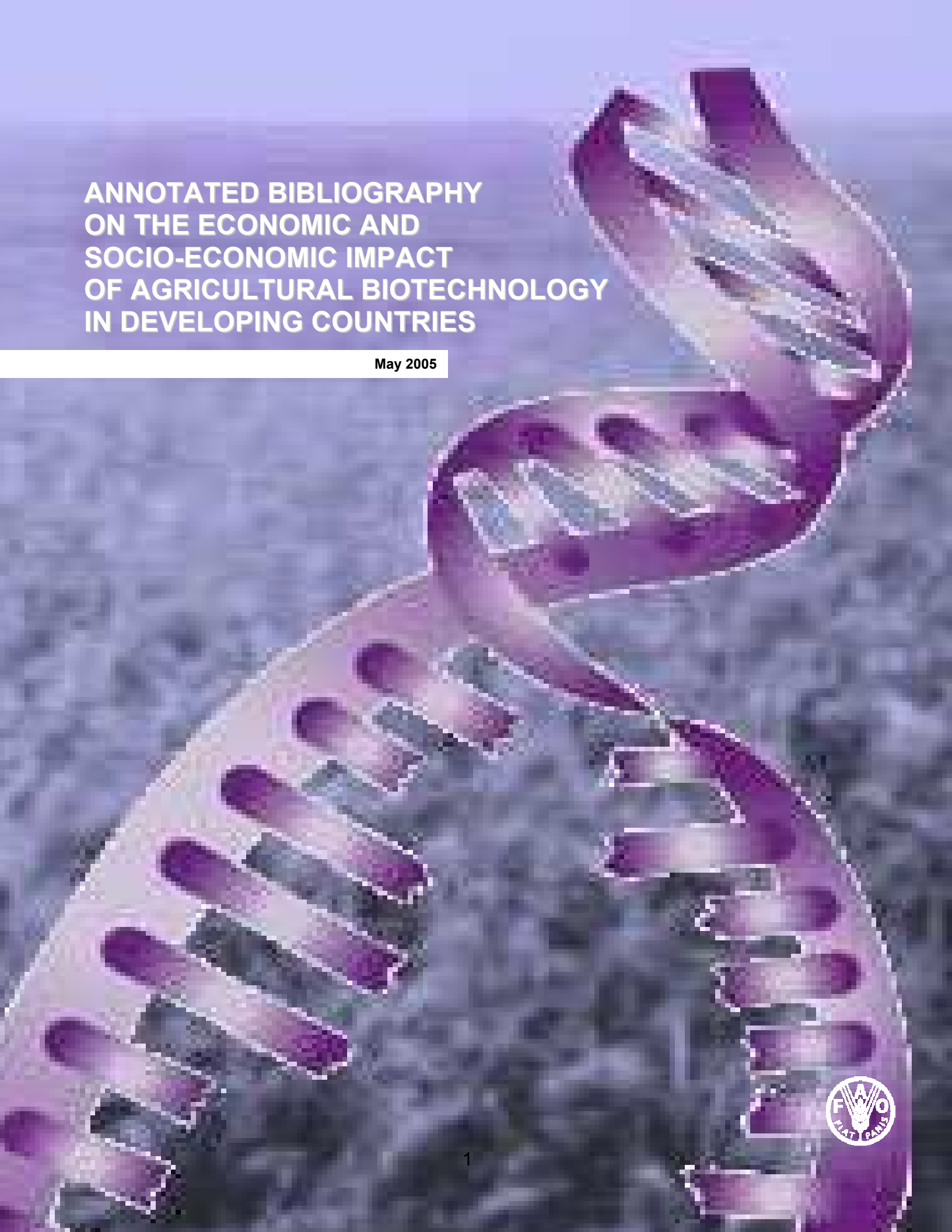

# ANNOTATED BIBLIOGRAPHY ON THE ECONOMIC AND SOCIO-ECONOMIC IMPACT OF AGRICULTURAL BIOTECHNOLOGY IN DEVELOPING COUNTRIES

May 2005

## Background

Assessment of the economic, social and environmental impact of new technologies, such as those used in agricultural biotechnology, is crucially important for both researchers and policy-makers. Impact studies can help policy-makers identify the most effective and cost-effective strategy to tackle specific social and economic problems. At the same time, impact assessments can help scientists as well as decision-makers in governments and international organisations set priorities and efficiently allocate limited resources for agricultural research. In this manner, social benefits in terms of poverty eradication and sustainability can be maximized. Impact studies are of particular importance in agricultural biotechnology, where choices have to be made regarding whether, and how much, to invest in technologies such as genetic engineering or marker-assisted selection.

While there is a growing literature on the impact of genetically modified organisms (GMOs), there is little information available on the impact of non-GMO biotechnologies. This bibliography brings together a wide range of assessments of the economic and socio-economic impact of agricultural biotechnology (both GMO and non-GMO) in developing countries. Due to the limited availability of literature on the impact of biotechnology applications in other sectors, it focuses on crop biotechnology but also includes a small number of studies on forestry and livestock.

The studies included utilize economic, socio-economic, sociological and anthropological methodologies. Both ex ante and ex post impact assessments are covered.

The bibliography is organized as follows: The first section (I) contains important publications on methodologies for impact assessment, the second (II) is devoted to studies on non-GMO biotechnologies, and the third section (III) contains sources on GMOs. Within each section, the publications are generally listed by year of publication. In order to keep similar publications together, however, this order is not strictly followed. An index at the end of the document allows to search for publications by author, crop, country and keyword.

*Comments* on this bibliography are very much welcome, as well as suggestions for new references. Please send your input to SDRR-portal@fao.org.

## Acknowledgements

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**Table of contents**

## I. Methodologies for impact assessment

*Scatasta, S./Wesseler, J. (2004), A Critical Assessment of Methods for Analysis of Environmental and Economic Cost and Benefits of Genetically Modified Crops in a Survey of Existing Literature, Paper presented at the 8th conference of the International Consortium on Agricultural Biotechnology Research (ICABR) on "Agricultural Biotechnology: International Trade and Domestic Production", held at Ravello (Italy), July 8 – 11, 2004*
*(http://www.economia.uniroma2.it/conferenze/icabr2004/papers/Scatasta%20.zip)*

This paper is a review of existing literature and contributes to the ongoing discussion about environmental and economic costs and benefits of genetically modified (GM) crops by focusing on methodological issues arising from this literature. The authors focus on the production function framework commonly used to quantify costs and benefits of GM crops at farm level and on equilibrium displacement models used to quantify impacts of GM crops on social welfare. Methods are discussed in the context of uncertainty and irreversibility associated to costs and benefits of GM crops.

*Babu, S.C./Rhoe, V.D. (2003), Assessing Agricultural Biotechnology: Applications of Ex-ante and Ex-post Methods to Genetically Modified Crops, Asian Biotechnology and Development Review 5 (July 2003): 1-22*
*(http://www.agr.kuleuven.ac.be/aee/clo/euwab_files/Babu2003.pdf)*

The paper reviews the literature on the impact of biotechnology in developing and developed countries. Different approaches for conducting ex-ante and ex-post impact assessments are presented. Whenever possible, the authors give an example of the method being applied to a genetically modified crop. Before delving into the different methodologies, a conceptual framework for assessing the economic impact of crop biotechnology is presented. The importance of assessing the economic impact of adopting this technology is then explored. After understanding why economic assessment is essential, the various *ex-ante* and *ex-post* assessment methods are reviewed. Each methodology description explains how the assessment can be adapted to biotechnology products and what data is needed to undertake such an assessment. If an agricultural biotechnology case study is available, it is included with the explanation. Learning the different methods is only the first step in analyzing the economic impact of adopting genetically modified organisms. There are several challenges that restrict the use of these methods, which are discussed in the following paragraphs.

*Organisation for Economic Co-operation and Development (OECD) (2003), Accessing Agricultural Biotechnology in Emerging Economies, OECD Centre for Co-operation with Non-Members (CCNM), Paris, May 2003*
*(http://www.oecd.org/dataoecd/18/33/2081036.pdf)*

Part one of this report about the actual and potential use of biotechnology applications in developing, emerging and transition economies (DETEs)

discusses methods to assess the impacts of modern agricultural biotechnology. The two most widely used methods, the cost-benefit and economic surplus methods, are introduced and the literature on the impact of biotechnology in developed and developing countries is reviewed. Some methodological shortcomings of the above mentioned impact assessment methodologies as well as other methodological problems are discussed. It is argued that conventional economic impact assessment may not be broad enough to address the complex nature of a rural community in DETEs. The report introduces the sustainable livelihoods approach, which may provide a more appropriate framework to quantify and qualify the impact of biotechnologies in these countries. Part two deals with the development of and the access to biotechnology applications in DETEs. It is argued, that if theses countries are to benefit from the use of modern biotechnology in agriculture, then the key constraints within the research, technology development and delivery system need to be clearly identified and the appropriate policy measures taken. Developing and emerging economies are extremely heterogeneous in terms of their current policies on agricultural biotechnology and many lack the institutional framework needed to develop and monitor modern technologies. A country's ability to benefit from modern technologies is influenced by several factors including; its research capacity, level of investment in research, regulatory framework, especially for biosafety and IPRs in the seed sector, and a well functioning market for biotechnology inputs and products. Therefore, a typology of DETEs is proposed based on the country's ability to exploit the new technologies and a range of different policy options are outlined.

*Adato, M./Meinzen-Dick, R. (2002), Assessing the impact of agricultural research on poverty using the sustainable livelihoods framework, International Food Policy Research Institute (http://www.ifpri.org/divs/eptd/dp/papers/eptdp89.pdf)*

The paper reports on the approach used in a multi-country study of the poverty impact of research programs under the Consultative Group on International Agricultural Research (CGIAR). The studies use an expanded understanding of poverty that goes beyond income or consumption-based headcounts or severity measures, to consider many other factors that poor people in different contexts define as contributing to their vulnerability, poverty, and well-being. The sustainable livelihoods framework provides a common conceptual approach to examining the ways in which agricultural research and technologies fit (or sometimes do not fit) into the livelihood strategies of households or individuals with different types of assets and other resources, strategies that often involve multiple activities undertaken at different times of the year. Applying this framework requires interdisciplinary research and a combination of quantitative and qualitative methods. The paper reports on the conceptual framework, methods, and findings to date of these studies. The paper provides an overview of the sustainable livelihoods approach, how it can be applied to agricultural research, and describes detailed methods and results from five case studies: (1) modern rice varieties in Bangladesh; (2) polyculture fishponds and vegetable

gardens in Bangladesh; (3) soil fertility management practices in Kenya; (4) hybrid maize in Zimbabwe; and (5) creolized maize varieties in Mexico.

*Quaim, M./V. Braun, J. (1998), Crop Biotechnology in Developing Countries: A Conceptual Framework for Ex Ante Economic Analyses, ZEF Discussion Papers on Development Policy No. 3, Center for Development Research, Bonn, November 1998 (http://www.zef.de/download/zef_dp/zef_dp3-98.pdf)*

This paper provides a conceptual framework for ex ante economic studies in developing countries – a framework within which the efficiency and equity implications of specific technologies can be analyzed quantitatively. Technological impacts also depend on institutional arrangements and on political support systems, dynamics that are explicitly taken into account by the proposed scenario approach. The findings of such analyses can such provide assistance in political decision-making at various phases of the technology path.

*Mills, B.F. (1998), Agricultural Research Priority Setting: Information Investments for the Improved Use of Research Resources, The Hague/Netherlands: International Service for National Agricultural Research (http://www.isnar.cgiar.org/publications/pdf/mills98.pdf)*

Managers face a number of practical issues in designing procedures for agricultural research priority setting: Who will set priorities? What skills or tools do they need? Similarly, socio-economists and others who implement priority-setting processes need concrete advice on how to undertake each step. This book addresses issues of process design and implementation. It leads readers through the major steps and questions involved in setting program-level priorities in agricultural research organizations. The approaches introduced include spatial analysis for exploring both the local relevance and broad applicability of research alternatives, needs assessment and economic methods for evaluating different research options. Examples from the Kenya Agricultural Research Institute (KARI) illustrate applications of the methods and issues discussed. Exercises, some using the spreadsheets that are included on an enclosed computer diskette, provide readers with hands-on experience in doing some of the calculations.

*Alston, J./Norton, G.W./Pardey, P. (1995), Science under Scarcity: Principles and practice for agricultural research evaluation and priority setting, Cornell University Press, Ithaca/NY (USA)*

This often cited book provides a guide to the theory and methods necessary for evaluating agricultural research and for setting priorities for resource allocation. It reviews, synthesizes and extends such methods as economic surplus analysis, econometric techniques, mathematical programming procedures, and scoring models. It discusses these practices in the context of scientific policy, describes their conceptual foundations and explains how to undertake such methods to evaluate agricultural research and assist in research priority setting. One of the methods detailed by the authors is the Dynamic Research Evaluation for

Management (DREAM) economic surplus model used by the International Food Policy Research Institute (IFPRI).

## II. Impact of Non-GMO Biotechnologies in Developing Countries

### 1. Developing Countries in General

#### a) Reproductive cell biology techniques

*Jones, M. (2004), From Asia to Africa. Nerica fighting Africa's war against poverty and hunger, Paper presented at the International Year of Rice & World Food Prize Celebration, October 14–15 2004, Des Moines, Iowa, USA (http://www.worldfoodprize.org/Symposium/04presentations/jones.pdf)*

New Rice for Africa (Nerica) is a new type of rice that combines the best traits of African rice (Oryza glaberrima) and Asian Rice (Oryza sativa). It resulted from the wide hybridization of these two species for which embryo-rescue and anther culture have been used. In this speech Jones talks about the history and the qualities of Nerica and summarizes the efforts that are being made to disseminate Nerica varieties in different African countries. Some figures of its current and future adoption and its likely economic impact in terms of saved rice imports are given.

*Harsch, E. (2004), Farmers embrace African 'miracle' rice high-yielding 'Nerica' varieties to combat hunger and rural poverty, in: Africa Recovery, Vol. 17, No. 4, p. 10-22 (http://www.un.org/ecosocdev/geninfo/afrec/vol17no4/174rice.htm)*

The article explains what Nerica (New Rice for Africa) is (including it virtues like higher yields, improved nutritional quality, weed competitiveness and early maturity) and discusses its potential impact in West Africa and beyond. It states that by mid-2003, Nerica varieties were grown in 12 (mainly West) African countries and give some anecdotal evidence on its current impact, including gender issues. The author further talks about estimations of the future impact of these varieties, which are promoted by the African Rice Initiative.

