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## OECD Global Forum on Knowledge Economy - Biotechnology

# IMPACT ASSESSMENTS AND AGRICULTURAL BIOTECHNOLOGY - RESEARCH METHODOLOGIES FOR DEVELOPING, EMERGING AND TRANSITION ECONOMIES

**DIRECTORATE FOR FOOD, AGRICULTURE AND FISHERIES**

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## NOTE BY THE SECRETARIAT

Modern agricultural biotechnology is of increasing relevance and importance to developing, emerging and transition economies (DETEs). Two activities of the Directorate for Food, Agriculture and Fisheries (AGR) provide the framework for an integrated work programme on modern agricultural biotechnology in non-OECD countries. First, the 2001-2002 programme of work on food safety [AGR/CA/APM(2001)13] includes an activity to examine some of the main economic issues surrounding the development and introduction of modern agricultural biotechnology in DETEs. Second, under the auspices of the Centre for Co-operation with Non-Members (CCNM), the Division for Agricultural Policies in Non-Member Economies is to pursue a policy dialogue with DETEs on the use of modern biotechnologies in the agro-food sector.

To initiate internal discussion on these issues, an informal "brainstorming" meeting was organised by the OECD Secretariat, involving academics, industry and farm organisations, and representatives from the FAO and WHO, and held on 11-12 September 2001 in Paris. The purpose of this meeting was to help identify and clarify the key issues and concerns of DETEs with respect to modern agricultural biotechnologies, as well as the possible analytical work that could be undertaken by the Secretariat.

The brainstorming session identified significant gaps in the approaches and analytical work devoted to the potential impacts of modern biotechnologies on the diversified farming systems of non-OECD countries. This report, prepared by the International Service for National Agricultural Research (ISNAR) in close co-operation with the OECD Secretariat, examines approaches to assessing the potential economic benefits and costs of introducing modern biotechnologies in selected developing, emerging and transition economies. The authors gratefully acknowledge the valuable contributions of participants at the June 2001 ISNAR consultation on "Biotechnology and Rural Livelihood --Enhancing the Benefits".

# EXECUTIVE SUMMARY

Recent advances in agricultural applications of modern biotechnology show a significant potential to contribute to sustainable gains in agricultural productivity, reducing poverty and enhancing food security in developing countries. As these innovations are increasingly adopted, impact assessment becomes a critical tool for addressing potential socio-economic and environmental costs and benefits.

A key message of the report is that conventional economic impact assessments may not be broad enough to address the complex nature of a rural community in developing, emerging and transition economies (DETEs). The report introduces a Sustainable Livelihoods approach, which may provide a more appropriate framework to quantify and qualify the impact of biotechnologies in these countries. The Sustainable Livelihoods approach is a broad based inclusive framework that facilitates and requires multi-disciplinary work to assess impact in a community. It considers the vulnerability context, as well as the policies, community portfolio of assets, institutions, and significantly the linkages between these components.

While there are several conceptual and implementation issues that still need to be resolved regarding the specific nature of biotechnology innovations, the Sustainable Livelihoods approach can be a very valuable tool to guide research. The approach requires a change of mentality on the part of the impact assessor, development agencies and research institutions in the sense that the community in the end guides the research. This bottom-up approach to research identification and evaluation in some cases may mean that alternative approaches, besides biotechnology, may need to be explored and researched.

Impact assessment is critical for confirming whether biotechnology has extended to small holders or farming communities beyond the reach of markets and most importantly if these biotechnologies have accomplished the ultimate goal of improving the livelihood of communities in DETEs. Studies reviewed in this report indicate that the current wave of input reducing biotechnologies can and does provide positive benefits to producers in DETEs. The need for DETEs to develop their own capacity to assess the impact of biotechnologies is stressed.

These studies also indicate a number of policies and infrastructure requirements needed to ensure that biotechnology will benefit rural communities such as:

- Capacity to generate, adapt, and/or negotiate access to biotechnology innovations;
- Capacity to generate good quality animal and plant germplasm where biotechnology can be used;
- Ability to identify and prioritise critical problems affecting the rural poor that may be addressed by biotechnology;
- Existence of a technology and information delivery system;
- Existence of a rational (science-based), transparent and expedient biosafety regulatory system;
- Ability of the public sector and the international agricultural research centres to negotiate and promote private-public partnerships in an environment where pro-poor biotechnologies can be considered public goods.

Finally, development of a long term, systematic programme of comparative studies is recommended to ensure ongoing monitoring and analysis of the impact of existing or near-term introductions of biotechnology products in DETEs. In turn this would provide reliable information to decision makers about the expected benefits, costs and risks of such technologies.

# IMPACT ASSESSMENTS AND AGRICULTURAL BIOTECHNOLOGY – RESEARCH METHODOLOGIES FOR DEVELOPING, EMERGING AND TRANSITION ECONOMIES

## Introduction and Background

### *Purpose and objectives*

1. The United Nations (1999) expects that by 2030, the world's population will rise to 8.1 billion. According to FAO (2000), almost all of this population increase will occur in DETEs (Developing, Emerging and Transition Economies). These are countries that can ill-afford additional population increases that will increase food demand. Some authors (Douthwaite, 2001; Moore-Lappé *et. al*, 1998) propose that there is currently sufficient food to feed the world's population; the problem of world hunger is not of quantity, but of unequal distribution. However, even if in the short-run we resolve the issue of distribution, with a growing population the amount of food demanded will necessarily grow in the long run. The challenge is not only having to feed more people, but to do so taking into account production of food with less arable land available to agriculture, fewer non-renewable resources, less water and fewer people engaged in primary agriculture (Kishore and Shewmaker 1999; Conway 1999).

2. Agricultural biotechnology may contribute to solving the issues of poverty and food insecurity given the increasing constraints faced by agriculture in DETEs. However, decision makers need to have answers to critical questions in order to ensure that pro-poor biotechnologies will reach and address the problems of their intended targets. The critical questions in this discussion are: What are the necessary institutional and research infrastructures to supply appropriate agricultural biotechnologies to DETEs? How can DETEs guide the development of pro-poor agricultural biotechnologies? What is the impact of biotechnology on the environment, human health or on the livelihood of the rural poor? Debate over these questions has generated very passionate exchanges of opinions and controversies in different forums.

3. These questions are of paramount importance given that innovators in OECD nations develop the majority of applications of modern biotechnology for market-based economies, or for commodities used in highly productive environments. The need for pro-poor biotechnologies should be weighed against current technological capacity, the current trend of declining public investment in agricultural research in many DETEs, and the perception that biotechnologies have no place in poverty alleviation strategies. Indeed, part of the criticism directed against biotechnology, particularly towards genetically modified crops, is that few or no benefits accrue to poor farmers, or consumers in DETEs. Biotechnology critics are often unable to base their opinions on sound facts, as there is very little information about the long-term cost, benefits and risks associated with using biotechnology, especially for the poor in rural communities. Addressing these issues may help answer the questions raised above.

4. A limited number of studies have applied different methodologies and approaches to assessing the impact of new agricultural biotechnologies in developing countries. These studies have suggested positive impacts for small-scale farmers[1]. While the foregoing studies provide valuable insights, the evidence of impact of biotechnology is still fragmentary. New approaches, which are more comprehensive,

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1. These studies have also suggested that certain conditions are necessary if farmers are to reap maximum benefits from what the technology has to offer, such as improved management practices or improved seed distribution.

are required to better understand the likely impact of agricultural biotechnology products on rural livelihoods, positive or negative.

5. The purpose of this report is twofold. First, the report reviews and discusses findings and limitations of existing socio-economic methodological approaches to analyse impacts of biotechnology. The main limitation of existing socio-economic methodologies is that they tend to focus on a narrow disciplinary emphasis when in fact impact occurs at many levels within a community, hence the need for comprehensive evaluation methodologies. Second, we introduce the comprehensive Sustainable Livelihood (SL) conceptual framework, and suggest how this framework could be applied to measure the impact of agricultural biotechnologies.

6. The SL framework utilises the concepts of vulnerability, community assets, policies and institutions, and the linkages between these factors. The SL methodology allows a better understanding of the likely impacts, positive or negative, of agricultural biotechnology products on the livelihoods of rural communities in DETEs. We expect that this report will contribute to policy discussions, within both DETEs and OECD countries, on how to evaluate the role of biotechnology in agricultural development strategies for developing countries. This will improve the ongoing debate and provide essential information to policy makers, researchers, leaders of communities and civil society.

7. In this report, we concentrate on social and economic impact assessments as compared to the SL methodology[2]. In the remainder of this section, we provide a working definition of biotechnology and a brief summary of the status of public sector biotechnology research in selected DETEs. The second section will discuss the relevant concepts related to benefits, costs and risks of agricultural biotechnologies in DETEs. Section three provides a review of the literature for existing socio-economic impact assessment methods as well as exploring existing cases of impact assessment drawing particularly on the experience of DETEs. In the fourth section, we introduce the Sustainable Livelihood methodology. The SL methodology is a broad based methodology that seeks to address the existing linkages affected by the introduction and adoption of a technology in a community. Crucial issues and limitations to implementing the methodology are discussed, and ongoing impact assessment research activities that use the SL framework are reviewed. The final section draws conclusions about impact assessment methodologies and various policy issues arising from the discussion.

## *Brief description of biotechnology in DETEs*

### *Definition and scope of biotechnology*

8. This report uses the definition of biotechnology proposed by Cohen (1999). In this definition, biotechnologies are the products arising from cellular or molecular biology and the resulting techniques coming from these disciplines for improving the genetic makeup and agronomic management of crops and animals[3]. These techniques include fermentation, microbial inoculation of plants, plant cell and tissue culture, enzyme technologies, embryo transfer, protoplast fusions, hybridoma or monoclonal antibody technology and rDNA technologies. This definition allows for a focus on products arising from the research continuum in between traditional and modern biotechnology. The artificial segregation between

2. Impact assessment practitioners have developed distinct methodologies for environmental, risk, environmental health, and strategic environmental assessments (IAEG, 2000). However, a review of these alternative impact methodologies falls outside the scope of this report

3. This definition is similar to the working definition of biotechnology used by OECD (OECD, 1999).

modern and traditional biotechnologies will certainly disappear, as laboratories world-wide incorporate modern biotechnology techniques into their daily research operations.

*Public biotechnology research in developing countries – The state of the art*

9. As access to biotechnology tools and research increases among developing countries, biosafety regulatory, trade related and economic impact assessments will become more essential. Such studies will help to minimise the costs and risks and maximise the benefits of biotechnology research. Recognising the need for this information, ISNAR's Biotechnology Service began a research project regarding the use, regulatory status and constraints facing developing country *public sector* research organisations.

10. This study, titled Next Harvest, is comprised of data collected from and with a number of public sector institutes in Asia, Africa and Latin America. This information has a specific focus on food crops, and hence fibre and animal transgenics have not been included. ISNAR collected data for the food crop to be modified, its source of germplasm, the transgenic event employed, its biological use, regulatory status and means for deployment. By collecting data in this comprehensive manner, it is possible to bring together concerns of access, use and benefit from biotechnology research; relation to breeding and varietal registration; regulatory categories and status; and, plans for dissemination to users. Data has been assembled by country, and it is now possible to derive preliminary summaries as shown below. Comprehensive summaries will be available only after all data and conclusions are verified with participating countries.

11. In addition to ISNAR's data, other sources of information exist as collected by the Pew Initiative on Biotechnology (2001) and by Burrill and Company (2000). These reports describe the range of temperate crops, traits and technologies being advanced by public and private research in industrialised countries. While the first tier of commercial products has been primarily focused on new inputs to help farmers (herbicide, insect and disease resistance), a far broader range of products is expected from the coming wave of research (see below).

12. Currently, based on data from 11 countries, the following preliminary findings can be discussed:

- *The research pipeline is increasing and diversifying*. An increasing diversification of crops being transformed in industrialised country research is readily seen. This trend is also seen among developing countries. These include all basic food commodities, fruits and vegetables, tree species, papaya, and oil palm.

