raised by participating countries during IBS policy seminars, and at biosafety meetings where this topic is stretched to accommodate other debates. These more adaptive challenges relate directly to the policy and management challenges facing leaders in developing countries seeking to employ the products of new agricultural technologies.

Initiating programs to address some of the above considerations often exceeds the funding base provided for the international programs. However, some of the international programs have begun this experimentation and data collection, as is being done for rice (Gould, 1997). There is an equally great need to build such understanding among those responsible for agricultural research in the developing countries. Unfortunately, developing countries cannot derive much information from analysis by regulatory agencies in developed countries for permits or notification for small-scale field testing of transgenic products, because the trial is conducted within parameters taking into account isolation, pollen flow, and avoiding persistence of crops at field sites.

These criteria and parameters enable those conducting tests to demonstrate that transgenic plants are as safe as other plant varieties. However, such isolation practices established for the needs of trials in the U.S. and Europe do little to satisfy the concerns (as listed above) anticipated for tropical ecosystems or centers of diversity. Of course, this is not the purpose of trials carried out in developed countries. The questions are: who will determine and how, whether the new plants are of no greater danger to tropical ecosystems than plants produced traditionally, and how will technical estimates for the two quality indicators be prepared in this regard?

AGROECOSYSTEM QUALITY AND CHALLENGES AHEAD — ADAPTIVE PROBLEMS REVISITED

The various points to be covered in this chapter are now complete, as summarized in Table 1. While it is not common to pose agricultural questions in the context of technical and adaptive problems, this distinction has much to offer discussions concerning biotechnology, especially when considering the range of questions that may be asked by various stakeholders regarding agronomic inputs and biodiversity. For biotechnology-derived improvements to have acceptability, clear demonstrations of utility with regard to stakeholder concerns for environmental and productivity considerations are needed.

As mentioned above, agroecosystem quality may be improved by eliminating or minimizing dependence on chemical inputs (quality indicator 2), although clear data on this is lacking at the present time. They may also affect perceptions regarding biodiversity (quality indicator 1) leading to widespread use of a variety or, in the case of transgenic maize, have implications for gene transfer in a center of diversity, or on horizontal gene transfer (Harding, 1996). The examples used (durable blast resistance and B.t. technologies) indicate potential suitability for farmers lacking access or money for chemical inputs, where it is desired to reduce chemical inputs in traditional systems or where minimal disruption of biological populations is desired. In the case of tropical maize with insect resistance, since the technologies have not yet been used or tested in the field, it was not possible to obtain estimates on expected decreases in the use of pesticides, as related to the second quality indicator.

As seen in the policy seminars, new products often focus attention on acceptance issues, which can be related to indications of agroecosystem quality. Consequently, in each seminar, socioeconomic methodologies are explored in regard to how stakeholders benefit from investments in biotechnology, and how such analysis can contribute to the learning required to address environmental and productivity questions. Follow-up to the seminars gives attention to identified needs, providing the opportunity to approach them as adaptive problems, often requiring changes in stakeholder values, attitudes, or behavior.

This supports points emphasized by Whalon and Norris (1998), as much remains to be learned regarding the wise management and deployment of genes introduced through biotechnology. Thus, findings point to where future work can be anticipated that it is hoped will diminish the learning required for adaptive situations. In many cases, these situations will weigh productivity issues of profitability, market acceptability, and overall agronomic performance with effects on agroecosystem quality. Neither dimension (environment or productivity) can be ignored. At the present time, adaptive problems arising from international biotechnology efforts are encountered not in the context of agroecosystem quality, but under the heading of biosafety considerations. The relation among biosafety, solutions offered by biotechnology, and more complex considerations of ecosystem effects is seen at many workshops.

hnologies used by farmers will raise adaptive problems, of which
erations may be one part. Stakeholder involvement will be essential
hese cases, especially given that local land-use knowledge continues
to food production in the tropics and in traditional agroecosystems
93). Such knowledge reflects experience gained over many genera-
contribute much toward sound management practices. Using local
en determining quality indicators could be done in conjunction with
mine natural resource or ecologically sound management practices.
ready stated, such measurements have human biases or judgments
n and reflect the stakeholders involved.

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