*Africa Rice Center (WARDA) (2003), Assessing the Impact of Nerica Rice Varieties: Not Just Surveys and Simple Mathematics, in: WARDA, Annual Report 2002-03 (http://www.warda.cgiar.org/publications/AR2002-03/assessing%20the%20impact.pdf)*

This chapter of WARDA's annual report raises some methodological question about how to conduct an impact assessment. It only contains limited information on the current impact of Nerica varieties, which is mainly due to the fact that Nerica has first been grown only in 1996 (in the framework of research activities) and that there is a time-lag between development of a variety, its release and subsequent wide-scale adoption. The paper concentrates on actual and future adoption rates and argues that the market share of Nerica varieties will sharply rise in the next years.

**b) Marker-assisted selection**

*Leung, H./Wu, J./Liu, B./Bustaman, M./Sridhar, R./Singh, K./Redona, E./Quang, V.D./Zheng, K./Bernardo, M./Wang, G./Leach, J./Choi, I.R./Vera Cruz, C. (2004), Sustainable disease resistance in rice: current and future strategies, Paper presented at the 4th international crop science congress held in Brisbane, Australia, 26 September – 1 October 2004*
*(http://www.regional.org.au/au/cs/2004/symposia/3/7/1022_leungh.htm)*

Through the Asian Rice Biotechnology Network, marker-aided analyses of pathogens and host plant resistance have been practiced by several national breeding programs resulting in the production of elite or commercial lines with multiple disease resistance genes. A unique feature of ARBN is the continuing effort to capture new findings from host-pathogen interaction research and apply them in breeding. This network approach is essential for sharing resources and providing sustained training in the adoption of tools and genetic knowledge in individual breeding programs. Several studies have demonstrated the successful application of candidate genes selection for enhancing blast and bacterial blight resistance in breeding lines and varieties. This paper gives examples of improved varieties that have been developed using marker-assisted selection. Some information on their adoption and agronomic impact is presented. The authors argue that advances in genomic research will provide new approaches to determine the relationship between genetic variation, disease resistance phenotypes and performance in the field. The prospects for achieving sustainable disease control in Asia are therefore judged to be good provided that breeding programs are enabled to access and apply tools to address local problems.

*Dreher, K./Khairallah, M./Ribaut, J.-M./Morris, M. (2003), Money matters (I): costs of field and laboratory procedures associated with conventional and marker-assisted maize breeding at CIMMYT, Molecular Breeding, Vol. 11, No. 3, p. 221-234*

This article presents selected results of a study that was carried out in Mexico at the International Maize and Wheat Improvement Center (CIMMYT) and compares the cost-effectiveness of conventional and marker-assisted maize breeding. Costs associated with the use of conventional and marker-assisted selection (MAS) methods were estimated using a spreadsheet-based budgeting approach. This information was used to compare the cost of using conventional screening and MAS to achieve a well-defined breeding objective - identification of plants carrying a mutant recessive form of the opaque2 gene in maize that is associated with Quality Protein Maize (QPM). In addition to generating empirical cost information that will be of use to CIMMYT research managers, the study produced four important insights. First, for any given breeding project, detailed budget analysis will be needed to determine the cost-effectiveness of MAS relative to conventional selection. Second, direct comparisons of unit costs for MAS methods and conventional selection methods provide useful information for research managers, but factors other than cost are likely to play an important role

in driving the choice of screening methods. Third, the choice between MAS and conventional selection may be complicated by the fact that the two are not always direct substitutes. Fourth, when used with empirical data from actual breeding programs, spreadsheet-based budgeting tools can be used by research managers to improve the efficiency of existing protocols and to inform decisions about future technology choices.

*Morris, M./Dreher, K./Ribaut, J.-M./Khairallah, M. (2003), Money matters (II): costs of maize inbred line conversion schemes at CIMMYT using conventional and marker-assisted selection, Molecular Breeding, 2003, Vol. 11, No. 3, p. 235-247*

This article presents selected results of a study carried out in Mexico at the International Maize and Wheat Improvement Center (CIMMYT) to compare the cost-effectiveness of conventional and biotechnology-assisted maize breeding. Costs associated with the use of conventional and marker-assisted selection (MAS) methods at CIMMYT were estimated using a spreadsheet-based budgeting approach. This information was used to compare the costs of conventional and MAS methods for a particular breeding application: introgressing an elite allele at a single dominant gene into an elite maize line (line conversion). At CIMMYT, neither method shows clear superiority in terms of both cost and speed: conventional breeding schemes are less expensive, but MAS-based breeding schemes can be completed in less time. For applications involving tradeoffs between time and money, relative profitability can be evaluated using conventional investment theory. Using a simple model of a plant breeding program, we show that the optimal choice of a breeding technology depends on the availability of operating capital. If operating capital is abundantly available, the "best" breeding method will be the one that maximizes the net present value (i.e., MAS), but if operating capital is constrained, the "best" breeding method will be the one that maximizes the internal rate of return (i.e., conventional selection). This insight may help to explain why private firms tend to invest more aggressively in biotechnology than public breeding programs, which are more likely to face budgetary constraints.

*Dreher, K./Morris, M./Khairallah, M./Ribaut, J.-M./Pandey, S./Srinivasan, G. (2002), Is marker-assisted selection cost-effective compared with conventional plant breeding methods? The case of quality protein Maize, in: Evenson, R./Santaniello, V./Zilberman, D. (eds.), Economic and social issues in agricultural biotechnology, Wallingford/UK, p. 203-236*

This chapter presents the findings of a case study designed to compare the cost of using conventional plant breeding methods with the cost of using a new DNA-based crop selection technique known as marker-assisted selection (MAS). The case study, which was carried out in Mexico at the International Maize and Wheat Improvement Centre (CIMMYT), focused on a narrowly defined breeding objective - transferring the quality protein maize (QPM) phenotype, controlled primarily by a mutant allele of a gene called opaque2, from one elite maize inbred line to another elite inbred line. Costs associated with use of conventional breeding methods and

MAS for QPM line conversion were estimated using a spreadsheet-based budgeting approach. First, field and laboratory operations involved in conventional and MAS breeding were identified and costed out. Second, representative conventional and MAS breeding schemes were identified. Third, the unique laboratory and field parameters set forth in each breeding scheme were used to calculate the total cost of implementing that particular scheme. Results of the budgeting exercise suggest that currently at CIMMYT, the relative cost-effectiveness of conventional breeding methods as compared to MAS for QPM line conversion differs depending on the circumstances. In cases where it is possible to identify segregating materials by visually inspecting ears in the field, conventional breeding methods can be very cost-effective, but in cases where visual selection is not possible, use of molecular markers can lead to significant cost savings. CIMMYT's experience with MAS parallels the experience of many other breeding programmes. Even though MAS has come to play a prominent role in the field of plant breeding, for many practical applications the economics of MAS are still being worked out on a case-by-case basis. The continuing uncertainty concerning the utility of MAS in specific applications should not give rise to undue pessimism, however. Everything that made MAS attractive in the first place still holds true; the key to successfully integrating the technology into applied breeding programmes will lie in identifying applications in which molecular markers offer real advantages over conventional breeding methods. MAS should be able to offer significant advantages in cases where phenotypic screening is particularly expensive or difficult, including breeding projects involving multiple genes, recessive genes, late expression of the trait of interest, seasonal considerations or geographical considerations. In addition to reducing the cost of breeding, MAS also has the potential to generate time savings. Depending on the benefits that a breeding programme realizes from earlier release of its breeding products (which typically differ between the private and public sectors), the value of these time savings can be enormous - often justifying the additional cost involved in using MAS. Continuing refinement of molecular marker technologies will make MAS cheaper and more effective in coming years, but at the same time it would be a mistake to assume that marker technologies represent a 'silver bullet' solution to every breeding problem. As this case study has revealed, conventional breeding methods still provide a cost-effective option for many types of breeding project, and they will continue to be attractive for many years to come.

*Ribaut, J.-M./Bänziger, M./Betran, J./Jinang, C./Edmeades, G.O./Dreher, K./Hoisington, D. (2002), Use of molecular markers in plant breeding: drought tolerance improvement in tropical maize, in: Kang, M.S. (ed.), Quantitative Genetics, Genomics and Plant Breeding, Wallingford, UK: CABI International; p. 85-99*

CIMMYT is working since 1994 with marker assisted selection (MAS). Although the work that they illustrate has been successful, they enumerate the lessons learned and the limitations of the MAS approach in improving drought tolerance in maize. They provide an estimate of the cost of applying MAS in a breeding program, a relative rarity in the literature. This information is sobering in light of the levels of research funding in developing countries and international research

centers alike. The authors also provide an indication of future plans to overcome this and other limitations.

*Morris, M./Ribaut, J.-M./Khairallah, M./Dreher, K. (2001), Potential Impacts of Biotechnology-Assisted Selection on Plant Breeding Programs in Developing Countries, in: Pardey, Philip (ed.), The Future of Food, Biotechnology Markets and Policies in an International Setting, Washington, DC/Baltimore, Maryland*

Michael Morris and colleagues assess the economics of biotechnology-assisted plant breeding programs, particularly those in developing countries. They focus on marker-assisted selection methods. The private sector makes extensive use of these techniques in their crop breeding work; less is done in the public domain, partly because of the costs involved. Decisions to invest in them involve economic choices, typically trading off increased costs (compared with conventional breeding techniques) against the benefits from speeding up the breeding cycle or spinning off new findings. The economic choices involved rely on empirical results; thus Morris et al. use an analysis of marker-assisted selection methods in maize breeding at the International Maize and Wheat Improvement Center (CIMMYT) to illustrate the issues involved. They also provide an assessment of the future, both in terms of marker technologies and their potential impacts on breeding programs worldwide, giving guidance to developing countries faced with using their scarce research resources wisely in light of these new crop-improvement possibilities.

### c) Selected livestock biotechnologies

*Rege, J.E.O. (2003), Agricultural Biotechnology: A menace or pathway to sustainable livelihoods in developing countries?, Paper presented at the conference Deutscher Tropentag 2003 on International Research on Food Security, Natural Resource Management and Rural Development at the University of Göttingen (Germany), October 8-10, 2003*
*(http://www.tropentag.de/2003/abstracts/full/425.pdf)*

The paper focuses on the relevance of biotechnology for Africa and includes a case study on the introduction of a new East Coast Fever (ECF) vaccine in Africa. It reports about an ex ante impact analysis for different production systems afflicted by ECF and gives information on the probable cost benefit ratios of the development of the new vaccine.

*Falconi, C.A./Omamob, S.W./D'Ieteren, G./Iraqi, F. (2001), An ex ante economic and policy analysis of research on genetic resistance to livestock disease: trypanosomosis in Africa, Agricultural Economics, Vol. 25, Issue 2-3, p. 153–163*

The article undertakes an ex ante economic analysis of research on how resistance to trypanosomosis—a dominant livestock disease in Africa—can be maintained and enhanced while retaining and reinforcing characteristics of economic importance to farmers, and on how 'trypanotolerance' can be imparted to susceptible animals while retaining their other important traits. The authors estimate the distribution of estimated welfare impacts between producers and

consumers, and across two research target zones (East and Southern Africa, West and Central Africa), and under four scenarios of technology development, release, and uptake. The results indicate that potential benefits to research — historically field-based but increasingly biotechnology-driven — range from two to nine times potential costs and that the internal rate of return on investments can be six times the real interest rate. Field-based research, while exhibiting lower potential benefits on aggregate than does biotechnology research (marker-assisted selection), is also less costly and, because of its more immediate payback, has higher internal rates of return. Returns to biotechnology research hinge on close links with field-based research and on strategic but relatively small incremental human and capital investments. The results also suggest that further research is needed to consistently identify and track the impacts of alternative intellectual property rights (IPRs) options on the levels and distributions of biotechnology research benefits.

*Tambi, E./Maina, O./Mukhebi, A./Randolph, T. (1999), Economic impact assessment of rinderpest control in Africa, Scientific and Technical Revue (OIE – World Organisation for Animal Health), Vol. 18 (2), August, p. 458-77*

The authors assess the economic impact of the Pan-African Rinderpest Campaign (PARC) which resulted in the development of a tissue culture attenuated vaccine for the control and eradication of rinderpest. From among the thirty-five countries that participated in PARC, ten countries were selected for the analysis, based on data availability. The three following key socio-economic issues were addressed: cost-effectiveness, returns to investment and the welfare gains of the intervention. The standard cost-benefit approach based on a computer spreadsheet model was used to assess the economic impact of rinderpest control. Benefits of the intervention consisted of increased revenue due to avoided production losses. Estimates of the value of production losses were obtained under both 'with PARC' and 'without PARC' scenarios and the incremental benefits were derived as the difference between the two scenarios. In addition, an economic surplus model was used to assess the distribution of welfare effects generated by the intervention. Analysis of funding for the national campaigns showed roughly equal commitment to the programme by national governments and the principal donor, the European Union. Examination of the implementation costs in the ten countries indicated that with the exception of one country, PARC was implemented in a cost-effective manner with average costs appearing within a relatively narrow range. The figures obtained in ECU (European currency units) were between ECU 0.27 and ECU 0.60 per head of cattle vaccinated. The estimated average return from the ten countries (ECU1.8 for each ECU invested in the campaign) demonstrates that based on the sample of countries, rinderpest control in Africa has been economically profitable. In each of the ten countries, estimated benefits at least covered the value of the investment in PARC. The programme has provided a total net present value of ECU 29 million for the ten countries, suggesting that the implementation of PARC has been a wise public investment decision. Analysis of the distribution of the welfare gains from PARC revealed that producers derived the greater share of the ECU 58 million in net value of production losses avoided due to rinderpest control in the ten countries.

Consumer gains accounted for approximately one-fifth of the total, due to lower prices from increased supplies.