- *Biotechnology objectives are primarily for disease/insect resistance*. Transformation events for tropical crops are primarily concentrated on disease and insect resistance. This is a principal difference with temperate crop biotechnology, where biotechnology objectives provide a far greater range of applications, including herbicide resistance, nematode resistance, and allergenicity reduction (Pew Initiative on Biotechnology, 2001).[4] The major focus for developing country public research is insect resistance in cereals (rice, maize, sorghum), virus resistance in vegetables, potato, papaya and resistance to Black Sigatoka fungus in banana.

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4. For developed countries, Burrill and Company (2000) document other applications in the research pipeline that include: (a) High-performance cooking oils: achieved by providing high levels of high oleic or low levels of linoleic acid; (b) Healthier cooking oils: reduced saturated fats; (c) Delayed ripening fruits and vegetables: superior flavor, color and texture for shipping; (d) Nutritionally enhanced foods: increased nutrients, vitamins and other nutrition related ingredients.

- *Wide access to proprietary genes and technologies*. At present, all countries studied show various methods to access modern technologies. This can be through license or transfer agreements, international collaboration, or a number of other mechanisms. Their use in transformation and as sources for biotic resistance is very clear and growing. In most cases, use of protected technology is being advanced, without serious IPR concerns. In many cases the problems are sorted out beforehand, or for local crops being transformed IPR concerns are not an issue because of the lack of export or trade implications.

- *Regulatory difficulties and challenges*. Besides the focus of transgenic events, the second biggest difference in developing country biotechnology is the scarce number of regulatory approvals provided for scale up or commercial release. This is not to say that all regulatory questions have been met, or that all necessary safety data have been provided. Rather it is to say that the most severe restriction to progress in this research at present is due to other regulatory difficulties (Cohen and Paarlberg 2002) and costs encountered as research moves to larger field scale testing (Cohen 2001). Thus while research is freer to advance in North America and other centres of innovation, it is often curtailed in developing countries, where, by and large, only commercial use of transformed cotton and soybeans has been allowed.

13. In the regulatory status data compiled to date, discrete categories were used, ranging from laboratory, to confined, scale up and ultimately, commercial release. By far, most developing country applications are at the stage of laboratory or confined release, with the exception of China. As for China, it has developed some crop events that are now in scale up testing or ready for commercial release. This also reflects the length of time needed to gain acceptance, approval and the best product from GM research. Few developing countries besides China can take advantage of such key investments to make their research available to farmers (Huang *et. al*, 2002; Huang *et. al*, 2001).

**Cost, benefits, and risks of agricultural biotechnologies in DETEs**

14. In this section, we describe the benefits, costs, and risks of biotechnologies. Table 1 provides a sample list of benefits, costs and risks in order to emphasise that the main imperative for DETEs is to examine agricultural biotechnologies with the appropriate impact assessment methodologies that will be able to address the complex adoption and diffusion, and hence impact, of innovation in DETEs.

15. Most current developments in transgenic crops aim to increase output per unit of land or reduce production costs.[5] Alternatively, current developments seek to increase value added of final products by improving quality. These types of improvements are characteristic of the first and second wave of GMO released commercially, or that are currently in the research pipeline. Biotechnologies, developed mainly for a developed country setting (*i.e.* Bt cotton or herbicide resistant soybeans), have diffused to regions and countries with similar agro-ecological characteristics, but this path of dissemination represents an exceptional case, not a result of DETEs' policy or strategies to develop biotechnologies.

5. Biotechnology companies in industrialized nations have developed most current biotechnologies for agricultural areas that already have high productivity levels.

Table 1. **A sample list of benefits, costs and risk of agricultural biotechnologies**

| BENEFITS | COSTS | RISKS |
|---|---|---|
| **Improved technologies**<br>• Unit cost reductions in production<br>• Reductions in pesticide applications<br>• Improved nutritional qualities<br>• Biotic and abiotic stress resistance<br><br>**Improved knowledge**<br>• Basic research (improved efficiency of future research)<br>• Applied techniques (improved efficiency of current research) | **"Economic"**<br>• Technology/User fees<br>• Additional farm management costs<br>• Increased prices of inputs (imperfect competition setting)<br>• Increased dependency<br>• Trade considerations<br><br>**Research costs**<br>• Capital & Human<br><br>**Safety**<br>• Risk avoidance<br>– Regulatory framework | **Financial risk**<br>• Liability and indemnification - after the fact compensation of damage<br>• Insurance value of technology fees<br><br>**Human health**<br>• Allergenicity<br>• Toxicity<br>• Antibiotic resistance<br><br>**Environmental**<br>• Impact on non-target organisms<br>• Unintended expression and effects<br>• Gene flow |

16. From the standpoint of DETEs, perhaps a more effective strategy would be to specifically target biotechnology innovations that may increase productivity in marginal areas, where an increase in food production is needed, where crop yields are significantly lower than those obtained in developed countries, and where all other technological means have been exhausted (Herrera-Estrella 1999). Making such productivity increases possible calls for technologies that combat low productivity levels, post-harvest losses in marginal areas, control pre-harvest pests and increase yields on unfavourable soil conditions.

17. We envision that poor producers and consumers in DETEs may benefit from biotechnology through the following pathways:

- Benefit poor farmers directly by increasing their level of on-farm production. This may involve production of more food for their own consumption, increasing the output of marketed products that increase farm income, and lowering costs per unit of output;

- Improve nutritional status of the poor from increased nutritional contents of targeted crops or animals;

- Benefit small farmers and landless labourers through greater agricultural employment opportunities and higher wages within the adopting regions;

- Improve environmental efficiencies/cost reduction, coming with decreased use of chemical inputs;

- Benefit a wide range of rural poor within adopting regions through growth in the local non-farm economy;

- Increase migration opportunities for the poor to other regions and urban areas; and

- Benefit both urban and rural poor by lowering food prices.

18. It is important to emphasise that the pathways by which biotechnology can help address the issues of poverty and food security cannot be examined in isolation from the socio-economic environment where the community exists. For example, even if biotechnologies manage to improve on-farm production in order to achieve household food security, this may not be enough to facilitate long-term household sustainable development if households cannot sell surpluses in functioning markets. Furthermore, if trade policies from developed countries depress food prices and reduce access to their markets, this can only mean negating potential opportunities to DETEs. The context of analysis should carefully consider the linkages with institutions and processes outside a community, in some cases outside the country or region that may affect, or even negate the possibility of benefiting from an innovation. Conventional socio-economic impact assessment methodologies may not address all (relevant) affected linkages in a community.

19. The National Academy of Sciences (2000) of the United States argues that in order to realise agricultural biotechnology benefits, public and private sector research institutions need to emphasise biotechnology innovations that will express the following traits:

- Pest resistance: offers benefit to farmers in need of genetic control mechanisms, where cultural practices are not effective, and where reduction in pesticides is advantageous, leading to needs for more research to assess sustainability of resistance expressed in transgenic pest-protected plants.

- Improved yield: isolation of dwarfing genes originally used to increase yields of cereals during the green revolution has now shown that they have same effect in other crops, such that this dwarfing technique has potential to increase yields in other crops.

- Tolerance to biotic and abiotic stresses: genetic control of the rice yellow mottle virus is one example of how transgenics can accomplish resistance when conventional approaches failed to do so, illustrating need for public funded GM work to extend such benefits to smallholder farming communities.

- Nutritional benefits: traditional breeding has generally not been successful in increasing nutritional elements of many plant varieties, but recent progress enhancing vitamin A content and elevated iron levels in rice shows the potential of such research for developing countries.

- Reduced environmental impact: producing crops that tolerate cultivation in stressful conditions, by introducing GM traits that control root disease, will help farmers cultivate crops where reduced tillage is essential.

20. The emphasis on genetic traits and research areas discussed above refers to end-products of research that poor farmers in DETEs may adopt for use. However, an important and often neglected benefit, particularly of more established biotechnologies such as tissue culture or of newer technologies such as genomics, is that they may improve existing research processes. For example, genomics may improve the efficiency of future basic or applied research. Increases in current research efficiency allow

innovating institutions to do better investment decisions, as the uncertainty associated with research output is reduced.

21. Integrating biotechnology with conventional technologies requires significant additional investments in research, human, and financial resources. The development of a gene construct may entail significant research resources. In addition, innovators have to comply with additional biosafety evaluation procedures that in some cases may constitute a limit to entry for smaller firms and the public sector. Public sector and smaller research institutions may not have financial or human resources to comply with required toxicological, allergenicity and animal testing required for novel products.

22. Biotechnology innovators recuperate the cost of development by charging technology or user fees. Producers consider technology or user fees when deciding whether to adopt (and continue using) a particular biotechnology. Producers base this assessment on biotechnology's ability to provide enough benefits to recuperate additional input costs and compensation for the risks of using the technology. For example, in the case of input enhancing technologies, particularly GMOs designed to address biotic challenges, producers have to pay for the technology up-front without knowing if they need the technology, and thus face additional financial risks beyond conventional technologies. Financial risk arises because biotic challenges are random and vary from year to year.

23. In addition, with growing demand for identity-preserved or labelled products, producers who use biotechnology products may be penalised by purchasers of outputs because of potential trade considerations particularly in the case of nations with an active international trade with countries that restrict the sale of biotechnologies. Increasingly, impact assessment will need to include insurance value to the producer.

24. An issue which is increasingly being considered, particularly after the Starlink maize incident[6] in the United States, is the issue of after-sale risk avoidance in the form of liability and indemnification. Institutions will have to increase resources to protect themselves from this form of after the fact compensation of damage. All of these development costs increase the cost to the final user.

25. The discussion so far has concentrated on private costs, benefits and risks. However, biotechnologies also imply potential benefits, costs and risk of significant societal value. Individual producers cannot capture societal benefits and society does not expect them to cover all of these costs and risks. Several Non-Governmental Organisations (NGOs) and researchers that oppose biotechnology have portrayed biotechnology products as harmful to the environment (Clark, 1998), to human health (Ho, 1999), and to the socio-economic status of small farmers (Shiva, 2000). These authors indicate that biotechnology has potential risks, such as allergenicity and toxicity, induction of antibiotic resistance, environmental and vertical movement of genes, impact on non-target organisms and other unintended effects. These authors' arguments rely on preliminary or laboratory level research that indicates a potential risk with existing technologies. However, the "absence of evidence, does not constitute evidence of absence". It is important to point out that, although a high proportion of land in the United States and Argentina is sown to GMO varieties, there is, as yet, no scientifically verified case of any person's health being directly affected by the technology (Kaeppler, 2000; Thompson, 2000).

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6. Starlink, an insect resistant variety of maize, was approved temporarily for animal use only in the United States due to concerns of potential allergenicity problems. Traces of Starlink® were found in human food for consumption. The contamination may have occurred at any point of the commercialization channel. The innovator destroyed all available seed, abandoned the development of this biotechnology and purchased back all known stocks of grain.

26. Reports made by the Royal Society of the United Kingdom (2002), the Commission of European Communities (2002), and of a Workshop held at the University of California-Berkeley[7] (Altieri, 2000) indicate that up to now there has been no catastrophic event recorded or scientifically documented from the release of genetically modified organisms. The European Commission publication reviewed biosafety assessments of 81 projects funded by the European Commission from 1984 to 2000. This report concludes that substantial efforts have been made to assess biosafety and that a growing knowledge stock has been accumulated about the risk characteristics of GMOs. However, the University of California-Berkeley conference report raised questions about the long-term risks and the sparseness of environmental information of GMOs.

**Methodology and findings of socio-economic assessment of the impact of biotechnology**

27. Socio-economic impact assessment is not an end in itself, but rather a way to identify alternatives, so that scientists can enhance the benefits and minimise the cost of the adoption and diffusion of innovations. Alternatively, socio-economic impact assessment can be incorporated into the decision making process to improve its quality. Socio-economic impact assessment will always be speculative and results of its estimations need to be taken with caution. Even in the case of an *ex post* analysis, there will always be parameters and other variables which are subjected to biases, either of the researcher or from the data sources, or uncertainties about the true values of the parameters being measured.