### d) Different biotechnologies

*Qaim, M. (2000), Potential Impacts of Crop Biotechnology in Developing Countries, Peter Lang Verlag, Frankfurt/Germany*

In his PhD thesis, Qaim applies an analytical framework for the *ex ante* evaluation of the introduction of biotechnological innovations in smallholder agriculture. He conducts three case studies in Kenya and Mexico. These are the use of transgenic potatoes in Mexico, the use of tissue culture banana plantlets in Kenya and the introduction of genetically modified sweet potatoes in Kenya. The author analyzes the distributional effects for different groups of farmers and estimates the welfare effects for producers and consumers. In the analysis of the welfare effects, Qaim develops different scenarios to show how political intervention like subsidies can help to maximize the welfare effects of the use of biotechnological innovations. It is shown that biotechnology holds great potential for poor agricultural producers and consumers. Yet appropriate institutional adjustments are required to capitalize on these potentials. Implications for national and international biotechnology policies are discussed.

*Qaim, M./Virchow, D. (2000), The Role of Biotechnology for Global Food Security, Agrarwirtschaft, Vol. 49, p. 348-356*
*(http://www.zef.de/download/articles/Biotech-MQDV_Article.pdf)*

Biotechnology per se is not a panacea for the world's problems of hunger and poverty. However, genetic engineering in particular offers outstanding potentials to increase the efficiency of crop improvement. Thus, biotechnology could enhance global food production and availability in a sustainable way. Two case studies from Kenya and Mexico also demonstrate that transgenic crops are very appropriate for agricultural producers and consumers in developing countries. As the entire technology can be packaged into the seed, it can easily be integrated into traditional smallholder farming systems. Except for a few innovative transfer projects, though, the application of biotechnology until now remains concentrated in the industrialized world. Combined with insufficient own scientific and regulatory capacities, the increasing privatization of international agricultural research and the strengthening of intellectual property rights complicate the access of developing countries to biotechnology. Profound institutional adjustments are essential to ensure that biotechnology does not bypass the poor.

*Sasson, A. (1998), Biotechnology and food production: Relevance to developing countries, in: Altman, A. (ed.), Agricultural Biotechnology, Marcel Dekker, New York, p. 691-729*

This book chapter contains information on the impact of tissue culture in China and other developing countries among others.

*Galhardi, R. (1996), Trade Implications of Biotechnology in Developing Countries: A Quantitative Assessment, Technology In Society, Vol. 18, No. 1, p. 17-40*

The effects of biotechnological advances on the employment and income of the rural labour force in developing countries may be analysed by means of estimates and scenarios. Improved varieties of crop could help increase physical output and therefore the income and employment opportunities for rural workers/producers. The results, however, are not obvious, especially for the small, poorer farmers and wage workers restricted to marginal areas in developing countries. Biotechnology developments could lead to changes in the international trade pattern by enhancing the possibilities for crop substitution, by the introduction of new plant characteristics, by changes in food processing such as improvements in the fermentation and enzymatic processes or by the industrial production of synthetic substitutes of plants or their components. The development of tropical plants tailored to meet the specific needs of processing countries' industry and consumers is likely to lead to overproduction, declining prices and economic and social instability in Third World exporting countries. The employment and income implications of such substitution depend on the quantitative significance of these displacements. A decrease in the labour force requirements may accrue even if the internal consumption and production increase at the expected rates. The replacement of export crops by a more labour-intensive production of selected basic grains may generate a net gain in employment. The net employment effects of biotechnology-induced substitution for tropical crops will depend on the alternative production activities adopted by the affected producers and workers to overcome the adverse impact and on the relative labour coefficients of the crops involved in the substitution and diversification.

## 2. Country Specific Studies

### a) Micropropagation

*Gallez, A./Runyoro, G./Mbehoma, C.B./Van den Houwe, I./Swennen, R. (2004), Rapid mass propagation and diffusion of new banana varieties among small-scale farmers in north western Tanzania, African Crop Science Journal, Vol. 12, No. 1, p. 7-17*

Since the seventies, factors such as declining soil fertility and the emergence of pests and diseases have reduced banana (Musa spp.) yields from about 10 to 4 t ha-1 in the Kagera region, North Western Tanzania, where banana is the most important staple food. Thus, clean planting materials are required to solve the problem of pests and disease infection. To this effect, new banana varieties were introduced, multiplied locally and distributed to more than 0.5 million people since 1997. The target was set to have 1 million plants of superior varieties in the farmer's fields by March 2003 which accounts to about 1.5% of the total banana population in the region. A total of 21 varieties were introduced and evaluated for their palatability and field performance by the local communities. Fourteen

varieties were multiplied In vitro. A total of 71,000 In-vitro plants were introduced in the region since 1997 and multiplied in 35 nurseries by field decapitation. These multiplication fields contain 84,000 stools and are spread over the entire region. To date 340,000 suckers have been distributed by the project and 680,000 suckers from farmer to farmer, amounting to 1,020,000 suckers. The best performing varieties are FHIA-17, FHIA-23, SH3436-9 and Yangambi. Results of an impact assessment survey show that the superior varieties outyield the local varieties by an average of 40%.

*Lusty, C./Smale, M. (eds.) (2003), Assessing the Social and Economic Impact of Improved Banana Varieties in East Africa, Proceedings of an Interdisciplinary Research Design Workshop jointly organized by the International Network for the Improvement of Banana and Plantain (INIBAP) and the International Food Policy Research Institute (IFPRI) in Kampala/Uganda, November 7-11, 2002 (http://www.ifpri.org/divs/eptd/ws/papers/eptws15.pdf)*

The report documents the discussions and results of a research design workshop held by the participants of a project that is aimed at assessing and enhancing the social and economic impact of improved banana varieties on smallholder farmers in Uganda and Tanzania. The workshop brought together economists, sociologists and agricultural scientists to discuss the design of the impact study and the practicalities of its execution. For this study, a conceptual framework is developed that integrates economics tools and sociological methods.

The contributions include a discussion of social science methods to use ex ante assessment to improve the impact of improved banana varieties on the livelihood of smallholder farmers. For the evaluation of the impact and dissemination of biotechnology applications, Melinda Smale argues for the use of a combination of simulation (i.e. by applying an economic surplus model like *Dynamic Research Evaluation for Management (DREAM)* developed by Alston et al.) and econometric findings as well as tools of sociological and anthropological analysis that are both quantitative and qualitative in nature.

Other contributions include a brief review of impact assessment studies of banana improvement in East Africa, the preliminary findings of an impact assessment of improved banana varieties in a specific region in Tanzania and information of the socio-economics of banana production and consumption in Uganda and Tanzania. The report further contains a brief discussion of the potential importance of biosafety regulations for banana breeding research and for the import and export banana of banana. A conceptual framework to help countries design and implement their own biosafety regulatory system developed by ISNAR is presented.

Additionally, an ongoing research project in Uganda is presented. It addresses the question which technologies are most likely to be adopted and by whom. This research can help banana researchers in Uganda to set research priorities. An agricultural household model that takes into account that smallholder farmers produce partly for their own consumption and partly for sale is applied. In order to properly understand the factors that are crucial for technology adoption, variety consumption and production attributes are modelled applying a household production framework. The resulting theoretically-based hypotheses about factors

influencing adoption of new banana varieties can then be tested empirically using econometric analysis.

Another ongoing study presented in the report analyzes the development of banana production in central and south-western Uganda, in particular the household response to changes in commodity and factor prices and access to off-farm employment opportunities. For this purpose, a bioeconomic model is being formulated to analyze the likely impact of selected policy instruments on banana production and soil quality/degradation. The model is based on the household production framework.

The report further contains information on a household survey that is being conducted on banana farmers in 107 communities in Uganda. This survey focuses on both socio-economic factors and the use of banana varieties. Another contribution looks at the preliminary findings of an ex ante evaluation of the potential economic costs and benefits of improved banana productivity. Using IFPRI's DREAM model, the benefits (or losses) associated with the new technology are estimated, including distributional effects on different income groups on the district and regional level. Another model used in the impact assessment is a CGE (Computational General Equilibrium) model constructed to analyze aggregate and feedback effects across commodities and sectors, including employment, wages, poverty rates, transport costs, foreign exchange and trade. Finally, the report contains an introduction to the sustainable livelihoods framework and information on what has to be borne in mind when applying the framework on banana growing farmers in East Africa.

*Mbogoh, S./Wambugu, F./Wakhusama, S. (2003), Socio-economic impact of biotechnology applications: some lessons from the pilot tissue-culture (TC) banana production project in Kenya, 1997-2002, Proceedings of the 25th International Conference of Agricultural Economists (IAAE), held in Durban, South Africa, 16-22 August 2003, p. 1084-1094*
*(http://www.ecsocman.edu.ru/images/pubs/2003/11/30/0000135584/089.pdf)*

The paper discusses the results of two socio-economic impact studies of the introduction and adoption of tissue-culture (TC) technology in banana production in Kenya. The authors argue that a prudent introduction of TC technology can make a positive contribution to the socio-economic status of resource poor farmers in Kenya. While TC-banana production is found to be relatively more capital intensive than non-TC banana production, they show that the cost-benefit ratio of using TC-plantlets is more favourable than the one for conventional banana plants. The authors also observed higher yields per unit of land of and an increase of the monthly net income of banana farmers when comparing the situation of a sample of farmers before and after adopting the new technology. The economic analysis which mainly focuses on business aspects also takes into consideration marketing aspects.

*Wambugu, F./Kiome, R. (2001), The Benefits of Biotechnology for Small-Scale Banana Farmers in Kenya*, *International Service for the Acquisition of Agri-biotech Applications (ISAAA), ISAAA Brief No. 22*
*(http://www.isaaa.org/kc/Publications/pdfs/isaaabriefs/Briefs%2022.pdf)*

The paper presents a project of ISAAA to introduce micropropagation to improve banana production in Kenya by promoting the delivery of disease-free planting material. It analyzes the impact of the introduction of the improved plantlets and a micro-credit scheme introduced to increase their adoption. The benefits to the farmers, to the wider communities and new economic possibilities offered by more regular harvests and greater quantity of fruit as well as strategies to counter adoption constraints are discussed. In the last chapter, plans for a second phase of the project are presented. This second phase aims at establishing a self-sustaining system for the production, distribution, and utilisation of tissue-culture banana plantlets, providing long-term benefits for farmers and further entrepreneurial opportunities for the private sector.

*Qaim, M. (2000), Biotechnology for small-scale farmers: a Kenyan case study, International Journal of Biotechnology, Vol. 2, No. 1-3, p. 174-188*

The paper analyses ex ante the potential economic effects of tissue culture biotechnology, which is being introduced into the Kenyan banana sector through an international collaborative project. The expected yield and income gains are sizable, because the pathogen-free banana planting material could substantially reduce the current crop losses induced by pests and diseases. However, using the technology is associated with relatively high setup costs for farmers. This might discourage innovation adoption, especially for the smallholders. Lowering the price of tissue-culture plantlets could help to avoid undesired income distribution effects among the banana growers. Furthermore, community-based initiatives for local biotechnology dissemination could ameliorate the adoption conditions. The example demonstrates the great potential of biotechnology to contribute to welfare growth in developing countries. Yet public support is needed to make sure that certain disadvantaged groups are not excluded from the benefits.

*Karembu, M./Njuguna, M. (2000), Institutional Issues in Biotechnology Applications: Concepts and Empirical Evidence from Kenya, in: Qaim, M./Krattiger, A.F./von Braun, J. (eds.), Agricultural Biotechnology in Developing Countries: Towards Optimizing the Benefits for the Poor, Kluwer Academic Publishers, Boston and Dordrecht, p. 175-188*

The paper identifies the institutional factors that have led to the successful introduction of tissue culture banana in Kenya. It states that the use of participatory approaches from the first phase of problem definition to the final phase of technology adoption – are prerequisites for optimizing biotechnology's benefits for the poor. The Kenyan case study exemplifies the value of effective partnerships between various public and private sector institutions, including community-based groups, that build on comparative advantages. Banana growers were involved at an early stage of project conceptualization to better understand their needs and constraints. In this way, they developed "ownership" of the technology early on and did not feel that the technology was being imposed to them.

*Qaim, M. (1999), Assessing the Impact of Banana Biotechnology in Kenya, International Service for the Acquisition of Agri-biotech Applications (ISAAA), (http://www.isaaa.org/kc/Publications/pdfs/isaaabriefs/Briefs%2010.pdf)*

The study is an ex-ante assessment of the potential impact of tissue culture technology in Kenyan banana production. It builds upon farm level data—as currently observed, i.e. without the widespread use of in vitro plants—and on banana experts' projections and estimates about future developments. The potential effects of TC plants are analyzed for the three different farm types. The expected aggregate welfare effects of the biotechnological progress are analyzed by means of an economic surplus model, which builds on the results from the farm-level analysis. The model is run until the year 2020. In the analysis of the welfare effects, Qaim develops different scenarios to show how political intervention like subsidies can help to maximize the welfare effects of the use of biotechnological innovations.

*Qaim, M. (1999), A Socioeconomic Outlook on Tissue Culture Technology in Kenyan Banana Production, Biotechnology and Development Monitor, No. 40, p. 18-22, article based on Qaim, Matin (1999), Assessing the Impact of Banana Biotechnology in Kenya (http://www.biotech-monitor.nl/4008.htm)*

The article deals with the socioeconomic effects of the introduction of tissue culture technology (TC) to produce pathogen-free banana plantlets in Kenya on the farm and on the market level. It projects the distributional effects on small-scale, medium-scale and large-scale farmers and concludes that adopting TC could bring about substantial yield increases for all three farm types. In relative terms, the potential gains are most pronounced for the smallholders who would also bear the highest relative cost increases associated with the TC planting material. Although the additional costs are likely to be more than offset by higher yields, the author argues that technology adoption is likely to be slower for the small-scale farmers than for the larger ones. On the basis of the farm level assessment, the study also simulates the likely effects of TC technology for the Kenyan banana sector as a whole until the year 2020. The simulation includes the welfare effects of the introduction of the new technology by expected benefits for producers and consumers. It concludes that the total benefits and especially the benefits to small-scale farmers crucially depend on the future price of TC plantlets. The benefits could also be increased by combining technology delivery with relevant extension services. The author recommends to combine the adoption of TC technology with technical and financial support to women's groups and other rural grassroot organizations.

*Blomme, G./Dochez, C./De Schutter, B./Gockowski, J./Gold, C./Green, K./Hartman, J./Hauser, S./Hughes, J. d'A./Nolte, C./Okech, S./Pillay, M./Ragama, P./Speijer, P./Tenkouano, A./Tshiunza, M./Ude, G./Vuylsteke, D. (2000), Project 7. Improving Plantain- and Banana-based Systems, in: International Institute of Tropical Agriculture (IITA), Annual Report 1999, p. 59-61 (http://www.iita.org/research/projann1999/IITAProj7-1999.pdf)*

The paper assesses the impact of the introduction and mass propagation of cooking banana using tissue culture in Nigeria. Plantlets are produced in two laboratories located at IITA High Rainfall Station (Onne, near Port Harcourt) and the Agricultural Development Programme at Owerri (Imo State). With the collaboration of 24 institutions, vegetatively propagated planting materials (suckers) were distributed to 29,585 farmers in 710 villages. An impact assessment study examined the adoption and diffusion of cooking banana in Nigeria (IITA 2000). Cooking banana gained a high level of acceptance and spread among the people, and thus established itself within the farming system in the region. The crop has been adopted by 55% of farmers, occupying about 26% of total fields, while its cultivation has increased by more than 930% since the introduction, with a multiplication rate of 600% across farmers. Bearing in mind that cooking banana was neither a traditional crop nor an improved cultivar from an existing one, the level and rate of adoption and diffusion are quite high and encouraging. At the end of the 1990s, about 80% of farmers who adopted this new crop were selling 10 to 90% of their total cooking banana production, while the other 20% produced entirely for household consumption. About 58% farmers sold at least 50% of their cooking banana. At the end of the 1990s, the average selling price of cooking bananas was N6.5 per kg compared to N13.3 per kg for plantains (about US $ 1 = N 111). However, the cooking bananas may have an increased overall value because of their significantly higher bunch weight than plantains. The introduction of cooking bananas and their subsequent adoption and diffusion made a positive impact in the region: on farmers' farm enterprises, farm resource use and allocation, income and food base of the people as well as employment generation. Therefore, the potential of cooking banana in contributing to bridging the hunger gap, and uplifting the income level of farmers in the region is quite high.

*Ruiz, J./Segovia, V./Tabares, E./Hincapie, F./Cock, J./Parra, F./Lentini, Z. (2004), In Vitro Vegetative Propagation and Regeneration of Solanum quitoense (Lulo) Plants and Their Use as Elite Clones by Farmers, Poster presented at the 2nd Colombian Congress on Biotechnology held in The Camara de Comercio and Universidad Nacional, Bogota, 1-3 September 2004*

In Colombia lulo is becoming an important commodity on the agricultural market. Nevertheless, there are several limitations for the adoption of the crop by farmers. The objective of this work is to develop in vitro protocols that facilitate (a) conservation of germplasm in vitro, (b) selecting and distribution of healthy elite clones of farmers and (c) facilitate genetic transformation. Plants grown using preliminary local protocols developed by other authors for in vitro propagation of lulo, were weak, characterized by thin stems and small leaves. Earlier research showed that ethylene accumulated in the sealed culture containers reduces the growth and development of lulo plants in vitro. An efficient protocol of propagation of clones selected by the farmers has been obtained. The agronomic performance of the regenerated plants in the field as well as their fruit yield and fruit quality are discussed. Currently, collaboration with selected small farmers from one of the main areas of commercial production is in progress for the evaluation of these protocols and their adaptation for routine use.

*Wakhusama, S./Kanyi, B. (2002), Biotechnology in Tree Production: Creating a Self-Sustaining Production and Dissemination System in Kenya, International Service for the Acquisition of Agri-biotech Applications (ISAAA), ISAAA Brief No. 25 (http://www.isaaa.org/kc/Publications/pdfs/isaaabriefs/Briefs%2025.pdf)*

The report looks at a project attempting to increase the area of forest and the supply of forestry products and services using tissue culture in Kenya. The project aims at alleviating the widespread deforestation and forest degradation resulting from land clearance for agriculture and increasing demand for wood (particularly fuelwood) by improving the supply of cheap, fast-growing planting material. By facilitating public-private cooperation, the project promotes the production of large amounts of disease-free tree plantlets. This can be done faster and more efficiently through tissue culture and clonal technology. So far, a seedling nursery has been established that is currently producing 500,000 seedlings annually, with plans to expand production to 3 million a year by the end of 2005. The project aims to create a self-sustaining production and dissemination system, driven by private enterprise. Initial sales will therefore be targeted at commercial enterprises involved in forestry or using wood. As production increases and economies of scale are achieved, small-scale farmers and the urban poor are estimated to become the project's major beneficiaries. The report summarizes the findings of a study on the marketing potential of tree seedling types which projected a high demand for seedlings derived from clonal production. It also predicted that the nursery would be profitable after 5 years of production. It is planned to introduce additional clones to broaden the genetic base and provide a wide range of materials adapted to each agro-ecological zone. The report predicts that a broad range of benefits to incomes, living standards, food security, human health and the environment will result from the introduction of clonal technology for tree seedling production, addressing the needs of both larger-scale commercial enterprises and small-scale farmers These include the increased availability of fuelwood in rural and urban areas, a reduction of the cost of fuelwood and charcoal for the urban poor, additional time for productive activities for peasants (who are currently spending a considerable share of their time collecting fuelwood), reduced erosion and a whole range of other indirect positive effects. The report further contains a brief description of a similar project being implemented in Uganda with the additional aim of serving the demand for wood by Ugandan saw mills, including information of the expected impact of the project.

*Eastmond, A./Robert, M.L. (2000), Henequen and the Challenge of Sustainable Development in Yucatan, Mexico, Biotechnology and Development Monitor, No. 41, p. 11-15 (http://www.biotech-monitor.nl/4104.htm)*

The article discusses the use of micropropagation to produce improved henequen (*Agave fourcroydes*) plantlets. Henequen is a fibre-producing plant that is mainly used for the production of rope, cloth, sacks and carpets. The Mexican government initiated a programme to support its struggling henequen industry that includes plans to extend the area planted with henequen considerably. For this initiative to succeed, micropropagation for the production of high-quality planting material was introduced in the mid-90s. There is a brief analysis of the economic impact of the introduction of micropropagation into the Mexican henequen sector which includes its impact on yields, growth speed,

fibre content, simplification of agricultural procedures, reduced risk of fires on agava fields, reliability of (disease-free) planting material, employment, income (including distributional effects on smallholders and large-scale producers) and potential adverse environmental effects.

*Thro, A.M./Roca, W./Restrepo, J./Caballero, H./Poats, S./Escobar, R./Mafla, G./Hernandez, C. (1999), Can in vitro biology have farm-level impact for small-scale cassava farmers in Latin America?, In Vitro Cellular and Developmental Biology - Plant, Vol. 35, No. 5, p. 382-387*

In 1998, the Cassava Biotechnology Network (CBN) convened a workshop of cassava stakeholder groups in Latin America. After hearing an opening statement from representatives of small-scale cassava producers and processors, stakeholders formulated a consensus set of research and development (R&D) priorities. An adequate supply of good-quality planting material of desired varieties was clearly the most urgent, followed by R&D on market-value traits; yield losses due to pests, diseases, and drought; and cropping system flexibility. Two new projects are using *in vitro* techniques to address priorities of small-scale cassava farmers in Latin America. One project in Colombia combines a nongovernmental organization, a local farmers' association, and the international research center, CIAT, to explore affordable micropropagation. Findings to date show that most culture medium components can be replaced with local products, and a rustic growth room permits good culture growth without electricity or air conditioning. Low-costs system(s) developed will be assessed as a local microenterprise. A second project, in Ecuador, couples local cassava germplasm (with oral histories and an in vitro back-up collection) and elite clones (introduced *in vitro*) with new concepts in agribusiness development, to restart local farmers' cooperatives after the disastrous 1998-99 el Niño floods. The project was developed through group planning by the cooperatives, the local technical university, the national agricultural research program, and CIAT. Research to improve *in vitro* tools focuses on safe and stable conservation and exchange of cassava genetic resources, long-term, less expensive conservation, rapid clonal propagation, and ultimately, genetic transformation technologies to add desired traits to useful cassava varieties.

*Thro, A.M./Roca, W./Iglesias, C./Henry, G./Ng, S.Y.C. (1998), Contributions of in-vitro biology to cassava improvement, African Crop Science Journal (Kampala), Vol. 6, Nr. 3, p. 303-315 (http://www.bioline.org.br/request?cs98032)*

Cassava (Manihot esculenta) is a tough and productive survival crop of smallholder farmers in the tropics. It is often grown where other crops fail. Research can make important contributions to food security and economic development in cassava-growing areas. This can be enhanced through in-vitro propagation methods for this crop, due to its slow vegetative propagation. For useful biotechnology innovations to reach smallholder cassava farmers, a combined effort is essential, with participation of farmers and other partners in research and development. The Cassava Biotechnology Network combines forces to mobilise biotechnology as a tool for enhancing cassava's value for food security and as a means of access to economic development. In-vitro biology methods are essential to safe and efficient conservation and exchange of

cassava diversity. Transgenic methods, now nearing the stage of first field trials, may offer a means of adding disease resistance or enhanced crop quality characteristics to existing preferred varieties.

*Fuglie, K.O./Zhang, L./Salazar, L.F./Walker, T.S. (1999), Economic Impact of Virus-Free Sweet Potato Planting Material in Shandong Province, China, International Potato Center, Lima/Peru, 27 p. (http://www.eseap.cipotato.org/MF-ESEAP/FI-Library/Eco-Imp-SP.pdf)*

This study on the economic impact on the introduction of virus-free sweet potato seed in China's Shandong Province covers the use of improved planting material between 1994 and 1998. Tissue culture propagation and ELISA testing methods were used to develop disease-free mother plants for existing varieties. This planting material was estimated to have reached 84 percent of the sweet potato area in Shandong Province by 1998. The availability of virus-free seed is estimated to have increased average sweet potato yield amongst adopters by at least 30 percent, with little or no change in the use of other inputs. The internal rate of return is estimated at 202 percent, with a net present value (assuming a 10 percent real discount rate) of $550 million. By 1998, annual productivity increases were valued at $145 million annually, improving the agricultural income of the province's 7 million sweet potato growers by 3-4 percent.

*Woodward, B./Brink, J./Berger, D. (1999), Can agricultural biotechnology make a difference in Africa?, AgBioForum, 2(3&4), 175-181f*

The paper deals with the potential impact of biotechnology on development in Africa and argues for the application of modern plant biotechnology techniques in conjunction with conventional plant breeding and good crop management. Among other things, it cites evidence of a positive impact of the use of tissue culture for the reintroduction of wild potatoes on resource-poor farmers in South Africa. The "Wild" or "Livingstone" potato (*Plectranthus esculentus* N.E.Br) is an indigenous, semi-domesticated plant of high nutritional value that was once part of the diet of rural communities in the Northern Province of South Africa. Tissue culture provided a way of rapidly producing planting material to satisfy the growing demand of local farmers.

*Hwang, S.-C./Su, H.-J. (1998), Production of virus-free banana plantlets in Taiwan, and Taiwan Banana Research Institute, Chiuju, Pingtung, Taiwan (http://www.fftc.agnet.org/library/data/eb/eb460/eb460.pdf)*

This Bulletin discusses the use of banana plantlets produced by tissue culture in Taiwan. The tissue culture program for banana was begun in 1983. Originally started to produce plantlets free of fusarium wilt, the program is now also used to ensure that banana planting materials are free of virus. A total of 26 million plantlets have been produced under the program. The advantages of TC plantlets are discussed, and also their disadvantages, such as their susceptibility to herbicide damage and occasional rooting problems. Finally, the Bulletin

describes a series of cultural methods to protect disease-free plantlets from virus reinfection in the field.

*Uyen, N.V./Ho, T.V./Tung, P.X./Vander Zaag, P./Walker, T.S. (1996), Economic impact of the rapid multiplication of high-yielding, late-blight-resistant varieties in Dalat, Vietnam, in: Walker, T./Crissman, C., Case studies of the economic impact of CIP-related technology, International Potato Center (CIP), p. 127-138 (http://www.cipotato.org/Market/ImpactCS/seedviet.htm)*

The paper updates the work of Uyen and Vander Zaag on the impact of the farmer-based production of high-yielding, late-blight-resistant potato cultivars using tissue culture in Vietnam. By the time the study was prepared, Vietnamese farmers had been growing tissue-culture plantlets for 14 years. Altogether, the potato yields in the study region are conservatively estimated to have doubled from about 10 to 20 tons per hectare since the advent of rapid multiplication and improved varieties since the early 80s. The authors argue that the introduction of tissue-culture production of potato plantlets is one of five factors for this yield increase. It is estimated that the adoption of tissue culture in conjunction with the introduction of improved varieties lead to a yield increase of 6 tons/hectare. The authors conclude, that the establishment of an efficient seed system had a considerable leverage on overall productivity. Given the low cost of the introduction of tissue culture technology and given the fact that the farmer-based plantlet production system became fully self-supporting after a short period of time, the rate of return on investment in the new seed system was highly favourable.

*Lubulwa, G./Arifin, M.S./Dodd, W./Davis, J. (1994), Project development assessment: the application of plant tissue culture techniques to the propagation and breeding of tea in Indonesia, Australian Centre for International Agricultural Research (ACIAR), Economic Evaluation Unit, Working Paper No. 14 (http://www.aciar.gov.au/web.nsf/doc/JFRN-5J472F/$file/WP14.pdf)*

The paper provides an economic ex ante assessment of a proposed project to improve the socio-economic position of the smallholder tea grower in Indonesia by promoting the supply of low-cost high-yielding planting material through the application of plant tissue culture techniques. For assessing the economic impact of the project, a standard economic-surplus framework is used and the cost and benefits accruing to producers and consumers in Indonesia and 63 other countries or regions are estimated. Furthermore, the Internal Rate of Return (IRR) and the Net Present Value (NPV) of the Project are calculated. The assessment shows that there are significant benefits to be derived by Indonesia and the rest of the world.