28. In most cases, results from a case study can only be applied to the place were the study was conducted. Socio-economic impact assessment practitioners can extrapolate results to other regions in a limited amount of cases and with extreme care. A practitioner cannot, and should not make over-generalisations as a result, from estimations. To deduce general conclusions about the impact of agricultural biotechnology, it is important to review socio-economic impact assessment studies from different regions or countries and under diverse socio-economic circumstances. This exercise may allow identifying critical components that affect the impact of biotechnologies on communities.

29. This section will briefly describe the two most widely used methods of socio-economic impact assessment of technologies, the Cost/Benefit and Economic Surplus methods. In addition, we discuss some methodological shortcomings of these two methodologies. The purpose of discussing the impact methodologies here is to provide a background to better understand the discussion of empirical impact assessment studies in the next section of the report.

30. It is important to point out that impact assessment methodologies can be used in an *ex ante* or *ex post* setting. *Ex ante* impact assessment, refers to the analysis that estimates the potential impact of the adoption and diffusion of an innovation. Practitioners customarily perform *ex ante* analysis to evaluate competing project options and to allocate resources based on a priority setting exercise. In an *ex ante* analysis, the researcher proposes plausible values for key parameters in the model chosen.

31. In contrast, *ex post* impact assessment refers to the analysis that evaluates past performance and achievements. This is an after-the-fact analysis that examines use of inputs and seeks to provide information to policy makers. In an e*x post* analysis; the researcher collects data on key parameters from primary or secondary sources. The probability of success, adoption rates, and information about production performance are known or can be estimated from different sources.

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7. The Consultative Group on International Agricultural Research Non-Governmental Organizations Committee (CGIAR-NGO) organized this Workshop. This Workshop was co-sponsored by the Institute for Food and Development Policy (Food First) and the Center for Biological Control, University of California at Berkeley.

32. One of the critical issues of e*x post* (and to a lesser degree *ex ante*) analysis is making the appropriate comparison between the "with" and "without" innovation scenarios. Agronomic and other life sciences experiments customarily deal with the appropriate comparison by comparing the proposed treatments with a control. In the case of economic impact studies, the control option is not possible; the next best solution is to use information available for the conventional (older) technology. The researcher can make estimations of the "without-innovation" prices and quantities using formulas derived from the system of supply and demand equations. In the economics literature, the "without innovation" scenario is known as the counter-factual scenario.

### *Cost/Benefit and Net Present Value methods*

33. Cost-Benefit (CB) analysis is a widely used and documented method, whose purpose is to provide consistent procedures to evaluate decisions in terms of their consequences. Often the literature distinguishes between two different sub-sets of approaches in CB analysis. The first one, the financial approach, includes examination of cash costs and benefits only. This is the procedure used by private firms and individuals to examine competing projects. The decision rule to accept a project is simply that a project is undertaken as long as benefits exceed costs. This decision rule is equivalent to positing that net benefits are greater than or equal to zero. The second, the socio-economic approach, adds the cost of alternatives (opportunity cost) and external influences on society. Alternative costs are customarily valued using "shadow prices", prices that include all the cost incurred by society in order to supply a good in the market.

34. Analysts have to apply "shadow prices" rigorously in DETEs, because of market imperfections, distortions induced by the State, price and wage rigidities, unequal income distribution, and fragmentation of the capital markets. The aforementioned characteristics do not affect CB analysis exclusively; they are common to all impact assessment methodologies. However, this methodology often has to rely on other socio-economic methodologies to estimate the impact of a particular innovation on prices and other parameters in a society. This dependence on other methodologies may complicate the CB analysis tremendously and may even negate its major virtues of expediency and simplicity.

35. To reflect the time value of money, researchers need to discount the flow of future net benefits using the appropriate discount factor or interest rate. Thus, discounting is a procedure to estimate the present value of benefits and costs realised during the course of the project. The process of discounting assumes that money spent today is more valuable than money spent in the future, as today's money can be invested, and thus can generate income until future use. In addition, discounting assumes that most people prefer to consume now rather than later. Discounting also assumes that the future is uncertain, and that for most people it is hard to delay consumption that produces immediate gratification.

36. The Net Present Value is thus the sum of the discounted stream of annual net benefits. Net Present Value requires subtracting all the costs necessary to bring the project into existence. An alternative measurement is the Internal Rate of Return (IRR), which is simply the rate of interest which, when applied to discount the stream of net benefits, makes the NPV equal zero. The analyst compares the IRR to an existing benchmark rate of interest, usually the prevailing bank-lending rate. If the IRR is greater than the benchmark rate of return, then the project is accepted.

### *Economic surplus*

37. The economic surplus methodology seeks to estimate net additional benefits to the economy due to an innovation. This methodology is also known as economic welfare analysis. The economic surplus methodology is based on the principle that supply and demand for a particular good reaches an equilibrium

point. Equilibrium represents a combination of prices and quantities, where at the given price the quantity demanded by individuals exactly equals the amount supplied by firms or producers[8]. Changes in the equilibrium quantity and price occur because of external shocks to the system of supply and demand functions (*i.e.* introduction of a biotechnology innovation). External shocks induce a shift in the demand or supply functions and a new equilibrium combination of prices and quantities. In the particular case of technology, innovation may cause a per-unit cost reduction (increase) or equivalently more (less) output produced with the same amount of inputs.

38. Economic surplus is composed of consumer and producer surplus. Both producer and consumer surplus are customarily measured as changes with respect to a counterfactual case, usually no innovation available or, alternatively, usage of an older technology. Change in consumer surplus arises through the associated price decrease due to adoption of the innovation that causes the shift in supply, multiplied by the quantity of the good consumed. Change in producer surplus arises from the change in net benefits associated with increased post-innovation output. Net benefits may be a result of an increase in output produce or from a decrease in the cost of production. In both cases, an output increase or cost of production decrease, the researcher measures changes net of the loss due to the price change induced by the innovation.

39. This is a well-established methodology in the economic literature and has been shown to provide valuable contributions to impact assessment efforts.

40. Researchers initiate the estimation procedure of economic surplus by deciding on the type of model to use. A decision on the type of model to use, will also include decisions about the type of functions (linear vs. curvilinear) and the type of supply or demand shift (parallel or pivotal). If there is a need to have preliminary estimations, the procedures that use a parallel shift and linear functions are very handy. This decision will also have to consider whether or not there is sufficient good quality data to do an econometric study.

41. Impact assessment practitioners have used several estimation procedures to estimate economic surplus. The main advantage of econometric methods is the ability to test hypotheses about the parameters in the model. The econometric method requires extensive good quality data, often not available in DETEs. The mathematical programming method obviates the need for extensive data and requires extensive knowledge about the processes and production characteristics of the innovation, but it is hard to judge the robustness of the model.

42. The quasi-rent approach provides an expedient and simple first approach to measure economic surplus. However, the quasi-rent approach is significantly close to economic surplus only when the change in supply or demand is small, and the elasticity of supply is unitary. If the innovation in analysis departs from these narrow assumptions, quasi-rents and economic surplus will diverge. The equilibrium displacement models provide a stronger theoretical background, allow for multiple modelling possibilities of policies, and are relatively simple and expedient to use. Very little data is required and the existing literature provides the data. However, because the equilibrium displacement models are based in linear functions and parallel shifts, they may not be suitable for all potential problems to be confronted by the practitioner. Table 2 provides a description of the characteristics of each estimation procedure described previously.

43. The obvious question that arises from the previous discussion and from Table 2 is how does a researcher choose between these methodologies and estimation methods? The evaluation criteria to choose

8. The economic surplus method is thus a static model because there is no mention of how equilibrium is reached.

the appropriate methodology are expediency, available resources, data availability and quality, and the type of research or policy question to be answered. For example, the quasi-rent, standard surplus models, and the Equilibrium Displacement Models are very expedient, with little data required, and require relatively few resources to implement. However, the quasi-rent approach can only be thought of as a first approximation to check results from other economic surplus models. The Equilibrium Displacement Models can model policy implications readily, however, they require the modeller to have advanced knowledge of economic concepts and methods, as well as extensive knowledge of the policy implications in hand.

Table 2. **Advantages and disadvantages of economic surplus estimation approaches**

| ESTIMATION APPROACH | ADVANTAGES | DISADVANTAGES |
|---|---|---|
| Standard models | • Very little data required<br>• Simple models<br>• Most data found in the literature | • May be inflexible<br>• Linear models may not be appropriate for some production processes |
| Econometric | • Ability to test statistically hypotheses about parameters<br>• Possibility of addressing some data problems | • Large amount of good quality data required |
| Equilibrium Displacement Models (EDM) | • Ability to model explicit economic and policy considerations<br>• Very little data required<br>• Data available in the literature | • Linear models may not be appropriate for some production processes |
| Linear programming | • Very little data required | • Extensive production (engineering) knowledge required<br>• In most cases unable to statistically test hypotheses about parameters |
| Quasi-rent approaches | • Expedient<br>• Relatively little data required | • Converges to standard models of economic surplus only when cost or yield changes are small and when the elasticity of supply is unitary |

***Existing cases of socio-economic impact assessment in DETEs***

44. Assessing the socio-economic impact of technology has been the subject of several studies, conferences and discussions. However, there is a scarcity of conclusive data for biotechnology,[9] partly because of its novelty. Furthermore, it is important to point out that developed countries have done much of the existing socio-economic impact research. In this section, we review the few existing socio-economic

9. Examples of biotechnology impact papers are those presented in the conferences hosted by the International Consortium on Agricultural Biotechnology Research (ICABR) conferences in Ravello, Italy.

impact papers in DETEs. At the same time, we point out existing gaps in the knowledge continuum in DETEs.

45. Excellent literature reviews of existing agronomic and socio-economic studies done in developed countries can be found in Marra, Pardey and Alston (2002); Shelton, Zhao and Roush (2002); and a Working Paper of the Commission of the European Communities (2002). The main conclusions from these papers is that the varieties derived from biotechnology research first released commercially can provide significant benefits to adopting farmers, while at the same time decreasing the amount of pesticides applied or allowing substitution of less toxic active ingredients. In some cases, using biotechnology may facilitate the adoption of erosion reduction methods such as no-tillage or reduced-tillage practices. In most cases the benefits accrued to the farmer compensate the extra-cost of fees paid to the biotechnology innovators for its use.

*Insect resistance*

46. Table 3 presents a sample of selected studies that have examined the distribution of benefits and the economic impact of biotechnologies in developing countries. Most of the impact studies done in developing countries to date have concentrated on insect-resistant cotton (Bt cotton).[10] This is in part because Bt cotton is one of the most widely diffused biotechnologies in developing countries, but also because Bt cotton is well suited for smaller scale farming. In addition, Bt cotton has the potential to decrease highly toxic pesticide levels and may have other environmental and public health implications.

47. Studies that document the potential impact of this technology have been conducted in China (Huang *et. al*)[11], Mexico (Traxler *et. al*), and South Africa (Beyers *et. al*). They indicate that the adoption of Bt cotton leads to higher yields and a marked decrease in pesticide use, which may bear substantial environmental and human-health benefits. Thus, the planting of Bt cotton enhanced farmers' incomes, as the increase in yields and reduction in chemical applications outweighed higher seed costs. During the analysed planting seasons, a significant share of total benefits accrued to farmers, with smaller portions going to consumers and seed companies.

48. Huang, Hu, Pray, Qiao and Rozelle (2001) estimated the impact of Bt cotton in China. China approved Bt cotton for cultivation from 1998. Two competing sets of Bt cotton varieties were approved for cultivation in different provinces. Thus, the two sets of varieties are not allowed to compete with each other. The first one is a set of varieties produced by the Chinese Academy of Agricultural Sciences. The second is a set of cotton varieties produced and introduced into China by a joint venture between Monsanto Corporation and a Chinese partner. Estimations from these researchers indicate that Bt cotton in general has a significant advantage over conventional cotton. In the surveys conducted in 1999 and 2000, the authors reported that, on average, growers using Bt cotton reduced pesticide use from 55 to 16 kg of formulated product per hectare. In addition, Bt cotton adopters reduced the number of insecticide sprays per crop from 20 to 7.

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10. For a literature review of agronomic and socioeconomic impact assessment for insect resistant cotton, please consult Edge *et. al* (2001), and Falck-Zepeda, Traxler and Nelson (1999, 2000). For economic impact assessment of Bt cotton in the United States please review Falck-Zepeda, Traxler and Nelson (2000a, 2000b); Falck-Zepeda, Traxler and Nelson (2001).

11. These papers where presented in the Consultation Biotechnology and Rural Livelihood - Enhancing the Benefits, June 25–28, 2001. A consultation organized by the International Service for National Agricultural Research, The Hague, The Netherlands. ISNAR's Briefing Paper 53 (Falck-Zepeda, Cohen, Meinzen Dick, and Komen; In Press) summarises these papers, as well as, conclusions and recommendations from the consultation.

49. In addition to a 70% pesticide reduction, the authors also noted the almost complete elimination of highly toxic organochlorines and organophosphates insecticides. Preliminary evidence in this study suggests that the use of Bt cotton resulted in a significant positive effect on farmers' health. The authors noted that 30% of farmers who used conventional cotton varieties reported health problems associated with spraying compared with only 9% who used Bt cotton. The authors concluded that the evidence is quite clear that Bt cotton reduces pesticide use and is likely to be beneficial to health and the environment.

Table 3. **A sample of case studies estimating the impact of insect resistant cotton biotechnology**

| AUTHORS | COUNTRY CONDUCTED | YEARS OF ANALYSIS | ESTIMATION METHOD | RESULTS |
|---|---|---|---|---|
| Huang, Hu, Pray, Qiao and Rozelle 2001 | China | 1999 | Net returns, Econometric | MNC Bt cotton net revenue per hectare was RMBY 855. China's Bt cotton varieties average net returns were RMBY 1433. Non-Bt in the sample reported a 2229 loss per hectare. |
| Traxler, Godoy-Avila, Falck-Zepeda and Espinoza-Arellano 2001 | Mexico | 1997<br><br>1998 | Economic surplus | Producers captured 10%, Innovators 90% of additional income.<br><br>Producers captured 90%, Innovators 10% of additional surplus |
| Beyers, Ismaël, Piesse and Thirtle 2001 | South Africa | 1998<br>1999 | Accounting and Econometric | In 1998 gross margins per hectare almost the same between adopters and non-adopters. In 1999, adopters had a 58% higher gross margin per hectare.<br><br>For 1998, results show that adopters averaged 88% efficiency, as compared with 66% for the non-adopters. In 1999, the equivalent figures were 74% and 48%. |
| Falck-Zepeda, Traxler and Nelson 2000a | U.S.A. | 1996 | Economic surplus | U.S. Producers captured 59%, Innovators 26%, and the "rest of world" (ROW) 6% of additional benefits. |
| Falck-Zepeda, Traxler and Nelson 2000b | U.S.A. | 1997 | Economic surplus | U.S. Producers captured 42%, U.S. consumers 7%, Innovators 44%, and the ROW 6% of additional benefits |

50. Beyers, Ismaël, Piesse and Thirtle (2001) estimated the impact of the adoption of Bt cotton in Makhatini Flats in South Africa in 1998 and 1999. In 1998 the researchers did not find significant differences in net benefits, contrary to 1999, where net benefits were 58% higher for adopters of the Bt cotton technology. In their study, econometric estimations indicated that in 1998 adopters of Bt cotton were more efficient in using their resources compared to non-adopters. The difference between adopters and non-adopters was even more significant in 1999, with adopters achieving an 88% efficiency with respect to the potential production possibility. The significance of these results is the additional benefit of technology pushing adopters to a higher efficiency level compared to non-adopters. This observation magnifies the significance of information reaching producers to maximise the technology benefits.

51. Traxler, Godoy-Avila, Falck-Zepeda, and Espinoza Arellano (2001) examined the impact of the adoption of Bt cotton in the Comarca Lagunera region in northern Mexico in 1997 and 1998. The Mexican government gave Monsanto a provisional permit to offer Bt cotton for cultivation as of 1996. The researchers used an economic surplus model where a small open economy adopts a technology. In this model, because of the openness of the economy and the inability to affect prices, consumers in the region do not see additional surplus from the innovation, whereas the producers and innovators capture all the rents produced. Results presented in this paper indicate that in 1997 producers captured 10% of the additional rents and innovators the remaining 90%. In contrast, in 1998 producers captured 90% of additional rents and innovators the remaining 10%. Differences in infestation levels and the need to control insect populations explain mostly these inter-year differences in rent distribution.

52. The Traxler *et. al* paper also serves to highlight the adoption decision estimations made by producers in this area. From a producer standpoint, biotechnology has additional deployment costs compared to conventional counterparts. The biotechnology innovators in the private sector have charged producers in the area technology and user fees. These technology and user fees were charged in addition to those made for the equivalent conventional technology. For example, the average technology fee charged to cotton farmers for Bt cotton in northern Mexico amounted to USD 80 per hectare. This is the same technology fee charged to producers in the United States. In the region, producers plant Bt seed cotton at an average rate of 14 kilograms per hectare. To recuperate the additional cost of Bt cotton in northern Mexico, producers would have to get either reduced sprays of pesticide or an increase in lint production of USD 50.90 per hectare. At a world price of USD 1.42 per kg, this represents 35 kilograms of extra lint per hectare. Conversely, the additional cost of the Bt seed could be recuperated with a reduction of 1.3 sprays per production cycle[12].

53. The papers examined here highlight the importance for researchers to examine all the linkages affected by the introduction of a technology in a community. For example, the China study shows public health and environmental implications that may escape traditional socio-economic studies. What is more important is the need to examine the impact of the technology on the community as a whole. Communities in developing countries are bound to use additional measurements of wealth and security apart from monetary considerations. In addition, communities may use informal and formal institutions, as well as intangible interrelationships between different members in a community to deal with innovations.

54. An additional critical point is that even in the case of a country such as the United States, where innovators have very strong intellectual property protections, the innovators were unable to capture all the additional rents created by the technology. In essence, innovators have to share rents with farmers to provide incentives for the adoption and continued use of the technology. This experience, also observed in countries with less protection, indicates the need to provide sensible policies that will foster the use of the technology and at the same time reduce the possibility of above-competitive, monopolistic prices.

*Herbicide resistance*

55. Pachico *et. al* (2001) presented an *ex ante* study of the income and employment effects of herbicide resistant cassava in Colombia. This study used the DREAM software from IFPRI to develop economic surplus estimates of the adoption of herbicide tolerant cassava compared to conventionally-bred cassava technology that uses either hand labour or mechanical cultivation and harvesting. The herbicide resistant technology evaluated increased consumer and producer surplus compared to conventionally bred

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12. We estimate these figures by dividing the 14kg of seed sown per hectare by the 22kg of seed per bag; then multiply by the cost per 22kg bag of USD 80. This figure is calculated at an average cost of pesticide application of USD 37.03 per hectare.

cassava with either mechanical or hand labour. In an expected result, herbicide resistant cassava decreased the amount of labour required in the region analysed. In some regions in Colombia, particularly the region where the study was conducted, there are labour shortages now. Thus, a labour saving technology may be appropriate for these regions. Furthermore, in some regions in Colombia mechanical cultivation of cassava is not possible due to their topography.

56. The impact assessment experience in developed countries with herbicide resistant products is mixed. Two papers by Duffy (2001, 2002) indicate that in 1998 and in 2000 herbicide resistant soybeans did not offer any significant economic advantage over conventional varieties. In practical terms, this means that the potential savings in equipment depreciation, fuel, and a reduction in herbicide costs per unit of land do not offset the additional cost of the technology and user fees charged for the herbicide resistant soybeans. The paper also indicates that the yield of herbicide tolerant soybeans is slightly lower than for conventional soybeans.[13] What then explains the continued adoption of herbicide resistant soybeans in the United States and elsewhere? According to Duffy, the main considerations by producers are convenience and management simplification. Although many papers have indicated the possibility that convenience and management simplification may be significant factors explaining the adoption decision of herbicide resistant crops, very few have presented formal models to incorporate this behavioural assumption into them. Demont and Tollens (2001) discuss one of the most interesting models that incorporate convenience in the adoption process.

*Virus resistance*

57. Qaim (1999a) examines the case of virus-resistant sweet potatoes in Kenya. According to Qaim, poor small farm holders in Kenya cultivate sweet potatoes as insurance because of its hardiness in hostile growing conditions. Yields are low in Kenya compared to other regions in the world partially because of disease attacks. The main disease affecting sweet potatoes is the sweet potato virus disease (SPVD), which is a complex system of different viruses. Average crop losses due to SPVD can be as high as 12%. A concomitant pest is a sweet potato weevil, which may increase yield losses to 20%. There is no effective treatment for the SPVD and the weevil.

58. A joint project between the Kenya Agricultural Research Institute (KARI) a public sector research institute and Monsanto Corporation was initiated in 1992 with mediation from International Service for the Acquisition of Agri-biotech Applications (ISAAA). Monsanto agreed to develop the virus-resistance technology specifically for the Kenya situation, to negotiate royalty-free transfer of technology and expertise and the allowance of a royalty-free licensing agreement that would allow diffusion of the transgenic sweet potatoes in Kenya and other African countries. *Ex ante* estimates from Qaim, indicates the welfare gains in Kenya due to the adoption of transgenic sweet potatoes can vary between USD 5.4 and USD 9.9 million. Of these additional rents producers will capture 74% whereas consumers the rest. This is an expected outcome as producers benefit through subsistence consumption. On the other hand, poor urban consumers will benefit through a reduction in prices.

59. Qaim's *ex ante* estimates of the rate of return to research involved in the creation of transgenic sweet potatoes are around 60% return on investment. This includes research and technology transfer costs of all research institutes, but does not include the basic research done by Monsanto. This case study highlights the possibilities of public-private partnerships mediated through an honest broker, the ability to address a production problem that had no solutions with existing technology, and the potential distribution of benefits because of a publicly available technology being released in a community.

13. The yield drag of herbicide resistant soybeans has been observed by Benbrook (1998).

60. Qaim (1999b) examined the *ex ante* case of transgenic virus resistant potatoes in Mexico. This is a joint project between CINVESTAV (Centre for Research and Advanced Studies), a public research institute in Mexico, and Monsanto Corporation. In contrast to the Kenya case, transgenic potatoes in Mexico used existing technology developed for the United States market. This implied that Monsanto provided strict guidelines to use the technology in Mexico, leaving the door open for future market penetration by one of its subsidiaries.

61. Qaim's *ex ante* welfare analysis indicates that if current institutional arrangements of poor seed distribution channels were kept, gains would represent USD 30.3 million of which producers would capture 46% and consumers 54%. On the other hand, if the public sector provides the improved technology under improved access conditions to small holders, benefits can increase to USD 45.1 million and producers' share of total surplus increases to 51%. Qaim disaggregates benefit distribution among potato producers. If the present institutional arrangement is kept, mostly large-scale producers will capture gains. In contrast, if the improved technology is provided under improved access to small holders, their ability to capture additional surplus increases substantially, even obtaining a higher percentage than large-scale producers.

### *Discussion of DETE data problems, biotechnology specific problems and additional factors to consider*

#### *DETE data problems*

62. Analysis of the impact on farmers of the adoption of technologies in DETEs implies dealing with complex agro-ecological systems, often lacking access to modern marketing systems. Such farmers typically work in smallholder areas, depending on a few key commodities, livestock or aquatic resources for food consumption and sale. Many of these areas are remote, with delivery and use of modern agricultural inputs restricted. Farmers have little cash income, meaning that inputs are very difficult to obtain or purchase. From an ecological perspective, many of these areas are rich in agro-biodiversity, with some farmers working in centres of diversity for our major and minor food crops. For products derived from biotechnology to impact smallholder communities, they must address the needs and agro-ecological environment of farmers and the poor who are often beyond the reach and opportunity provided by modern markets. The special circumstance that producers face in DETEs causes researchers to have additional data collection and methodological limitations and challenges. In this section, we will discuss such limitations and challenges.