**b) Microbial biotechnologies for soil fertility enhancement**

*Boonkerd, N. (2002), Development of Inoculant Production and Utilisation in Thailand, in: Herridge, D. (ed.), Inoculants and Nitrogen Fixation of Legumes in*

*Vietnam. Proceedings of a workshop held in Hanoi, Vietnam 17–18 February 2001, p. 95-104*
*(http://www.aciar.gov.au/web.nsf/doc/JFRN-5J474T/$file/PR109e%20Chapter%2012.pdf)*

The paper discusses the use of Rhizobial inoculants to increase the productions of legumes like soybean, groundnut and mungbean in Thailand. It contains a brief analysis of the economic impact of the use of inoculants on the farm-level and on the national level in terms of impact on yields and net benefits. The author points out that in order to develop the potential of the inoculant industry, more on-farm research and demonstrations on the use of inoculant should be conducted. He further argues that in order to convince farmers of the benefits of inoculant use, the Government should stop providing free inoculant to farmers and that the price of inoculant should be determined by its cost of production. Research on inoculant production technology should be conducted in order to obtain a higher quality product.

*Hall, A.J./Clark, N. (1995), Coping with Change, Complexity and Diversity in Agriculture - The Case of Rhizobium Inoculants in Thailand, World Development, Vol. 23, No. 9, p. 1601-1614*

In recent years the accepted organizational pattern of relations between science and production has begun increasingly to be called in question. In the area of peasant agriculture, this generally takes the form of a critique of a system based upon centralized research institutes and hierarchically administered extension agencies. This paper explores this theme by means of an empirical study of the impact of rhizobium inoculant technology on selected areas of peasant agriculture in Thailand. The paper shows that this (core) scientifically derived technology has had widely different effects in different locations, and that these involve complex interactions with different biological systems. The evidence suggests that there are independent knowledge systems possessed by farmers who combine this knowledge innovatively with the core technology to produce outcomes that vary over time and space. The case, in common with many others, indicates also that core scientists are reluctant to accept technological complexity, preferring instead to leave responsibility for application to the extension system, even when it is clear that more research may be necessary.

*Hall, A.J. (1994), Agricultural biotechnology and small farmers in Asia: A case study of Rhizobium inoculants in Thailand, PhD dissertation, University of Sussex, Science Policy Research Unit, Brighton/UK*

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*Odame, H. (2002), Smallholder Access to Biotechnology: The Case of Rhizobium Inocula in Kenya, Institute of Development Studies, Sussex/UK, Environment Team, 19 p. (http://www.ids.ac.uk/ids/env/PDFs/OdameEPW.pdf)*

The paper explores ways to ensure that biotechnology applications are appropriate for smallholders in developing countries and ways to improve access to them. Using the case study of a Rhizobium inocula project in Kenya, it argues

that the main challenge to enhancing smallholder access to biotechnology lies in addressing the sources of institutional constraints in agricultural innovation processes. These constraints include sunk costs, uncertainty and political influence. How are mechanisms such as reducing uncertainty, building trust, and creating incentives at both national and local levels likely to improve smallholder access to Rhizobium inocula and transgenic crops in Kenya?

*Odame, H. (1999), Biotechnology and Smallholders. Institutional Rigidity and Change in Agriculture, Paper prepared for the regional workshop on "Biotechnology Assessment: Regimes and Experiences" organized by the African Centre for Technology Studies (ACTS) Nairobi, Kenya, September 27–29, 1999, 19 p. (http://www.acts.or.ke/Biotech%20-%20ODAME.pdf)*

The primary actors in agricultural biotechnology policy and programmes are often professionals—policymakers and scientists. Smallholder farmers tend to become passive beneficiaries or victims of these processes, rather than subjects who can take an active part in them. The smallholders' diversity, weak financial and technological capacities, implies limited power to press demands as well as high costs to consult and deliver services to isolated individuals. Programmes based primarily on building the capacity of professionals tend to neglect the role of smallholders in enhancing the capability of a national system. Using the case study of Rhizobium inocula technology (or Biofix) in Kenya, this paper explores the institutional rigidities that have made it difficult for farmers to influence biotechnology policies. It suggests mechanisms (including farmer participation) for integrating socio-economic concerns of smallholders into biotechnology innovation activities.

*Odame, Hannington (1997), Biofertilizer in Kenya: Research, production and extension dilemmas, Biotechnology and Development Monitor, No. 30, p. 20-23 (http://www.biotech-monitor.nl/3009.htm)*

The paper discusses the poor adoption of Rhizobium inocula ("Biofix") in Kenya. It examines why the adoption rate of Biofix has remained low in spite of its potential to replace often unavailable and expensive chemical fertilizers. Several related factors are discussed, including physical limitations, quality considerations, low production levels, ineffective extension and lack of policy support at the national level.

*Rola, A.C./Chupungco, A.R. (1996), Socioeconomic Evaluation and Policy Analysis of the Commercialization of the Rapid Composting Technology – Phase II, University of the Philippines at Los Baños/Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) (unpublished)*

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*Cuevas, V. (1997), Rapid composting technology in the Philippines: its role in producing good-quality organic fertilizers, University of the Philippines at Los Baños (http://www.fftc.agnet.org/library/data/eb/eb444/eb444.pdf)*

The study contains information on the socioeconomic impact of rapid composting technology in the Philippines. Having conducted a survey in two different regions of the Philippines, Rola/Chupungco (1996) observed an increase in rice yields, farmers' incomes, reduced fertilizer use and a number of farmers' perceived benefits, that are related to the physical and chemical properties of the soil (i.e. improvement of soil tilth and texture). She also observed the establishment of a profitable and growing compost production industry that includes plants producing the fungus that is used for composting. The paper further contains the findings of a cost-benefit-analysis of the government investment in the national program that had led to the introduction of the technology in the Philippines. It concludes that the use of the rapid composting technology allowed for an increase in total rice production in the Philippines of 0.11%. This translates into an estimated incremental value of US$13.3 million for the increase in rice production for the period 1992 - 1996. A computed cost-benefit ratio of 7.7 was calculated. The paper also reports of positive employment effect associated with the establishment of the new compost industry and positive environmental effects resulting from the use of agricultural waste for compost production.

### c) Reproductive cell biology techniques

*Diagne, A. (2004), Rate and Determinants of Adoption of A Technology with Partial Diffusion: The case of Diffusion and Adoption of NERICA rice varieties in Cote d'Ivoire, Working Paper, Africa Rice Center (WARDA), September 2004 (draft)*

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### d) Marker-Assisted Selection

*Hash, C.T./Yadav, R.S./Sharma, A./Bidinger, F.R./Devos, K.M./Gale, M.D./Howarth, C.J./Chandra, S./Cavan, G.P./Serraj, R./Kumar, P.S./Breese, W.A./Witcombe, J.R. (2002), Pearl Millet Molecular Marker Research, DFID Plant Science Research Programme, PSP Annual Report 2002, Page 35-41 (http://www.dfid-psp.org/highlights/2003/Molecular.pdf)*[1]

The paper focuses on the potential of MAS breeding programmes for the creation of improved pearl millet hybrids by using quantitative trait locus (QTL) mapping results. It describes the first marker-assisted backcrossing program to transfer downy mildew resistances and drought tolerance genes into commercial hybrid parental lines in India. The authors conclude that grain and biomass yields of the new varieties are superior to conventional pearl millet varieties. They also briefly

[1] This paper is available in two slightly different versions. The one with the more detailed impact analysis is called *Pearl Millet Molecular Marker Research* (7 pages, http://www.dfid-psp.org/highlights/2003/Molecular.pdf). The other one is called *Impact of Pearl Millet Molecular Marker Research* (8 pages, http://www.dfid-psp.org/highlights/2002/Molecular.pdf).

discuss the potential financial impact of the introduction of the new hybrid in northern India (especially in western Rajasthan and Haryana).

*Kristjanson, P.M./Zerbini, E. (1999), Genetic Enhancement of Sorghum and Millet Residues Fed to Ruminants. An ex ante assessment of returns to research. International Livestock Research Institute (ILRI), ILRI Impact Assessment Series No. 3, Nairobi/Kenya*
*(http://www.ilri.cgiar.org/InfoServ/Webpub/Fulldocs/Impact3/impact3.htm#Table%20of%20Contents)*

This ex ante impact assessment measures the potential economic impact of and returns to investment in a proposed research project on genetic improvement of dual-purpose (i.e. grain and fodder) sorghum and pearl millet using both marker-assisted selection and conventional selection in India. The approach taken links three methodologies to measure how much impact, where, and how to value it. A feed simulation model is used to measure the potential productivity gains from more, higher-quality crop residues in terms of meat and milk output. Primary survey data and geographic information systems (GIS) analyses of secondary data are used to assess where these gains are likely to be made. An economic surplus model that links the results of the GIS analysis with the output from the feed model is used to value the potential benefits versus the costs of the research.

### e) Several Biotechnologies

*Meerod, W. (2002), The economic impact of biotechnology on Thai agricultural sector, Paper presented at the 6th International ICABR Conference held in Ravello, Italy, from July 11-14, 2002*
*(http://www.economia.uniroma2.it/conferenze/icabr/papers/Paper/Meerod.zip)*

The paper presents four cases where Thailand benefited from the introduction of biotechnology applications: the reduction of losses in shrimp production made possible by the development of DNA probes for the rapid detection of major shrimp pathogens; the development and use of virus-free strawberry runners; the use of the nuclear polyhedrosis virus (NPV) as a method to control pests in grape production; and the use of tissue culture to produce planting material for the rehabilitation of degraded forests.

## III. Impact of Genetically Modified Organisms (GMOs)

### 1. Impact of GMOs in Developed and Developing Countries

*Sedjo, R. (2004), The Potential Economic Contribution of Biotechnology and Forest Plantations in Global Wood Supply and Forest Conservation, Chapter in: Strauss, Steven H./Bradshaw, H.D. (eds.), The Bioengineered Forest: Challenges for Science and Society, Resources for the Future, Washington, D.C.*

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*Sedjo, R. (2004), Tree Biotechnology: Regulation and International Trade, Paper presented at the 8th conference of the International Consortium on Agricultural Biotechnology Research (ICABR) on "Agricultural Biotechnology: International Trade and Domestic Production", held at Ravello (Italy), July 8 – 11, 2004 (http://www.economia.uniroma2.it/conferenze/icabr2004/papers/Sedjo.zip)*

This paper examines issues and problems related to international trade of transgenic wood and transgenic tree germplasm. While there is little reason to believe that transgenic wood flows would be negatively impacted, the transfer of technology in the form of transgenic germplasm is likely to find resistance entering some markets. This could result in increased the regional degree of specialization in wood production and result in larger volumes of exports from increasingly dominant global wood producers.

*Sedjo, R. (2004), Potential for Biotechnology: Application in Plantation Forestry, Chapter in: Christian, Walter/Carlson, Michael (eds.), Plantation Forests Biotechnology for the 21st Century, Forest Research, Rotorua/New Zealand*

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*Sedjo, R. (2001), Biotechnology's Potential Contribution to Global Wood Supply and Forest Conservation, Resources for the future, Discussion Paper 01–51 (http://www.rff.org/Documents/RFF-DP-01-51.pdf)*

Forestry today is on the threshold of the widespread introduction of biotechnology into its operational practices. In many cases, the biotechnology likely to be introduced is simply an extension of that being utilized in agriculture, such as herbicide-tolerant genes. However, biotechnology in forestry also is developing applications unique to forestry, including genes for fiber modification, lignin reduction and extraction, and for the promotion of straight stems and reduced branching. This paper gives information on the estimated cost reductions associated with the introduction of different biotechnology applications in wood production, including the introduction of herbicide tolerant eucalyptus in Brazil, and estimates the potential impact of the market introduction of herbicide tolerant trees worldwide. Three scenarios for maximum, intermediate, and low impact of the new technology are developed. According to Sedjo, the financial benefit of the introduction of herbicide tolerant trees could amount to a reduction in production cost of 1 billion $ annually, which would lead to the creation of a larger number of low-cost plantation forests and a lower prices of industrial wood associated with those plantations. Sedjo also predicts environmental benefits resulting from a reduction wood harvest from natural forests. In addition, the author discusses additional environmental benefits that could result from the introduction of other biotechnology applications in forestry.

*Anderson, K./Jackson, L.A. (2004), Standards, Trade and Protection: The Case of GMOs, University of Adelaide/Australia, Centre for International Economic*

*Studies (CIES), CIES Discussion Paper No. 0411 (http://www.adelaide.edu.au/cies/0411.pdf)*[2]

A global economy-wide model (GTAP) is used to go beyond estimating how GM crop variety adoption affects adopting and non-adopting economies, with or without policy responses to this technology, by indicating effects also on real incomes of farmers. The results suggest the EU moratorium on imports of GM food helps EU farmers even though it requires them to forego the productivity boost they could receive from the new biotechnology. An estimate of the cost of that EU moratorium to developing countries and the world also is provided.

*Parcell, J.L./Kalaitzandonakes, N. (2004), Do Agricultural Commodity Prices Respond To Bans Against Bioengineered Crops?, Canadian Journal of Agricultural Economics, Vol. 52, No. 2, p. 201-209*[3]

The study assesses the significance of bans imposed by major food companies against bioengineered commodities by investigating the response of commodity prices to such bans. The authors empirically examine whether soybean futures market prices react to news about voluntary bans against bioengineered commodities by food firms. Furthermore, the impacts of GM ban announcements on the returns of non-GM soybean futures are investigated. They conclude, that soybean futures markets responded little to ban announcements by major food companies against bioengineered commodities.

*Flatau, J./Schmitz, M. (2004), Economic Effects of Producing or Banning GM Crops, Paper presented at the 8th conference of the International Consortium on Agricultural Biotechnology Research (ICABR) on "Agricultural Biotechnology: International Trade and Domestic Production", held at Ravello (Italy), July 8 – 11, 2004 (http://www.economia.uniroma2.it/conferenze/icabr2004/papers/Flatau.new.zip)*

Currently, GM crops are produced on more than 67 million hectares worldwide. North and South America as well as China are the leading countries/regions using these innovations in agriculture. Far-reaching structural adjustments in production and trade are expected among countries/regions and commodities from this new technology. Those either countries or regions singly, which still ban or delay, the production and marketing of GM crops, like the European Union (EU), fear a loss of market shares and thus reduced competitiveness in international agriculture. In this article the price, production, trade, income, budget and welfare effects due to an introduction of GM crops in Brazil, China and the USA will be examined. Three different responses from the EU are assumed: in the first scenario the EU bans and in the second scenario it adopts this new technology. In a third scenario the economic effects of lifting its import ban will be analysed. To assess the impact of these three scenarios, a multi-commodity (9 commodities), multi-region (16 regions) partial equilibrium trade

[2] This paper has also been presented at the Annual Meeting of the American Agricultural Economics Association held in Denver, Colorado, 1-4 August 2004.