63. Scott (1995) discusses specific limitations and challenges of developing country data. The most important limitation is that data are often not available or are difficult to collect. Even if data are available, reliability becomes an issue. Long series of prices and quantities supplied and demanded are often not available in DETEs. This limits the possibility of time-series econometric analysis. Differences in data collection procedures and definitions also limit the possibility of cross national and regional comparisons. We will review critical data required for most methodological approaches and then discuss ways to overcome some of the limitations encountered in DETEs.

64. All of the methodologies described in the previous section consider a very limited set of outcomes from the adoption of an agricultural innovation mainly because they tend to be aligned along specific disciplines. As such, economists and sociologists have a very spotty record of collaboration and methodological convergence. This is the same story with anthropologists and political scientists. The lack of convergence between social science practitioners and methodologies has reduced the ability to understand the complexity of communities in DETEs, but also the complexity of the impact of innovation in these communities. Economists have traditionally relied almost exclusively on quantitative methods to

examine impact. In contrast, sociologists (and other social scientists) have used significantly qualitative methodologies.

*Limitations to supply and diffusion of biotechnologies in DETEs*

65. A very critical question to determine the methodological approach to measure the impact of biotechnology is whether biotechnology is different from other technologies studied in the past. If so, what is different about biotechnology? Answers to these questions will undoubtedly affect not only the design of any proposed study, but will also dominate the discussion on research and development and other policies. We propose that several issues separate biotechnology from other technologies.

- *Market structure, market power, and distributional implications*

66. Private sector companies have primarily researched, developed and marketed biotechnology products. This is a departure from the "Green Revolution" technologies of the 1950s and 1960s, such as semi-dwarf varieties of wheat, developed primarily by the public sector. Private sector exclusive ownership of current biotechnology innovations opens the possibility of private sector companies to exercise market power in the seed (and other input) markets. Economists and the public sector have traditionally been wary of increases in market concentration and the related increase in market power. Economist wariness is a result of monopolistic market structures being associated with above normal prices and extraction of rents from producers who buy inputs. In the specific case of seed markets, some authors (Doyle; Kloppenburg, 1988) propose that seed prices are higher than normal, and that the long-term goals of enhancing germplasm and improving genetic diversity have suffered with increases in market concentration.

67. It is important to emphasise the connection between market power and structure and its distributional implications. In a monopolistic market structure that arises because of the innovation, the innovator may be able to exercise market power. Innovators exercise market power by having the ability to charge consumers prices above those existing in a competitive market setting. The need to provide incentives for adopting the innovation, the availability of technological substitutes, and the potential entry of potential competitors who may see abnormal profits as a sign for potential lines of business may challenge the amount charged over the competitive price by the innovator.

68. The models used to evaluate impact under a monopoly, imperfectly competitive and competitive environments are different, and, most importantly, impact assessment results will differ between a competitive and a monopolistic situation. Estimates of the distribution of rents from the United States of Bt cotton from Falck-Zepeda *et. al* (2001, 2000a, 2000b) indicate that the innovators' ability to capture all rents, as predicted by some economists, is limited. The existence of other input alternatives and production possibilities particularly limits the ability of innovators to charge above competitive market prices. Studies cited in this report seem to support this conclusion. The relevance for DETEs of this finding is that the attention of policy makers should centre on providing the right incentives to the supply of appropriate (pro-poor) technologies and worry less about potential monopolistic pricing by the private sector. This should provide some leeway in designing and implementing biotechnology policies in DETEs.

- *Intellectual property issues*

69. An expanding body of literature exists showing that increasingly both private firms and public institutions claim property rights in agricultural research and biotechnology. Property rights instruments include patent rights; plant variety rights; and contractual rights arising from material transfer agreements (MTAs). The strengthening and enforcement of intellectual property rights (IPRs) throughout the world have dramatically influenced the processes for research collaboration and international transfer of new

technologies. While there is no conclusive evidence whether stronger IPRs enhance or impede the availability and diffusion of new technology to DETEs, it is important that research institutes carefully consider their IP management strategies and "freedom to operate" prior to embarking on new R&D projects. Given the general situation of "weak" protection of biotechnology inventions in most DETEs, problems of intellectual property infringement (of inventions protected in industrialised, but not DETEs) may generally, not be too serious. This could of course change in the future.

- *Environmental and biosafety regulatory issues*

70. There is a very significant disagreement on risk characteristics of Genetically Modified Organisms. Although there has not been one documented case, so far, of any environmental or human health damage, there are some aspects of the risk profile of GMOs that are not known, simply because the accumulated knowledge derived from the commercial-scale release of GMOs is still limited. This lack of familiarity has resulted, in a large number of countries, in stringent biosafety regulations and sluggish decision-making, thus adopting a precautionary approach to the diffusion of GMOs. It is important to point out that research can enhance familiarity with biotechnologies and contribute to informed biosafety decision making through risk assessment studies.

- *Consumer acceptability*

71. Consumers in Europe, to a lesser degree the United States and some countries in Asia, have not been supportive of current biotechnology products. There is an increasing body of literature documenting this phenomenon; however, the important factor is that consumer groups in Europe and Japan have been very vocal about their opposition to biotechnology and have managed to exercise political pressure on governments to stop the development of biotechnology products. According to Paarlberg (2002), the consequence of this political pressure is that developing countries may have an even smaller probability of accessing biotechnologies suited to answer their problems. This is because developing countries are afraid that Europe and Japan will shun imports from countries using biotechnologies. Furthermore, Paarlberg argues that increased European Union regulations on labelling and identity preservation will further discourage the creation and diffusion of genetically modified crops in poor countries.

72. The discussion of impact assessment papers, as well as other crucial issues related to biotechnology suggest that certain conditions are necessary if farmers are to reap maximum benefits from what the technology has to offer, such as improved management practices, or improved seed distribution. As such, the following discussion will use the specific case of GMOs; however, many of the issues discussed here can be applied to other types of biotechnology. It is obvious that there are a significant number of structural and institutional constraints in DETEs that may prevent producers from accessing biotechnology products. Many of these constraints lie outside the realm of agricultural policy formulation. Issues such as education, physical infrastructure or macroeconomic policy of a particular country will certainly have an effect on the availability of biotechnology. However, our intention in this report is to point out some of the constraints and bottlenecks that may be addressed under a comprehensive biotechnology policy with the expectation that specific exogenous issues may be addressed as they arise.

73. A key factor that needs to be analysed is the specific DETE policy on biotechnology.[14] A second key factor is whether the gene construct (gene and the transfer technology) exists or needs to be researched and developed. DETEs may take advantage of biotechnology events created to address the needs of developed countries. The critical access issue is the ability to negotiate licenses and other technology

14. Paarlberg (2000) provides a framework to classify different countries into categories according to the policy environment towards biotechnology.

transfer instruments to allow access to the technology. If there is no capacity to take advantage of the existing technology, either by the local public or by private sectors, multinational private firms may be granted access to markets in DETEs. The key issue then becomes the ability by multinational private firms to protect and enforce intellectual property in DETEs.

74. Even if the gene construct exists, the need arises of appropriate and adapted germplasm to insert the gene construct. Breeding and agronomic innovation is as important as the gene construct. Biotechnology requires both to be successful. In some DETEs, an alternative pathway to acquire biotechnologies would be to increase investments in breeding and agronomic innovations with the objective to broker deals with the innovators who have developed the gene constructs. Integration between biotechnology and breeding/agronomic innovation opens the door to private-public and private-private collaborations. In both cases, appropriate instruments to protect intellectual property need to be in place.

75. Another key factor is the existence of functioning seed or plant material markets. The public sector in DETEs usually does not have the resources to promote and market innovations. Biotechnology events have the additional complication of the requirements to comply with biosafety evaluation protocols and regulations. Biotechnology events demand increased flows of information and knowledge embedded in the technology. These information and knowledge flows need to reach producers in order to allow them to exploit the potential of the technology (Tripp, 2000). For example, in Bt cotton, there is the need to reserve tracts of land as refuges to reduce the possibility of insect resistance to the Bt toxin. Producers need to have access to this information coupled with knowledge of additional changes in management practices.

76. All of these key factors interact with each other. Consumer and policy-makers' acceptance will determine deployment of the biotechnology construct. Biotechnology policies are the result of consumer and policy-makers' knowledge and attitudes toward the technology. Consumer and policy-makers' attitudes may be biased depending on the transparency and credibility of the biosafety approval process and regulatory institutions, as well as the relevancy of the problems which biotechnology intends to address.

**Opportunities and challenges for using sustainable livelihood concepts for biotechnology impact**

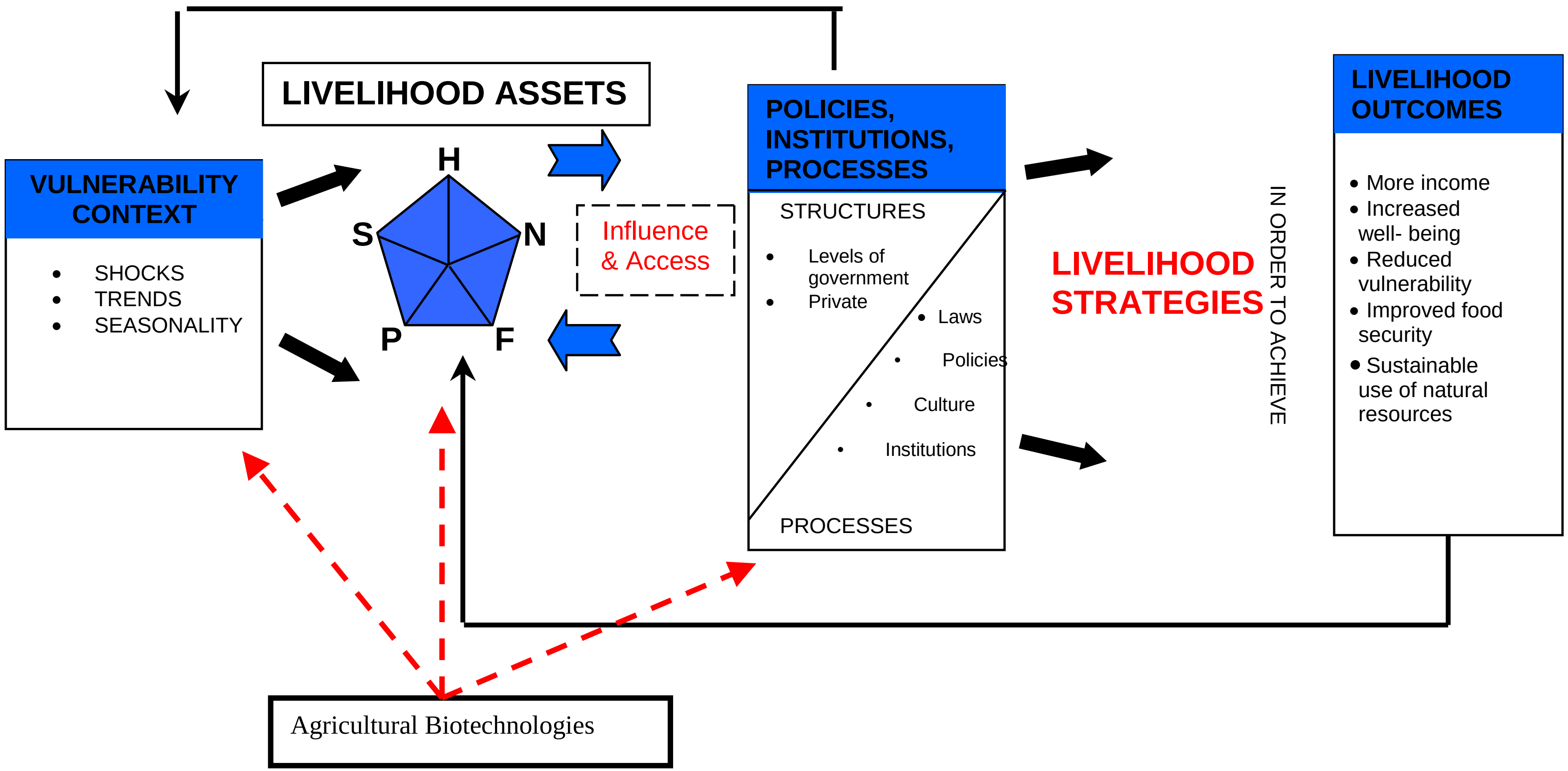
77. Information on yields and net benefits as presented in the studies reviewed previously are useful. Traditional economic impact studies are an important contribution to the debate on the impact of biotechnology in developing countries. However, among other things, some of these studies did not explicitly try to account for the environmental and human-health effects of agricultural biotechnology, or broader aspects such as poverty alleviation and food security. In this section, we introduce the Sustainable Livelihoods Framework as an alternative and comprehensive approach to examine the actual or potential impacts of a biotechnology in a community.