[3] This article has also been published as a book chapter in Evenson, R./Santaniello, V. (eds.) (2004), Consumer Acceptance of Biotechnology Foods, Wallingford, UK: CABI Publishers.

model is used. Furthermore, we will report on differences in the regulatory systems and agricultural policy regimes of Brazil, China, the EU and the USA regarding GM crops and their impact on world prices, production and welfare.

*Naylor, R./Falcon, W./Goodman, R./Jahn, M./Sengooba, T./Tefera, H./Nelson, R. (2004), Biotechnology in the developing world: a case for increased investments in orphan crops, Food Policy, Vol. 29, p. 15-44*[4]

This article examines the opportunities for using several forms of modern biotechnology to improve orphan crops in developing countries. These crops, including tef, millets, cowpea, and indigenous vegetables, fruits, roots, and tubers, tend to be locally important, but receive little public or private investment. Recent advances in the fields of genetics and genomics provide a more unified understanding of the biology of plants. The authors summarize some important ways in which genetic technologies can be harnessed for orphan crops and provide examples of potential genetic and genomics research that is likely to benefit poor regions. Finally, we suggest policies that could help create incentives for application of advanced science to orphan crops.

*Purcell, J.P./Perlak, F.J. (2004), Global impact of insect-resistant (bt) cotton, AgBioForum, Vol. 7, No. 1-2, p. 27-30*
*(http://www.agbioforum.missouri.edu/v7n12/v7n12a05-purcell.pdf)*

Insect-resistant (Bt) cotton has been rapidly adopted since its introduction in 1996. Farmers around the world, both large and smallholders, benefit from this technology through increased productivity, convenience, and time savings. The vast majority of farmers using Bt cotton globally are smallholder farmers. The economic, environmental, and social benefits derived from adoption of this important tool have very positive implications for the farmers, their surrounding communities, and the future of agriculture.

*Eaton, D./Achterbosch, T./de Maagd, R. (2003), Assessing the benefits & potential of genetically modified non-food crops in developing countries: the case of Bt-cotton, North-South Centre, Wageningen/Netherlands, International Cooperation Programme Policy Brief 2003-4*
*(http://www.north-south.nl/webfiles/21cf72fef0c22be17bb4dc77546e7389.pdf)*

Food crops, such as soybeans and maize, have generally been at the centre of the debate surrounding genetic engineering of agricultural plants. Policy makers need to advise on whether governments and public organisations will promote, simply permit, or even prevent the application of genetically modified (GM) crops for agricultural development. One way to assess policy options is to examine the benefits and potential risks according to different stakeholder groups. This brief summarises these issues for the case of Bt cotton, one of the most widely-cultivated GM crops. The difference between non-food and food crops illustrates that consumers are for the most part concerned about potential health risks from

[4] This article is also available online at
http://iisdb.stanford.edu/pubs/20403/biotechnology_Naylor_Falcon_2004_web.pdf.

consuming GM food substances, as opposed to biosafety risks from GM crops in general. In the case of Bt cotton, this attitude is probably strengthened by the immediate environmental benefits from reduced pesticide use, as well as the apparent economic benefits enjoyed by ever-growing numbers of smallholder farmers. Nonetheless, policy issues regarding resistance development and who enjoys the greatest share of the benefits demand ongoing attention.

*Lapan, H.E./Moschini, G. (2004), Innovation and Trade with Endogenous Market Failure: The Case of Genetically Modified Products, American Journal of Agricultural Economics, Vol. 86, No. 3, p. 634-648*

A partial-equilibrium, two-country model is developed to analyze implications from the introduction of genetically modified (GM) products. In the model, innovators hold proprietary rights, farmers are (competitive) adopters, some consumers deem GM food to be inferior in quality to traditional food, and the mere introduction of GM crops affects the costs of non-GM food (because of costly identity preservation). Among the results derived, it is shown that, although GM innovations have the potential to improve efficiency, some groups can be made worse off. Indeed, it is even possible that the costs induced by GM innovations outweigh the efficiency gains.

*Haggui, F./Phillips, P./Gray, R. (2004), Opposition To Genetically Modified Wheat and Global Food Security, Paper presented at the 8th conference of the International Consortium on Agricultural Biotechnology Research (ICABR) on "Agricultural Biotechnology: International Trade and Domestic Production", held at Ravello (Italy), July 8 – 11, 2004*
*(http://www.economia.uniroma2.it/conferenze/icabr2004/papers/Haggui.zip)*

On March 10, 2004, Monsanto Ltd. announced that it would cease to develop and commercialize its Roundup Ready variety of GM wheat. In effect, the technology has been shelved for a number of years, if not permanently. While there was substantial concern in North America and many developed countries about its commercial acceptability, many leaders in development agencies saw the technology as one of many applications of biotechnology that had the potential to improve food security around the world. The world currently has more than 840 million food insecure people, and at current rates of conventional technological change, the World Food Program targets for reducing malnutrition cannot be met. This paper examines the extent of the challenge and undertakes a modeling exercise—modifying the adoption decision in different markets such as China and the European Union to allow for direct feedbacks from consumer markets—to illustrate the array of potential outcomes. In effect, this paper highlights the opportunity cost of market resistance to RR wheat and the subsequent decision to stop introduction of the new technology.

*Smyth, S./Kerr, W./Davey, K. (2004), Have There Been Changes in Trade Patterns Due to the Commercialization of Biotechnology?, Paper presented at the 8th conference of the International Consortium on Agricultural Biotechnology*

*Research (ICABR) on "Agricultural Biotechnology: International Trade and Domestic Production", held at Ravello (Italy), July 8 – 11, 2004 (http://www.economia.uniroma2.it/conferenze/icabr2004/papers/Smyth.zip)*

This paper examines the extent of the challenge and undertakes a modeling exercise—modifying the adoption decision to allow for direct feedbacks from consumer markets—to illustrate the array of potential outcomes. In effect, this paper highlights the opportunity cost of market resistance to RR wheat and the subsequent decision to stop introduction of the new technology. This paper will compare international trading patterns for canola, corn and soybean varieties prior to commercialization of the genetically modified (GM) varieties with present trading patterns that include GM varieties. Any marketplace changes that have occurred will be analyzed to determine the cause for any market shifts. Genetically modified canola, corn and soybeans entered the marketplace successfully, but some international markets were lost because of the commercialization of the GM varieties. The paper examines if these industries were able to successfully identify any new marketplace opportunities and shift commodity exports into new markets.

*Lin, W./Johnson, D. (2004), Segregation of non-biotech maize and soybeans: who bears the cost?, in: Evenson, R./Santaniello, V. (eds.), The regulation of agricultural biotechnology, CABI Publishing, Wallingford/UK, p. 221-230*

Demand for non-biotech maize and soybeans has increased in recent years. It is against this backdrop that the US grain and oilseed industries face the challenge of meeting the needs of foreign buyers through segregation or identity preservation (IP). Suppliers' decisions about whether to segregate grains or oilseeds into biotech and non-biotech commodities depend crucially on the willingness of buyers to pay price premiums for non-biotech commodities. If price premiums cover the cost of segregation and provide sufficient incentives for producers, the US grain industry can accommodate foreign requirements. This study focuses on the economics of segregating US non-biotech maize and soybeans for shipments to Japan, the primary non-biotech export market for US grains and oilseeds, as a case study. The purpose is to 1) ascertain or estimate price premiums that buyers in both the US domestic and Japanese export markets were willing to pay for non-biotech maize and soybeans for the 2000 and 2001 crops; and 2) to examine who bears the cost of segregation.

*Traxler, G. (2004), The GMO experience in North & South America – where to from here?, Paper presented at the 4th international crop science congress held in Brisbane, Australia, 26 September – 1 October 2004 (http://www.regional.org.au/au/cs/2004/symposia/3/8/1344_traxlerg.htm)*[5]

In 2003 North and South America (NSAm) accounted fore more than 64 million ha, 94%, of total world area planted to genetically modified organisms (GMOs). Delivery has occurred almost entirely through the private sector and adoption has

[5] A Pdf version of this paper is available on the site of the United States Department of Agriculture (USDA) (http://www.fas.usda.gov/icd/stconf/event5/GTraxler.pdf).

been rapid in areas where the crops addressed serious production constraints and where farmers had access to the new technologies. Four countries (USA, Argentina, Brazil and Canada), four crops (soybean, cotton, canola and maize) and two traits (insect resistance and herbicide tolerance) account for the vast majority of global transgenic area. Colombia, Mexico, Honduras, Uruguay and Paraguay have also planted GMOs. The economic benefits of the diffusion of GMOs have been widely shared among farmers, industry, and consumers despite the fact that the products are patented. The GMOs have had a favorable impact on the environment by facilitating reduced pesticide use and the adoption of conservation tillage. This paper surveys the level and distribution of the economic impacts of GMOs in NSAm to date.

*Traxler, G. (2003), The Economic Impacts of Biotechnology-Based Technological Innovations, FAO, Agricultural and Economic Development Analysis Division, ESA Working Paper No. 03-XX*
*(http://www.card.iastate.edu/research/stp/papers/Traxler-F03.pdf)*

Global adoption of transgenic crops reached 58.7 million hectares in 2002 from 2.8 million in 1996. Delivery has occurred almost entirely through the private sector and adoption has been rapid in areas where the crops addressed serious production constraints and where farmers had access to the new technologies. Three countries (USA, Argentina and Canada), three crops (soybean, cotton and maize) and two traits (insect resistance and herbicide tolerance) account for the vast majority of global transgenic area. While some farmers in some developing countries are benefiting, most do not have access to transgenic crops and traits that address their needs. This paper surveys the level and distribution of the economic impacts of transgenic cotton and soybeans to date and reviews the impacts of these crops on chemical pesticide and herbicide use. It concludes with some considerations of ways to address the development and delivery of technological innovations to small farmers in developing countries.

*Abdalla, A./Berry, P./Connell, P./Tran, Q.T./Buetre, B. (2003), Agricultural biotechnology: potential for use in developing countries, Australian Bureau of Agricultural and Resource Economics (ABARE), ABARE eReport 03.17, Canberra (Australia)*

Apart from a general discussion of the risks and benefits of GMOs and other issues concerning the use of transgenic crops, the report estimates the economic impact of the global use of GMOs. The economic effects in different regions of the world of adoption and trade policies for agricultural biotechnology are estimated under three different scenarios. Scenario simulations were carried out using ABARE's global trade and environment model. Economic impacts are measured for fourteen regions, with each region falling in one of three income groups (low, medium and high income). A general conclusion to be drawn from the results of this analysis is that agricultural biotechnology could generate substantial economic gains in regions where it is introduced. The results suggest that, with full adoption of GM technology, aggregate income for all regions, measured by gross national product (GNP), is estimated to rise by US$210 billion

a year, by the end of the period. With restrictive EU production and trade policies for GM products in the second scenario and, added to that, reduction in the scope of adoption by low income developing countries in the third scenario, gains in global welfare are estimated to be lower — US$167 billion and US$134 billion respectively. Among different country groups, potential gains in GNP from the uptake of biotechnology are highest for developing countries, ranging between 2.1 per cent for low income regions and 0.5 per cent for middle income regions.

*Brookes, G./Barfoot, P. (2003), GM rice: will this lead the way for global acceptance of GM crop technology?, International Service for the Acquisition of Agri-biotech Applications (ISAAA), ISAAA Briefs No. 28*
*(http://www.isaaa.org/kc/Publications/pdfs/isaaabriefs/Briefs%2028.pdf)*

The report looks at the GM traits that are being developed in rice and will be introduced in the next few years and discusses the potential impact these developments could have on production costs and output, as well as on nutrition and food security in developing countries. Assumptions regarding the impact of rice research build the basis for projections of worldwide GM rice adoption rates and their impact on global rice supply and demand and the area required for rice production. Assuming an average adoption of 40%, the authors calculate two scenarios of the impact of yield increases of 10% and 15% associated with the introduction of transgenic rice for 2012. The authors also give estimations on the extent to which markets for GM rice and non-GM will segregate.

*Annou, M./Fuller, F./Wailes, E. (2003), Innovation and dissemination and the market impacts of drought-tolerant genetically modified rice, Paper presented at the 7th International ICABR Conference held in Ravello, Italy, from June 29 to July 3, 2003*
*(http://www.economia.uniroma2.it/conferenze/icabr2003/abstract/New%20products/Mamane%20Annou.doc)*[6]

Recently, researchers announced the development of a genetically modified (GM) rice variety that has tolerance to drought, cold temperatures, and soils with high salinity levels. The objective of this paper is to analyze the effects of drought-tolerant (DT) rice adoption on global rice production, consumption, trade volumes, and rice prices under the two approaches to dissemination of this innovation. The impacts of adoption are measured by simulating the Arkansas Global Rice Model (AGRM) given assumptions regarding DT rice adoption location, adoption percentage, productivity increases, and fees for the technology. The AGRM is a multi-market, partial-equilibrium agricultural policy analysis model that is capable of providing 10-year projections for rice supply and utilization, trade, and world prices in 28 major rice-producing or rice-trading countries. The model is used to generate annual baseline projections that can be used as a point of reference for policy analysis. When the model is used to

[6] This paper has also been published as a Staff General Research Paper 11576 of the Department of Economics of Iowa State University in Ames, Iowa, USA (http://econpapers.repec.org/paper/isugenres/11576.htm).

simulate global rice markets under policy or technology assumptions that differ from the baseline, the deviations of the new equilibrium from the baseline projections provide a measure of the effects of the policy and technology change.

*Benbrook, C. (2004), Genetically Engineered Crops and Pesticide Use in the United States: The First Nine Years, BioTech InfoNet, Technical Paper Number 7, October 2004 (http://www.biotech-info.net/Full_version_first_nine.pdf)*

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*Benbrook, C. (2003), Economic and Environmental Impacts of First Generation Genetically Modified Crops. Lessons from the United States, International Institute for Sustainable Development (IISD)/The International Centre for Trade and Sustainable Development (ICTSD)*
*(http://www.tradeknowledgenetwork.net/pdf/tkn_firstgen_gmo_us_sum.pdf)*

Despite its subtitle, the paper focuses on the economic and environmental impact of GMOs in both the USA and Argentina. It brings together a wide reading of the current agricultural research on GMOs, and data on planting, use rates and yields, focusing specifically on three crops: Roundup Ready (RR) soy, Bt cotton and Bt corn. The consolidation of information is conducted with a view to drawing out the implications for crop management strategies in the U.S. and Argentina—the two biggest users of the new technologies. The paper first looks at rates of adoption, herbicide use rates and yield data. As well, the paper examines the environmental effects of current practice. Those effects include several pieces of environmental good news, including benefits to soil conservation from new cropping techniques, and the benefits of using glyphosate in combination with RR soy, replacing more toxic and persistent herbicides. But the effects of current practice also have some worrying implications. Poor management of the new technologies risks undermining their effectiveness, while selection pressures lead to weed and pest shifts as well as increased resistance. The study predicts that in Argentina, with current levels and patterns of use, these problems should be surfacing soon, and may already exist. The study also looks at emerging issues that may impact the performance of RR soybean cultivars. New research shows that the process of making soy cultivars Roundup Ready may also impair their physiological performance under certain types of stress and growing conditions. Other research looks at the changes in soil microbial communities that are brought about by high levels of glyphosate use. Particularly worrying are the observed links between glyphosate use and increased levels of Fusarium—a fungus associated with a number of crop and livestock diseases. There are also observed negative effects of glyphosate on soybean root development and nitrogen fixation. The authors conclude that based on what is known today, the consequences of these environmental impacts and ecological responses are largely economic, played out in terms of crop yields and costs of crop production. The study makes a number of recommendations aimed at maintaining the benefits of the new technologies, including reducing the ratio of acreage devoted to RR vs. conventional soybean varieties, diversifying weed management systems and technologies, and reducing the over-reliance on any single strategy.

*Glick, H. (2003), Improved farm productivity and farm sustainability: Has biotechnology innovation delivered on its promise?, Paper presented at the 7th International ICABR Conference held in Ravello, Italy, from June 29 to July 3, 2003*

Researchers have analyzed transgenic crops in both highly technified, high yield agricultural production systems of North America and Europe and in low input, small holder production systems in developing regions of Asia and Africa. Despite the variability that is inherent in biological systems, the results of this research indicate several trends that are broadly consistent across the different crop production systems. In this review paper, data are presented on the economic and environmental impacts of transgenic crops compared to non transgenic crops that have been generated over the past 7 years of production.

*Kalaitzandonakes, N. (ed.) (2003), The economic and environmental impacts of agbiotech: a global perspective, New York, USA, Kluwer-Plenum Academic Publishers*

The book contains a wide range of studies on the economic and environmental effects of GMOs in developed and developing countries and a cohesive introduction and conclusion section written by the editor. It presents a comprehensive picture of the global impacts of crop biotechnologies thus far. For the most part, this is accomplished through chapters written by economists in the various regions of the world where crop biotechnologies have been commercialized. The global synthesis is left to the reader with some help from the editor in the concluding chapter. The book provides an inside into geographically diverse assessments and viewpoints on the topic of the impacts of crop biotechnologies. It also provides some state-of-the-art economic analyses that attempt to shed light on some of the most controversial aspects of these technologies—such as their impacts on pesticide use and consequent environmental impacts, on the relationship between adoption of these technologies and changes in agronomic practices and ecological impacts, and on human health and changes in other sources of risk. The first accountings of the farm-level nonpecuniary impacts of crop biotechnologies appear in this volume. The relationship between soil-saving production techniques and use of crop biotechnologies is studied in several chapters, using various state-of-the-art analytic methodologies.

*Wesseler, J. (2003), Resistance economics of transgenic crops. A real option approach, in: R. Laxminarayan (ed.) Battling Resistance to Antibiotics. An Economic Approach, Resources for the Future, Washington/D.C., USA, p. 214-237*

The development of pest resistance is one of the concerns, among others, about the long-term environmental consequences of planting transgenic crops. In this paper resistances are seen as additional irreversible costs related to the release of transgenic crops. These irreversible costs, their uncertainty, and the uncertainty about future direct benefits favor a delay in the release of transgenic

crops. In addition to irreversible costs, however, a release of transgenic crops may also provide irreversible benefits, for example due to a reduction in pesticide use. These irreversible benefits provide an incentive for an immediate release of transgenic crops in the environment. The optimal decision to release transgenic crops, hence, will not only depend on the direct costs and benefits, but also on the trade-off between irreversible environmental costs and benefits. The decision rule for releasing transgenic crops into the environment was formulated as: Postpone the release of a transgenic crop into the environment, if the irreversible costs are higher than the irreversible benefits plus the present value of an infinite stream of instantaneous additional net benefits, using the convenience yield as the relevant discount rate, divided by the hurdle rate. The approach is applied to the EU and results for different transgenic crops, like cotton maize, potatoes, rape seeds and soy beans are discussed.

*Munro, A. (2003), Monopolization and the regulation of genetically modified crops: an economic model, Environment and Development Economics, Vol. 8, No. 1, p. 167–186*

Although genetically modified organisms (GMOs) have recently attracted a great deal of public attention, analysis of their economic impact has been far less common. This paper puts forward variants of a simple model of crop production, each one tailored to a particular aspect of transgenic food technology. The focus is on the possibility of monopolization and its consequential welfare costs. Risk factors identified include moderate cost savings from transgenic varieties, high seed storage costs, and high risks of crop loss. The paper also discusses some of the possible remedies including tighter regulation of anti-competitive practices and liberalization of the regulations governing the introduction of new GMOs.

*Frisvold, G./Sullivan, J./Raneses, A. (2003), Genetic improvements in major US crops: the size and distribution of benefits, Agricultural Economics, Vol. 28, No. 2, p. 109-119*

The distribution of welfare gains of genetic improvements in major US crops is estimated using a world agricultural trade model. Multi-market welfare estimates were 75% larger than estimates based on the price-exogenous ‘change in revenue’ method frequently used by plant breeders. Annual benefits of these genetic improvements range from US$ 400–600 million depending on the supply shift specification. Of this, 44–60% accrues to the US, 24–34% accrues to other developed countries. Developing and transitional economies capture 16–22% of the welfare gain. The global benefits of a one-time permanent increase in US yields are US$ 8.1 billion (discounted at 10%) and US$ 15.4 billion (discounted at 5%). Gains to consumers in developing and transitional economies range from US$ 6.1 billion (10% discount rate) to US$ 11.6 billion (5% discount rate).

*Marra, M./Pardey, P./Alston, J. (2002), The payoffs to transgenic field crops: An assessment of the evidence, International Food Research Institute (IFPRI),*

*Environment and Production Technology Division (EPTD), EPTD Discussion Paper No. 87 (http://www.ifpri.org/divs/eptd/dp/eptdp87.htm)*[7]

This study which concentrates on the farm level impact of GM crops in the United States includes a good review on the literature of the impact of GM corps in the rest of the world, including developing countries like China, Mexico and Kenya. The purpose of the study was to collect and characterize the economic evidence available to date, organize it, and determine if any general implications can be drawn from it. The general classes of economic impacts at the farm level are discussed. The types of studies that generate estimates of these benefits are also characterized and categorized in terms of the implications for measuring economic impacts when the set of things held constant in the type of study does not correspond to those that economic theory suggests. The evidence is presented, along with some general implications drawn from the analysis. These implications are: (1) growing transgenic cotton is likely to result in reduced pesticide use in most years and is likely to be profitable in most years in most U.S. states in the Cotton Belt, (2) Bt corn will provide a small but significant yield increase in most years across the U.S. Corn Belt, and in some years and some places the increase will be substantial, and (3) although there is some evidence of a small yield loss in the Roundup Ready soybean varieties, in most years and locations savings in pesticide costs and, possibly, tillage costs will more than offset the lost revenue from the yield discrepancy. There is not yet enough evidence to generalize even these few conclusions to other countries. More farm- level studies in more years and across more locations are required before any additional implications can be drawn. Studies that measure the non-pecuniary benefits and costs of these technologies should be undertaken, as well.

*Sobolevsky, A./Moschini, G./Lapan, H.E. (2002), Genetically Modified Crop Innovations and Product Differentiation: Trade and Welfare Effects in the Soybean Complex, Iowa State University, Center for Agricultural and Rural Development (http://www.card.iastate.edu/publications/DBS/PDFFiles/02wp319.pdf)*

The authors develop a new partial equilibrium, four-region world trade model for the soybean complex comprising soybeans, soybean oil, and soybean meal. In the model, some consumers view genetically modified Roundup Ready (RR) soybeans and products as weakly inferior to conventional ones; the RR seed is patented and sold worldwide by a U.S. firm; and producers employ a costly segregation technology to separate conventional and biotech products in the supply chain. The calibrated model is solved for equilibrium prices, quantities, production patterns, trade flows, and welfare changes under different assumptions regarding regional government's production and trade policies, differentiated consumer tastes, and several other demand and supply parameters. Incomplete adoption of RR technology naturally arises in the free trade equilibrium, with the United States producing both genetically modified and conventional soybeans. The United States, Argentina, Brazil and the rest of the world all gain from the introduction of RR soybeans, although some groups of agents (producers or consumers) may lose. Compared to free trade with no domestic bans, a ban on RR production in the Rest of the World improves that region's welfare at some levels of segregation costs but

[7] A shorter version of this article (8 pages) has been published in AgBioForum 5(2): 43-50 (http://www.agbioforum.org/v5n2/v5n2a02-marra.pdf).

hurts the United States. Introduction of the same ban in Brazil benefits its farmers but makes the region worse off, and an import ban on RR products significantly reduces welfare of all agents. Price support programs for U.S. farmers, despite hurting the United States, have the potential to further improve the world's efficiency. The distribution of welfare between consumers and producers appears to be sensitive to several parameters of the model, but region-level outcomes are robust with respect to most of them and are sensitive only to parameters defining the share of consumers conscious of genetically modified organisms and the elasticity of demand for conventional product varieties.

*Shelton, A.M./Zhao, J.-Z./Roush, R.T. (2002), Economic, ecological, food safety, and social consequences of the deployment of Bt transgenic plants, Annual Reviews in Entomology, Vol. 47, p. 845-81*

Transgenic plants expressing insecticidal proteins from the bacterium, Bacillus thuringiensis (Bt), are revolutionizing agriculture. Bt, which had limited use as a foliar insecticide, has become a major insecticide because genes that produce Bt toxins have been engineered into major crops grown on 11.4 million ha worldwide in 2000. Based on the data collected to date, generally these crops have shown positive economic benefits to growers and reduced the use of other insecticides. The potential ecological and human health consequences of Bt plants, including effects on nontarget organisms, food safety, and the development of resistant insect populations, are being compared for Bt plants and alternative insect management strategies. Scientists do not have full knowledge of the risks and benefits of any insect management strategies. Bt plants were deployed with the expectation that the risks would be lower than current or alternative technologies and that the benefits would be greater. Based on the data to date, these expectations seem valid.

*Stone, S./Matysek, A./Dolling A. (2002), Modelling Possible Impacts of GM Crops on Australian Trade, Productivity Commission Staff Research Paper, Melbourne/Australia (http://www.pc.gov.au/research/staffres/gmcrops/gmcrops.pdf)*

This study examines the possible impacts of genetically modified (GM) technology on Australia's output, exports and imports of non-wheat grains and oilseeds using various assumptions about productivity gains, consumer attitudes and regulation costs in Australia and overseas. Since changes in Australia's trading patterns do not occur in isolation, the paper also provides an indication of some of the effects on Australia's main trading partners including China and Korea. The model used is the general equilibrium model GTAP (Global Trade Analysis Project).

*Lin, W. (2002), Estimating the Costs of Segregation for Non-biotech Maize and Soybeans, in: Evenson, R.E./Santaniello, V./Zilberman, D. (eds.), Market Development for Genetically Modified Foods, CABI Publishing, Wallingford/UK, p. 261-270 (http://www.agbiotechnet.com/pdfs/085199573x/085199573xCh21.pdf)*

This book chapter provides information on the costs of segregation and certification that are essential to the development of non-GM food markets. In a

scenario analysis, the costs of segregation for non-biotech maize and soybeans are estimated for grain handlers, from country elevators to subterminals and export elevators (without taking into account any additional costs that could be associated with segregation at the farm level and shipment expense beyond export elevators). It concludes that costs depend on tolerance levels for biotech content.

*Anderson, K./Nielsen, C./Robinson, S. (2002), Estimating the gobal economic effects of GMOs: the importance of policy choices and preferences, in: Evenson, R.E./Santaniello, V./Zilberman, D. (eds.), Economic and Social Issues in Agricultural Biotechnology, CABI Publishing, Wallingford/UK, p. 359-391*[8]

To illustrate the usefulness of quantitative models for informing GMO debates, the present paper draws on three recent studies by the authors that use existing empirical models of the global economy to examine what the effects of widespread adoption of genetically modified crop varieties in some (non-European) countries might be in light of different policy and consumer preference responses. Specifically, the effects of an assumed degree of GMO-induced productivity growth in selected countries for cotton, rice, and maize plus soybean are explored. In the latter case those results are compared with what they would be if (a) Western Europe chose to ban consumption and hence imports of those products from countries adopting GM technology or (b) some Western European consumers and intermediate users responded by boycotting imported GM crops. Then another global CGE model is introduced which distinguishes GM-inclusive from GM-free maize and soybean. It is used to explore the impact of increased preferences for GM-free food. The final section discusses areas where future empirical work of this sort might focus.

*Anderson, K./Nielsen, C. (2002), Economic Effects of Agricultural Biotechnology Research in the Presence of Price-distorting Policies, University of Adelaide/Australia, Centre for International Economic Studies (CIES), CIES Discussion Paper No. 0232 (http://www.adelaide.edu.au/cies/0232.pdf)*

The economic welfare implications of some countries using new genetically modified varieties in crop production will depend on which countries choose to adopt them and on whether others (notably Western Europe) ban their importation. They also depend on existing (non-GMO specific) agricultural policies in affected markets. This paper uses a well-received empirical economy-wide model of the global economy (GTAP) to quantify the effects of selected countries enjoying an assumed degree of productivity growth from adopting GMO maize and soybean. It does so first by leaving existing distortionary policies in place and then assuming agricultural policies in Western Europe are completely

[8] This article has also been published as a discussion paper of the Centre for International Economic Studies (CIES), University of Adelaide/Australia (CIES Discussion Paper No. 0032, http://www.adelaide.edu.au/cies/0035.pdf) and as Anderson, K./Nielsen, C. P./Robinson, S./Thierfelder, K. (2001), Estimating the gobal economic effects of GMOs, in: Pardey, P. G. (ed.), The Future of Food. Biotechnology Markets and Policies in an International Setting, International Food Policy Research Institute (IFPRI), Washington, D.C., p. 49-74.

liberalised. In both cases we investigate the effects of Western Europe refraining from using GMO technology in its own farm production but without versus with a ban on imports of GM products. The results suggest that (a) such an import ban would have a large adverse effect on economic welfare, particularly in Western Europe itself, and (b) while estimated global economic welfare benefits from the new biotechnology are not greatly reduced by Europe's traditional price-distorting policies, the reductions in technology gains are concentrated in non-European countries.