***The Sustainable Livelihoods framework***[15]

78. The Sustainable Livelihoods conceptual framework enhances the understanding of causes of poverty and food insecurity, by analysing relationships between relevant factors at the household, community and regional levels (Figure 1). This approach explicitly requires examining the context in which people live in a rural community. By including concepts of vulnerability, assets, and empowerment, the Sustainable Livelihoods framework goes beyond conventional socio-economic measures by augmenting these with values considered important by a community, but at the same time examining the critical pathways and linkages that connect these components.

15. This sub-section is based on Meinzen-Dick (2001) and Adato and Meinzen-Dick (2002).

Figure 1. **The Sustainable Livelihood framework and the impact of agricultural biotechnologies**



79. Figure 1 illustrates the Sustainable Livelihoods (SL) conceptual framework adapted from the United Kingdom Department for International Development (DFID) Sustainable Livelihood conceptual framework. The SL framework is dynamic, recognises changes due to both external fluctuations and the results of people’s own actions. The starting point of the framework is the vulnerability context within which people operate. External influences such as weather and price changes affect the vulnerability context. Vulnerability refers to issues outside people's own control. It is important to point out that it is not only objective “risk” that matters but also people’s subjective assessments of issues that make them vulnerable. These issues matter because both perceived and actual vulnerability can influence people's decisions and hence their livelihood strategies, and thus may affect people’s willingness to adopt agricultural biotechnologies. In turn, external influences may affect assets held by people in a community.

80. The SL framework proposes that people in a community hold a portfolio of assets. This portfolio of assets is a more inclusive and complete inventory of valued items by a community than monetary measurements used in traditional socio-economic studies. Assets included in the portfolio are social, natural, physical, financial and human, denoted in the pentagon in Figure 1 by the letters S, N, P, F and H respectively.

81. Natural capital may include land, water, forests, and biodiversity. Physical capital includes community infrastructure such as transportation, roads, buildings, water supply and sanitation, energy, technology, or communications. Financial capital includes savings in the form of cash or other liquid assets, credit from formal and informal sources, as well as inflows from state transfers and remittances. Human capital includes education, skills, knowledge, health, nutrition, and labour power. Social capital includes any community networks that increase trust, ability to work together, access to opportunities, and informal safety nets. The SL framework neatly separates assets into five categories; however, often assets in communities may not be cleanly allocated to a particular category. For example, for some communities cattle may be a physical asset, but at the same time a financial asset serving as a reserve or collateral account for emergencies.

82. Policies, institutions, and processes affect how people use and have access to their assets in pursuit of different livelihood strategies. The box in Figure 1 – Policies, Institutions, Processes- refers to both formal and informal institutions and organisations that shape livelihoods by influencing access to assets, livelihood strategies, and vulnerability. Civil society including the public and private sectors, and community institutions may all be relevant to consider in the analysis. All of these institutions influence people’s livelihood strategies. Assets interact with policies, institutions and processes, which in turn shape the choice of livelihoods strategies.

83. Livelihood strategies are choices that people employ in pursuit of income, security, well being, and other productive goals. What is important about the livelihood strategies approach is that it recognises that households and even individuals may pursue multiple strategies, either sequentially or simultaneously. Livelihood outcomes encompass many types of impact of agricultural research on poverty. Potential outcomes may include income, food security, and sustainable use of natural resources. Outcomes may be reflected in such things as strengthening the asset base, reduced vulnerability, and other aspects of well being such as health, self-esteem, and a sense of control.

84. The Sustainable Livelihoods framework brings in many considerations that are often not included in an impact study dealing with the impact of agricultural research. At the same time, it is often not easy to see how agricultural research and biotechnologies might fit into this framework. On Figure 1, we have indicated three ways in which the products of agricultural biotechnologies research can intervene in a community: by affecting the vulnerability context, through linkages to the asset base, or as part of the policies, institutions, and processes.

85. Agricultural biotechnology research can reduce vulnerability, such as when producers adopt GM insect resistant or disease resistant crops. Pest resistance makes farmers less susceptible to target pest infestations. Another example may be aluminium, salinity or drought tolerant crops. These biotechnologies reduce producers' vulnerability to crop losses. However, agricultural biotechnology can also increase vulnerability, such as when new varieties are more susceptible to crop failure due to other than target insect or disease susceptibility, or when farmers have to purchase the seed every year under conditions of cash and credit constraints. In the latter example, farmers' having cash and credit constraints is not an exclusive attribute of biotechnologies; rather these constraints will affect any technology offered to farmers. Furthermore, cash and credit constraints are in all possibilities, a major constraint to any development effort.

86. Agricultural biotechnology research and technology adoption may have strong links and help modify the asset base. Additional (excess) income may help improve human capital through education or help purchase new equipment that becomes part of physical capital. In addition, insect resistant crops may augment the population of beneficial insects above and below topsoil. Crops resistant to salinity capture excess salinity in the soil and thus improve or even eliminate the salinity problem. The aforementioned agricultural biotechnologies may improve the natural capital of land. This experience is not limited to the physical or natural asset base. Interesting experiences in Zimbabwe (Mnyulwa, 2001) and Colombia (Perry, 2001), have shown that participatory or action research processes can help improve significantly the biotechnology research process by strengthening the human and social capital asset base, as a consequence of knowledge generated by producers' groups.

87. The debate on the Green Revolution provides other interesting examples of technologies modifying the asset base. Most of the debate over the Green Revolution centred on whether large land holdings (natural capital) were required to adopt the various components of the Green Revolution package and thus take first-adopter advantage of the benefits of the technology package. In addition to the relationship between land holding scale and adoption, considerable research and policy efforts related to expanding agricultural credit (financial capital) and infrastructure (physical capital) in order to foster technology adoption.

88. Finally, agricultural biotechnology research can be considered as part of the policies, institutions, and processes box as a mechanism that creates options for people to build upon various assets to pursue their livelihoods. For example, drought-tolerant varieties can allow farmers without irrigation to pursue farming with less fear of disastrous losses. Insect-resistant rice may provide further incentives (less insecticide sprayed or more additional income) to adopt aquaculture technologies that allow people to increase efficiency of flooded land by adding fish for income and home consumption.

89. The prospect of covering all aspects of the sustainable livelihoods framework, or even all questions identified as critical for assessing the livelihood impact of agricultural research, can be overwhelming. This is a significant problem for econometric analysis, because there are many inter-related factors, which create statistical problems that require larger data sets in order to obtain meaningful results. To overcome the inherent complexity of the SL framework it is imperative to implement an integrated and interdisciplinary approach that draws upon both quantitative and qualitative data collection and analysis. In a typical Sustainable Livelihood study, the major data collection methods used include surveys, focus groups, key informant interviews, in-depth household case studies, and secondary data. Careful attention needs to be given to sampling in all types of data collection, with links between samples wherever possible. This raises a very positive attribute of the SL methodology as it forces researchers to understand the context in which an innovation is being deployed, as well as, provides the opportunity to incorporate and provide incentives for co-operation between multiple disciplines

***Limitations and challenges***

90. A fundamental difficulty with determining impact is the lack of a clear definition of concepts such as "Poverty" and "Sustainable Livelihoods." For example, in a particular community, farmers may not be the "poorest of the poor" themselves, but still have a major impact on poverty. The fundamental question of what constitutes poverty and sustainable livelihoods magnifies the problem of lack of information on the impact of technologies in the rural sector. This gap in knowledge increases the difficulty in identifying the direct and indirect linkages, and the cost and benefits of the introduction of a particular innovation in a community.

91. In our introduction of the SL methodology, we proposed three pathways through which agricultural biotechnology may affect the livelihoods in a community. However, the nexus between agricultural biotechnology research, technology generation and poverty alleviation still needs to be studied further. In most cases agricultural biotechnology policy has to be framed within the perspective of overall development goals and policies of a country or region. Biotechnology can be then viewed as a springboard to facilitate other activities or as a way of providing options to people. It is important to point out that the SL framework intervention is a way of identifying livelihood strategies and entry points from the bottom-up. If research priority setting, planning and implementation are done in this fashion, then the ideal of sustainability may be achieved. A perverse situation can occur where a researcher can conduct an SL study where there is a need to identify the "appropriate technology" from a pre-determined portfolio of technologies. The donor or the development agency willing to fund the programme pre-determines the technology portfolio. This of course, is the traditional "top down" approach to determine research priorities and intervention.

92. The SL framework has to be more than a good checklist or a tool that allows communication between disciplines by providing a common language and approach to conceptualise poor rural communities. The SL framework is a concept that should and must change mindsets to broaden our understanding of poor communities. The broadening of a mindset implies posing paradigm changing questions which may affect long established notions about development or socio-economic impact assessment.

93. For example, a long-held tenet in the economic development is that in DETEs with labour surpluses, is the imperative to promote labour using, not labour saving technologies. An example of labour saving technologies is herbicide use. However, as we have seen in the Pachico *et. al* paper, a developing country may have localised labour shortages. Alternatively, Dr. Florence Wambugu in a meeting of the American Association of Agricultural Scientists indicated eloquently that the most vulnerable groups in Africa, women and children, do most of the weeding in poor rural communities (cited by Gressel, 1996). A labour saving technology may free the most vulnerable groups in a community from backbreaking labour, thus freeing time for education and other self-improving endeavours. Alternatively, a country must make the alternate (hopefully informed) choice of maintaining the *status quo* and deny an additional opportunity for the most vulnerable groups in their society.

94. An important consideration is the correct identification of the counterfactual case. In many cases, the counterfactual can be no intervention at all. Yet, maintaining the "no intervention" counterfactual in all probabilities will have its own set of costs and benefits. In the examined examples of insect resistant Bt cotton, the "no intervention" option could be either to continue spraying with conventional insecticides, or drop cotton altogether from the household production plans.

95. There are operation and conceptual challenges as well as research issues that need to be resolved as research is conducted using the SL framework to evaluate the impact of biotechnology in DETEs. These

issues are the result of observations made from the initial implementation phase of the ISNAR SL project, but also of literature reviews of existing SL projects in other areas of impact assessment. These include:

- Currently, there is limited experience and data availability for research in sustainable livelihoods. In the particular case of biotechnology, most applications are still immature, hampering the ability to conduct multi-year, *ex-post* analysis.

- Coupling a Sustainable Livelihood approach with *ex ante* economic analysis will be difficult, as it will require the researcher to propose many assumptions about uncertain effects on existing community links. Still, it would be a useful approach to begin by identifying the livelihood asset base, “vulnerable” groups in a specific community or region and potential links affected by the introduction of a technology that will serve as a counterfactual and a benchmark with which to compare after the innovation is adopted in a community.

- The need to avoid the problem of being inundated by the massive amount of data collected and providing a defined message/lessons. Is the study replicable and does it comply with rigorousness tests of validity and reliability?

- The need to balance effort, expense and benefit while designing an SL project.

- Ability of researchers to identify, quantify and/or qualify the line of causality from intervention to poverty alleviation and reduction of food insecurity. This is indeed the problem of identifying causality and attribution.

- What is the relationship between adoption, the diffusion process and impact assessment?

- The institutional and regulatory context for the delivery and farm-level adoption of products from biotechnology. This is an important factor to consider, especially as regulatory hurdles may lead to delayed dissemination of transgenic products. It adds a new dimension to the analysis, thereby complicating future studies.

- Related to the point above, the uncertainties involved in foreseeing and evaluating potential concerns regarding the environmental/biosafety aspects and public acceptance of genetically-modified food products.

- Finally, what are the implications of an SL study for present and future research strategies/processes of the CGIAR system, other International Agricultural Research Centres and National Research Organisations and Systems?

***On-going and planned research initiatives/approaches***

*IFPRI/SPIA Sustainable Livelihoods impact assessment*

96. The question of impact of agricultural research on the rural poor continues to be widely discussed in the Consultative Group on Agricultural Research (CGIAR) and other venues. For example, the paucity of information led the CGIAR to formalise impact assessment on the rural poor through the Standing Panel on Impact Assessment (SPIA). The CGIAR commissioned IFPRI to perform an impact assessment project that started in the year 2000. The main objective of this project is to build capacity within the different

centres that compose the CGIAR to perform impact assessment of agricultural research on the rural poor. The IFPRI/SPIA project is reviewing five cases in Bangladesh, Kenya, Zimbabwe and Mexico.

97. This project is using the Sustainable Livelihoods methodology. The rationale for using this methodology in the IFPRI/SPIA project came partially from an extensive literature review conducted in a first phase of the project, which indicated that research might impact the livelihood of the poor in rural areas under certain conditions. This literature review also showed there were many pathways through which the rural poor might obtain benefits or incur costs. Some of these pathways had to be included to get a complete measurement of impact of agricultural research. The authors of the literature review, Kerr and Kolavalli, point out that "Technology's role in alleviating poverty is both indirect and partial; technology alone cannot overcome poverty, nor can continued poverty be blamed on improved technology." The approach builds upon a multi-country study of the impact of conventional agricultural research led by IFPRI on behalf of the Standing Panel on Impact Assessment (SPIA) for the CGIAR (IFPRI 2000).

*ISNAR/IFPRI biotechnology and SL*

98. ISNAR's Biotechnology Service (IBS) organised a Consultation in June 2001 to strengthen approaches for socio-economic impact analysis of biotechnology on the poor in developing countries. The Consultation examined the Sustainable Livelihoods framework as the basis for implementing impact assessments on inputs from agricultural biotechnology. At the Consultation, researcher scientists, potential institutional collaborators, representatives from CGIAR centres, and donor and development agencies examined conceptual and implementation issues surrounding the Sustainable Livelihoods framework, examined examples of recent economic impact of biotechnology products, and helped define selection criteria to examine the impact of biotechnology on the livelihood of poor producers in developing countries. These contributions became part of the project "Biotechnology and Sustainable Livelihoods – Examining Risks and Benefits", a collaborative effort that ISNAR, IFPRI and other collaborating international and national organisations will implement. The purpose of this project is to quantify and/or qualify the actual or potential impact of agricultural biotechnology on the livelihood of rural farmers in developing countries, to build institutional capacity in developing countries for such research and to generate first-hand information from selected study sites.

99. The current ISNAR project proposal suggests adopting a broader "Sustainable Livelihoods" approach to study the impact of agricultural biotechnology. Broader studies and methodologies to evaluate the complete impact of biotechnology would therefore increase understanding of how a range of agricultural research affects the lives of the poor. ISNAR and IFPRI are currently seeking funds to initiate this project. A pilot case study using some of the principles of the SL framework will be initiated this year to explore the *ex ante* case of insect resistant potatoes in Colombia in collaboration with the International Potato Center (CIP) and CORPOICA, a Colombian partner. This initial pilot study will be self-financed by ISNAR, and may develop into a full blown SL project if successful in obtaining extramural funds.

**Summary and conclusions**

100. Impact assessment can provide key information for decision makers in developing countries, who all too often are left to rely on risk analysis, distorted information from advocacy groups, or focus exclusively on trade consequences of the adoption of biotechnologies. Impact studies, such as the insect resistant cotton examples given in this report, offer an important source of scientific information to be used for both research and policy analysis, to guide future biotechnology interventions, and identify areas that may block or hinder expected gains from a given biotechnology.

101. The limited diffusion of food crop biotechnologies in DETEs is largely due to restricted regulatory and trade related issues. This is why the few existing studies using socio-economic impact assessment methodologies in DETEs have centred on Bt cotton. Bt cotton is the most widely used biotechnology crop in DETEs apart from herbicide resistant soybeans. The biggest challenge for impact assessment methodologies, however, will come with the evaluation of food crops. When developing countries increase the development and adoption of food crop biotechnologies, requests for high-quality impact assessments will also increase. While the Bt cotton studies examined in this report show positive impacts in terms of income and environmental benefits for cotton, what will be the impact of biotechnology-developed food crops?

102. The complexity and importance of food crops in DETEs is crucial to the selection of the appropriate impact assessment methodologies. In anticipation of this need, ISNAR will use the Sustainable Livelihoods framework as a broader tool for conducting impact assessment. As shown in this report, the SL framework offers the benefits over other methods, in that it provides a systematic and comprehensive way to examine relevant issues in poor communities such as vulnerability, community values and assets, institutions and strategies. This unified approach helps multi-disciplinary work come to fruition as it provides a common language and methodology where disciplines converge. Furthermore, adoption of the SL framework represents a mentality (and perhaps even a paradigm) change that induces researchers and development agencies to think about livelihoods as a state of nature that needs to develop from the bottom-up, and thus allow convergence with the body of scientific knowledge and human capital that rose using the traditional top-down approach to research.

103. However, we should note that many of the existing studies, as well as those just beginning, rely largely on funds from international donor organisations or foundations. There is very limited capacity in the DETEs themselves to conduct this work now, China being possibly the exception. In addition, as noted in this report, most releases are taking place in non-DETEs. For this reason, in DETEs there are more challenges and opportunities to conduct *ex ante* studies, build team approaches to account for technology policy issues as well as impact at the community or household level. The major response from the international community thus far has been given to biotechnology research itself, and biosafety. However, promoting further considerations of impact assessment, given an expectation for food crop technologies to become available, would now have much merit.

104. One fundamental challenge will be to ensure that impact assessments truly target the poor. Obviously, this has much to do with the impact assessment methodology employed, as well as with the assessed farmer community and system adopting a biotechnology. Impact assessment will be critical for confirming whether biotechnology has extended to small holders or farming communities beyond the reach of markets and most importantly if these biotechnologies have accomplished the ultimate goal of improving the livelihood of communities in DETEs. Studies reviewed in this report indicate that the current wave of input reducing biotechnologies can and does provide positive benefits to producers in DETEs. In the future, impact assessment will need to provide feedback to researchers and policy makers about the research gaps and the needs for alternatives to provide an ever-growing portfolio of approaches to address poverty alleviation in DETEs.

105. However, these studies also indicate a number of policies and infrastructure requirements needed to ensure that biotechnology will not only reach the poor, but that they will be pro-poor in nature. Such requirements will vary depending on a country’s existing capacity to produce, adapt and/or or access biotechnology innovations. Such requirements may include:

- The capacity to generate, adapt, and/or negotiate access to biotechnology innovations;

- The capacity to generate good quality animal and plant germplasm where biotechnology can be used;

- The ability to identify and prioritise critical problems affecting the rural poor that may be addressed by biotechnology;

- The existence of a technology and information delivery system;

- The existence of a rational (science-based), transparent and expedient biosafety regulatory system;

- The ability of the public sector and the international agricultural research centres to negotiate and promote private-public partnerships in an environment where pro-poor biotechnologies can be considered public goods.

106. It is not only important to consider how countries will develop or obtain access to appropriate pro-poor technologies, but as part of a longer-term perspective, to build capacity to evaluate impacts. One source of this expertise is with the CGIAR commodity and policy centres, where work has been ongoing by CIMMYT, IRRI, CIP, IFPRI, ISNAR, and others. Building such collaboration will strengthen local capacity while taking advantage of methodologies pioneered by the centres.

107. Policy and financing issues for DETEs governments will also need review. Biological scientists and those involved in regulation and IPR will not want to see precious resource diverted to impact analysis. However, if we are to be prepared for the release of important GM crop products, such as for rice, maize, potatoes, then we must also anticipate a role of growing importance for NARS in DETEs. How best to develop this local capacity, and convey assessment findings and implications to policy makers is now an important consideration, so that this input to decision-making and policy analysis can convey its findings in the most useful manner. Reviewing the history of impact assessment studies and their evolution as applied to the Green Revolution technologies is one starting point. In addition, a long-term, systematic programme of comparative studies should be developed to analyse the impact of existing or near-term introductions of biotechnology in DETEs in order to provide reliable information to decision makers regarding the expected benefits, costs and risks of such introductions. The complex nature of SL approaches reinforces the need to establish a long-term research effort. Moreover, the close involvement of economic, social and policy research institutes from DETEs is essential in this effort, thereby enhancing local analytical capacities to undertake such studies.

## BIBLIOGRAPHY


Adato, M. and R. Meinzen-Dick (2000),
"Assessing the Impact of Agricultural Research on Poverty Using the Sustainable Livelihoods Framework." *EPTD Discussion Paper 89/ FCND Discussion Paper 128,* International Food Policy Research Institute, Washington, DC.

Alston, J. M., G. W. Norton, and P. G. Pardey (1995),
*Science Under Scarcity: Principles and Practice For Agricultural Research Evaluation and Priority Setting*. Ithaca, New York: Cornell University Press.

Alston, J. M. and P. G. Pardey (2001),
"Attribution and other Problems in Assessing the Returns to Agricultural R&D". *Agricultural Economics*. 25: 141-152

Alston, J.M., R.J. Sexton, and M. Zhang (1997),
"The Effect of Imperfect Competition on the Size and Distribution of Research Benefits." *American Journal of Agricultural Economics*. 79: 1252-65.

Altieri, M. A. (2002),
"Executive Summary International Workshop on the Ecological Impacts of Transgenic Crops." University of California-Berkeley.

Burrill & Company, (2000)
Biotech 2000. Life Sciences: Changes and Challenges. Burrill and Company, San Francisco, CA.

Benbrook, C., 2000
"Who Controls and Who Will Benefit from Plant Genomics." Paper presented in the AAAS Annual Meeting Seminar: The 2000 Genome Seminar: Genomic Revolution in the Fields: Facing the Needs of the New Millennium.

Beyers, L., Y. Ismaël, J. Piesse, and C. Thirtle (2001),
"Can Gm-Technologies Help the Poor? The Efficiency of Bt Cotton Adopters in the Makhathini Flats of Kwazulu-Natal." Paper presented at the ISNAR Consultation "Biotechnology and Rural Livelihood — Enhancing the Benefits," The Hague.

Clark, E. A. (1998),
"Environmental Risks of Genetic Engineering in Field Crops." Paper presented to the NAEC workshop "Factoring in the Environment for Decisions on Biotechnology in Agricultural Production," Ottawa, Canada.

Cohen, J.I. (2001),
"Harnessing Biotechnology for the Poor: Challenges Ahead for Capacity, Safety and Public Investment". Journal of Human Development. Volume 2, No. 2.

Cohen, J.I. (ed.) (1999),
*Managing Agricultural Biotechnology*. CABI, UK.

Cohen, J.I. and R. Paarlberg, (2002),
"Explaining Restricted Approval and Availability of GM Crops in Developing Countries". AgBiotechNet, Vol. 4, ABN 097.

Commission of the European Communities (2002),
"Economic Impacts of Genetically Modified Crops on the Agri-Food Sector: A First Review." Working Document Rev. 2. Directorate General Agriculture.

Conway, G. (1997),
*The Doubly Green Revolution: Food for all in the 21st Century*. Penguin Books, UK.

Davis, G.C. and M.C. Espinoza (1998),
"A Unified Approach to Sensitivity Analysis in Equilibrium Displacement Models." *American Journal of Agricultural Economics*. 80(November 1998):868-79.

Demont, M. and E. Tollens (2001),
"Uncertainties of Estimating the Welfare Effects of Agricultural Biotechnologies in the European Union". *Working Paper Number 58*, Department of Agricultural and Environmental Economics, Katholieke Universiteit Leuven.

Douthwaite, B. (2001),
*Enabling Innovation. A Practical Guide to Understand and Fostering Technological Change*. London, Zed Books Ltd.

Doyle, J. (1985),
Altered Harvest. New York, New York: Viking Press.

Dryburgh, C. R. and C. J. Doyle. (1995),
"Distribution of Research Gains under Different Market Structure: The Impact of Technological Change within the U.K. Dairy Industry." *Journal of Agricultural Economics*. 46(January 1995):80-96.

Duffy, M. (2001),
"Who Benefits from Biotechnology". Paper presented at the American Seed Trade Association meeting, Chicago, Illinois, USA.

Duffy, M. (2002),
"Study Shows No Economic Advantage for Iowa Farmers to Plant GMO Crops." Article extracted from the Internet July 31, 2002. http://www.leopold.iastate.edu/newsletter/2001-4leoletter/gmo.html

Dunn, W.N. (2001),
*Public Policy Analysis: An Introduction*. Prentice Hall, 2$^{nd}$ ed.

Dyson, T. (1999),
*World food trends and prospects to 2025*. *PNAS* 96: 5929-5936.

Edge, J. M., J. H. Benedict, J. P. Carroll, and H. K. Reding (2001),
"Bollgard Cotton: An Assessment of Global, Economic, Environmental and Social Benefits." *Journal of Cotton Science*. 5: 121-136.

Falck-Zepeda, J. B., J. Cohen, R. Meinzen-Dick, and J. Komen.
In Press. “Biotechnology and Sustainable Livelihoods – An International Consultation’s Findings and Recommendations”. Forthcoming ISNAR Briefing Paper.

Falck-Zepeda, J. B., G. Traxler and R. G. Nelson (2001),
“Cotton GMO adoption and Private Profitability.” In *Genetically Modified Organisms in Agriculture-Economics and Politics*. G. Nelson ed. Academic Press, London, U.K.

Falck-Zepeda, J. B., G. Traxler and R. G. Nelson (2000a),
“Surplus Distribution from the Introduction of a Biotechnology Innovation.” American Journal of Agricultural Economics. 82 (May 2000):360-369.

Falck-Zepeda, J. B., G. Traxler and R. G. Nelson (2000b),
“Rent Creation and Distribution From Biotechnology Innovations: The Case of Bt Cotton and Herbicide-Tolerant Soybeans in 1997.” *Agribusiness*. February 2000.

Falck-Zepeda, J. B., G. Traxler and R. G. Nelson (1999),
“Rent Creation and Distribution from the First Three Years of Planting Bt Cotton.”. *ISAAA Briefs* No.13. ISAAA: Ithaca, N.Y. 18 pp.

FAO (2000),
“Agriculture: Towards 2015/30, Technical Interim Report.” Economics and Social Department Interim Report.

FAO (2001),
“The State of Food Insecurity in World, 2001.” Food and Agriculture Organization of the United Nations, Rome.

Gressel, J. (1996),
“Plant Biotechnology Can Quickly Offer Solutions to Hunger in Africa.” *The Scientist*. 10:10-14.

Herrera-Estrella, L. (1999),
*Transgenic plants for tropical regions: Some considerations about their development and their transfer to the small farmer*. Proceedings National Academy of Sciences. 93: 5978-5981.

Ho, M. W. (1999),
*Genetic Engineering Dream or Nightmare? Turning the Tide on the Brave New World of Bad Science and Big Business*, 2nd ed. Dublin: Gateway, Gill & Macmillan.

Huang, J., R. Hu, C. Pray, F. Qiao, and S. Rozelle (2001),
“Biotechnology as an Alternative to Chemical Pesticides: A Case Study of Bt Cotton in China.” Paper presented at the ISNAR Consultation “Biotechnology and Rural Livelihood — Enhancing the Benefits,” The Hague.

Huang, J., S. Rozelle, C. Pray and Q. Wang (2002),
“Plant biotechnology in China”. *Science*, 295: 674-677.

Huang, J., Q. Wang, Y. Zhang and J.B. Falck-Zepeda (2001),
“Agricultural biotechnology research indicators in China”. ISNAR Briefing Paper No. 01-5.

IAEG (Impact Assessment Group) (2000),
“Impact Assessment of Agricultural Research: Context and State of the Art.” Consultative Group on International Agricultural Research (CGIAR), TAC Secretariat, FAO Rome.

IFPRI International Food Policy Research Institute (2000),
“Impact of Agricultural Research on Poverty Reduction: An Integrated Economic and Social Analysis”. Proposal Prepared on behalf of the IAEG/SPIA by IFPRI.

Just, R. E. and W. S. Chern (1980),
“Tomatoes, Technology and Oligopsony.” *Bell Journal of Economics.* 11(Autumn 1980):584-602.

Just, R.E., D. L. Hueth, and A. Schmitz (1982),
“Applied Welfare Economics and Public Policy.” Englewood Cliffs, New Jersey: Prentice Hall.

Kay, R.D. and W. Edwards (1994),
“Farm Management.” 3rd Ed, McGraw Hill. New York.

Kaeppler, H. (2000),
“Food safety assessment of genetically modified crops”. *Agronomy Journal* 92:793-797

Kerr, J. and S. Kolavalli
“Impact of Agricultural Research on Poverty: Conceptual Framework with Illustrations from the Recent Literature.” Environment and Production Technology Division and Food Consumption and Nutrition Division, Research Paper 56, International Food Policy Research Institute.

Kishore, G. M. and C. Shewmaker (1999),
*Biotechnology: Enhancing human nutrition in developing and developed world.* Proceedings National Academy of Sciences, United States of America. Vol. 93: 5968-5972.

Kloppenburg, J.R. (1988),
*First the seed: The Political Economy of Plant Biotechnology*, 1492-2000. Cambridge, England: Cambridge University Press.

LaPlante, J. M. and T. R. Durham. *An Introduction to Benefit-Cost Analysis for Evaluating Public Expenditure Alternatives.*

Lindner, R.K. and F.G. Jarret. (1978),
“ Supply Benefits and the Size of Research Benefits.” *American Journal of Agricultural Economics*. 60(February 1978):48-58.

Losey, J.E., L.S. Rayor, and M.E. Carter (1999),
“Transgenic pollen harms monarch larvae”. *Nature* 399: 214.

Maredia, M., D. Byerlee, and J. Anderson
“Ex Post Evaluation of Economic Impacts of Agricultural Research Programs: A Tour of Good Practice.” Paper presented at the Workshop “The Future of Impact Assessment in CGIAR: Needs, Constraints, and Options”. Standing Panel on Impact Assessment (SPIA) to the Technical Advisory Committee, Rome, 3-5 May.

Marra, M.C., P.G. Pardey, and J.M. Alston
“The Payoffs to Agricultural Biotechnology: An Assessment of the Evidence.” *EPTD Discussion Paper No. 87*. IFPRI, Washington, D.C.

Moschini, G. and H. Lapan
"Intellectual Property Rights and the Welfare Effects on Agricultural R&D." *American Journal of Agricultural Economics.* 79(November 1997b):1229-1242.

Meinzen-Dick. R. S. (2001),
"Measuring the Livelihood Impact of Agricultural Research." Paper presented at the ISNAR Consultation Biotechnology and Rural Livelihood – Enhancing the Benefits.

Miller, G. Y., J. M. Rosenblatt, and L. J. Hushak (1988),
"The Effects of Supply Shifts on Producers' Surplus." *American Journal of Agricultural Economics*. 4 (November 1988):886-891.

Mnyulwa, D. (2001),
"The Sweet Potato Case Study in Zimbabwe." Paper presented at the ISNAR Consultation Biotechnology and Rural Livelihood – Enhancing the Benefits, June 25-28, 2001.

Moore-Lappé, F. J. Collins, P. Rosset, L. Esparza (1998),
*12 Myths About Hunger based on World Hunger: 12 Myths*. 2nd Edition, Grove/Atlantic and Food First Books.

Muth, R. F. (1964)
"The Derived Demand Curve for a Productive Factor and the Industry Supply Curve." *Oxford Economics Papers*. 16 :221-34.

National Academy Of Sciences of the United States (2000),
"Transgenic Plants and World Agriculture." Washington, DC: National Academy Press.

OECD (1999),
"Modern Biotechnology and the OECD." OECD Policy Brief, June 1999. *OECD Observer*.

Paarlberg, R. L. (2000),
"Governing the GM Crop Revolution." *Food, Agriculture and Environment Discussion Paper 33*, IFPRI.

Paarlberg, R. L. (2002),
"The Real Threat to GM Crops in Poor Countries: Consumer and Policy Resistance to GM foods in Rich Countries." *Food Policy*. Article in press.

Pachico, D., Z. Escobar, L. Rivas, V. Gottret, and S. Perez (2001),
"Income and Employment Effects of Transgenic Herbicide Resistant Cassava in Colombia: A Preliminary Simulation." Paper presented at the 2001 International Consortium on Agricultural Biotechnology Research (ICABR), Ravello (Italy), from June 15 to 18, 2001.

Perry, S. (2001),
"Participatory Biotechnology Plantain Programme for Small Farmers in Colombia." Paper presented at the ISNAR Consultation Biotechnology and Rural Livelihood – Enhancing the Benefits, June 25-28.

Pew Initiative for Biotechnology (2001),
Harvest on the Horizon: Future Uses of Agricultural Biotechnology, Washington DC.

Pinstrup-Andersen, P., N. Ruiz de Londoño, and E. Hoover (1976),
"The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Research and Policy." *American Journal of Agricultural Economics*. 58:131-42.

Pinstrup-Anderson, P., R. Pandya-Lorch, and M. W. Rosegrant (1999)
"World Food Prospects: Critical Issues for the Early Twenty-First Century". *2020 Vision Food Policy Report*. Washington DC, IFPRI.

Qaim, M. (1999a),
"The Economics of Genetically Modified Orphan Commodities: Projections for Sweet potato in Kenya." *ISAAA Briefs* N0. 13 International Service for the Acquisition of Agri-Biotech Applications, Ithaca, NY.

Qaim, M. (1999b),
"Potential Benefits of Agricultural Biotechnology: An Example from the Mexican Potato Sector." *Review of Agricultural Economics*. 21(2): 390-408.

Rose, R. N. (1980),
"Supply Shifts and Research Benefits: Comment." *American Journal of Agricultural Economics*. 62(November 1980): 834-40.

Royal Society of the United Kingdom (2002),
"Genetically Modified Plants for Food Use and Human Health- An Update." The Royal Society of the United Kingdom Policy Document 4/02.

Scott, G. J. (1995),
*Prices, Products and People: Analyzing Agricultural Markets in Developing Countries*. Lynne Rienner Publishers, Inc., Boulder: Colorado, United States of America.

Shelton, A. M., J. –Z. Zhao, and R.T. Roush (2002),
"Economic, Ecological, Food Safety, and Social Consequences of the Deployment of Bt Transgenic Plants." *Annual Review of Entomology*. 47:845-81.

Shiva, V. (2000),
*Tomorrow's Biodiversity (Prospects for Tomorrow).* London: Thames & Hudson.

Tripp, R. (2000),
"Can Biotechnology Reach the Poor? The Adequacy of Seed and Information Delivery." Paper presented at the 4th International Conference on the "Economics of Agricultural Biotechnology" Ravello (Italy), from August 24 to 28, 2000.

Thompson, L. (2000),
Are bio-engineered foods safe? FDA Consumer (http://www.fda.gov/fdac/features/2000/100_bio.html)

Traxler, G., S. Godoy-Avila, J. B. Falck-Zepeda, and J. de J. Espinoza-Arellano (2001),
"The Impact of Bt Cotton in Mexico." Paper presented at ISNAR Consultation "Biotechnology and Rural Livelihood - Enhancing the Benefits," The Hague, June 2001.

Ulrich, A., H. Furtan, and A. Schmitz (1986),
"Public and Private Returns From Joint Venture Research: An Example From Agriculture." *Quarterly Journal of Economics*. 51(1986):103-129.

United Nations (1999),
"World Population Prospects: The 1998 Revision", New York.

Voon and Edwards (1991),
"The Calculation of Research Benefits with Linear and Nonlinear Specifications of Demand and Supply Functions." *American Journal of Agricultural Economics*. 73:415-20.

Weimer, D. L. and A. R. Vining (1998),
*Policy Analysis: Concepts and Practice*. Prentice Hall. 3rd ed.