*James, C. (2002), Global review of commercialized transgenic crops: 2001 feature: Bt cotton, International Service for the Acquisition of Agri-biotech Applications (ISAAA), ISAAA Briefs No. 26*
*(http://www.isaaa.org/kc/Publications/pdfs/isaaabriefs/Briefs%2026a.pdf)*

The paper gives information on the development of the global market for GM crops, focusing on Bt cotton, and discusses its impact. Eight country case studies are presented which provide detailed and current information on all aspects of the cultivation, adoption and performance of Bt cotton, including an assessment of the agronomic, economic, environmental, health and social impact of the technology. Country studies are presented for the USA, Australia, China, India, Mexico, Argentina, South Africa and Indonesia which collectively have six years' experience with the production of transgenic cotton. It concludes that all countries that have introduced Bt cotton have derived significant and multiple benefits. These include increases in yield, decreased production costs, a reduction of at least 50% in insecticide applications, resulting in substantial environmental and health benefits to small producers, and significant economic and social benefits. The paper also estimates the potential impact of an adoption of Bt cotton by 50 key countries that grow cotton throughout the world.

*Jarvis, L. (2002), The Potential Effect of Recombinant Bovine Somatotropin on World Dairying, in: Evenson, R.E./Santaniello, V./Zilberman, D. (eds.), Economic and Social Issues in Agricultural Biotechnology, CABI Publishing, Wallingford/UK, p. 101-11*
*(http://www.agbiotechnet.com/pdfs/085199573x/085199573xCh9.pdf)*

Recombinant bovine somatropin (rbST) is a hormone produced by a GM bacterium that is used in milk production. The paper analyses the adoption and profitability of rbST in the USA and 16 developing countries. It further discusses the potential of the use of rbST in less developed countries. Jarvis concludes that, when administered to *B. taurus* cattle in favourable production conditions and managed effectively, rbST consistently offers a moderate, but limited reduction in milk production costs. These conditions prevail in nearly all developed countries. The use of rbST will not be profitable in most parts of most developing countries in the foreseeable future since the yield increases obtained from administering rbST to *B. indicus–B. taurus* crossbred animals, which produce the bulk of milk in developing countries, are too small.

*Jarvis, L. (1996), The potential effect of two new biotechnologies on the world dairy industry, Westview Press, Boulder/Colorado (USA)*

Biotechnology is expected, by many observers, to have a significant impact on the world dairy industry over the next decade. In this timely volume, Lovell Jarvis analyzes the potential effect of two biotechnologies – multiple ovulation and embryo transfers (MOET) and recombinant bovine somatotropin (rbST) – on the dairy industry around the world. According to Jarvis's research, the effects of these two technologies will vary greatly between the developed and developing nations. He predicts that the technologies will be most profitable for the developed nations, where their use will increase milk production and strengthen their positions in dairy export markets. Developing country dairy sectors will probably lose from the use of these two biotechnologies, as their own international trade position will be weakened, though their own consumers should benefit. Jarvis concludes his study with a look at alternative approaches that might improve the competitive position of developing countries in the dairy sector.

*Araji, A.A./Guenthner, J.F. (2001), The Economic and Environmental Impacts of Investments in the Development and Adoption of Genetically Modified Potato, Paper presented at the 5th International Conference on Biotechnology, Science and Modern Agriculture: a New Industry at the Dawn of the Century in Ravello (Italy), June 15-18, 2001*

The authors apply an ex ante approach to estimate the economic and environmental impacts of the introduction of genetically modified potatoes in the major potato-producing regions of the world. It projects annual gross benefits attributed to the development and adoption of a genetically modified late-blight-resistant potato of over $4.3 billion. The estimated present value of the flow of annual gross benefit projected over 25 years productive life expectancy of the variety and estimated probability of adoption is over $27 billion. The annual present value to producers and consumers of potato is over $1.082 billion. In addition to the economic benefit, the adoption of the genetically modified potato will eliminate the use of an estimated 41,154,274 kg of active toxic chemical ingredients.

*Traxler, G./Wilson, N./Jefferson, K./Falck-Zepeda, J. (2001), The Economics of Value Enhanced Transgenic Crops: Status, Institutional Arrangements and Benefit Sharing, Paper presented at the 6th International Conference on Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer held at Ravello (Italy) from July 11 to 14, 2001*

In this paper, the authors estimate the distribution of benefits from output trait GMVs using a standard economic surplus approach, modified to account for conditions of imperfect competition. Benefits are partitioned as accruing to domestic (U.S.) and Rest of World (ROW) consumers, domestic and ROW producers, industry suppliers of biotechnology inputs, and the purchasers of the enhanced output. The benefits from high oil corn which is a commodity

developed through conventional breeding but which required vertical coordination between Pioneer Hi-bred and Continental grain to bring to market are examined. This case study was chosen because it is a product already on the market and should lend insight into the effect of monopsonistic output market combined with a monopolistic input market on benefit distribution. The distribution of benefits for less widely grown biotechnology produced products such as high lysine corn, are also examined.

*Lin, W. (2001), Price Premiums for Nonbiotech Corn and Soybeans: Implications for the Costs of Segregation, Paper presented at the 6th International Conference on Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer held at Ravello (Italy) from July 11 to 14, 2001*

Despite their importance, little is understood about price premiums that buyers are willing to pay for non-genetically modified (non-GM) grain in both the U.S. domestic and international markets. The availability of both non-GM soybean futures prices and U.S. undifferentiated soybean futures at Tokyo Grain Exchange offers a rich data source for deriving price premiums for non-GM soybeans. In addition, price premiums can be obtained from surveying Japanese grain trading houses, especially those located at the Pacific Northwest region (PNW). These price premiums will capture the bulk of segregated, non-GM corn and soybean shipments from U.S. export ports because segregation is primarily done for the Japanese export market. Also, these price premiums eventually would be translated into price premiums that first grain handlers (local elevators) are willing to pay U.S. producers for non-GM corn and soybeans. If the U.S. grain marketing system is efficient, knowledge about the differences in price premiums that buyers are willing to pay in the international and U.S. domestic markets can arrive at estimates of the costs of segregation. Accordingly, the purposes of this paper are two-fold: 1) to estimate price premiums that buyers in both the U.S. domestic and international markets are willing to pay for non-GM corn and soybeans; and 2) to draw implications for the costs of segregation for non-GM corn and soybeans. Price premiums for non-GM soybeans will be estimated by comparing non-GM soybean futures and U.S. soybean futures at Tokyo Grain Exchange. Interviews with Japanese grain trading houses, primarily at PNW, will provide a crosscheck of the above estimate and a source for arriving at price premiums for non-GM corn. Price premiums that local elevators paid to producers will be arrived at by reviewing the literature as well as popular news media reports.

*Lin, W./Price, G./Allen, E. (2001), Starlink: Impacts on the U.S. Corn Market and World Trade, in: Feed. Situation and Outlook Yearbook, United States Department of Agriculture (USDA), p. 40-48*
*(http://usda.mannlib.cornell.edu/reports/erssor/field/fds-bby/fds2001.pdf)*

StarLink has disrupted the U.S. corn market since some shipments destined for food uses or export markets tested positive and were rerouted to approved animal feed and non-food industrial uses. The potential (upper-bound) volume of marketed StarLink-commingled corn from the 2000 crop located in areas near wet and dry millers prior to October 1, 2000, is estimated at 124 million bushels. The actual volume of commingled corn may differ from the potential volume

estimated in this study. Price differentials between StarLink-free and StarLink corn existed during the early stage of the incident. However, at present, the price differentials are small or nonexistent. The zero tolerance for unapproved biotech varieties adopted by buyers in major export markets (mainly Japan) raises the question of whether the grain industry can segregate grain supplies. Restrictions imposed on the use of StarLink corn in some major U.S. export markets, such as Japan and South Korea, appear to have had a negative impact on U.S. corn exports. The zero tolerance for StarLink and disputes over testing protocol have also disrupted corn shipments destined for these export markets.

*Elbehri, A./Hertel, T./Lin, W. (2001), Regulations and Market Segregation of Biotech Crops: Implications for Global Agricultural Trade, Paper presented at the 6th International Conference on Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer held at Ravello (Italy) from July 11 to 14, 2001*

This paper describes an empirical multi-country, multi-sector model of global trade and production that has been specifically constructed to examine the trade effects of biotech regulation and market segmentation. The model features product differentiation based on country of origin as well as a sector level differentiation between biotech and non-biotech varieties, which substitute imperfectly in consumption. The model is employed to analyze the trade and welfare effects of heterogeneity in biotech acceptance among markets, differential adoption of bio-technology between countries, and potential regional specialization induced by segregation costs. Empirical results are based on a three-region, three-commodity version of this model with particular emphasis on one product, soybeans imported into the Japanese market. Given the uncertainty about key parameters (e.g., elasticity of substitution between biotech and non-biotech soybeans), empirical results are presented in the form of a distribution of outcomes (mean and standard deviation) based on formal systematic sensitivity analysis.

*European Commission (2001), Economic Impacts of Genetically Modified Crops on the Agri-Food Sector, Directorate General for Agriculture*
*(http://europa.eu.int/comm/agriculture/publi/gmo/fullrep/index.htm)*

Following an inventory of the state of agricultural GMO production worldwide, the report deals with the role of the life science companies in biotechnology in general and the seed market in particular. It further analyses the economic reasons for the rapid and vast uptake of GM crops by US farmers and the farm-level profitability of GM crops, highlighting the increased labour productivity and savings in crop-specific labour costs associated with GMOs. It also covers the differences in citizen concerns and consumer preferences between the EU and Northern America, since they constitute an important demand side factor for the profitability of GM crops. The report finally covers means to assure the possibility to keep track of the origin and the nature of crops such as Identity Preservation (IP) and of GM labelling. The costs associated with IP are quantified.

*Moschini, G./Lapan, H.E./Sobolevsky, A. (2000), Roundup Ready Soybeans and Welfare Effects in the Soybean Complex, Agribusiness, Vol. 16, p. 33-55*[9]

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*Anderson, K./Nielsen, C. (2001), GMOs, Trade Policy and Welfare in Rich and Poor Countries, in: Maskus, K./Wilson, J. (eds.), Quantifying the Impact of Technical Barriers to Trade: Can it be Done?, University of Michigan Press, Ann Arbor/MI (USA)*[10]

The new agricultural biotechnologies that are generating genetically modified organisms (GMOs) are seen as exciting and valuable developments by some people, while others are objecting strongly to their use. Both environmental and food safety concerns have been raised by opponents of GM crops. That in turn is causing consumers and policy makers in numerous countries around the world to react and in some cases to over-react. A majority of people want at least to have labels on products that may contain GMOs, while the most extreme opponents (particularly in Western Europe) want to see GM crops totally excluded from production and consumption in their country. This paper first examines the ways in which the emergence of GMOs is generating policy reactions which, in extreme cases, may lead to trade disputes in the WTO. It then uses an empirical model of the global economy (the GTAP model) to quantify the effects on global production and trade patterns and national welfare of certain (non-European) countries adopting the new GMO technology in the context of different policy reactions in Western Europe. Specifically, the effects of an assumed degree of productivity growth in the maize and soybean sectors in selected countries are explored, and those results are then compared with what they would be if Western Europe chose to ban imports of those products from countries adopting GM technology. The effects of an alternative market-based shift in consumer preferences are then compared with this regulatory approach. The estimated implications for developing countries' participation in world agricultural and food trade, and for their economic welfare, are highlighted.

*Anderson, K./Nielsen, C. (2001), Global Market Effects of European Responses to Genetically Modified Organisms, Weltwirtschaftliches Archiv [Review of World Economics, Kiel/Germany], Vol. 137, No. 2, p. 320-346*[11]

Current debates about genetically modified organisms (GMOs) in agriculture reveal substantial differences in perception of the associated risks and benefits. Genetically modified crop varieties allegedly provide farmers with various agronomic benefits, but serious environmental, health and ethical concerns also

[9] This research has also been published as a book chapter in 2000 (Moschini, G./Lapan, H.E./Sobolevsky, A., Trading Technology as Well as Final Products: Roundup Ready Soybean and Welfare Effects in the Soybean Complex, in: Lesser, W.H. (ed.), Transitions in Agbiotech: Economics of Strategy and Policy, Storrs, CT: Food Marketing Policy Center).

[10] This article has also been published in 2000 as a discussion paper of the Centre for International Economic Studies (CIES), University of Adelaide/Australia (CIES Discussion Paper No. 0021, http://www.adelaide.edu.au/cies/0021.pdf).

[11] This article has also been published in 2000 as a discussion paper of the Centre for International Economic Studies (CIES), University of Adelaide/Australia (CIES Discussion Paper No. 0032, http://www.adelaide.edu.au/cies/0032.pdf).

are being raised. A majority of people in numerous countries want at least to have labels on products that may contain GMOs, while the most extreme opponents (particularly in Western Europe) want to see GM products totally excluded from production and consumption in their country. This paper first discusses the ways in which the emergence of GMOs is generating policy reactions, which could lead to trade disputes between Western Europe and the United States. It then uses an empirical model of the global economy to quantify the effects on production, prices, trade patterns and national economic welfare of certain (non-European) countries adopting GM crops. Those results are compared with what they would be if Western Europe banned imports of those products from countries adopting GM technology. An alternative market-based approach also is considered, whereby a shift in consumer preferences in Europe is investigated.

*Anderson, K./Nielsen, C. (2001), Cultures Transgeniques et Commerce International, Economie Internationale, No. 87, p. 45-62*

Les débats actuels sur les organismes génétiquement modifiés (OGM) dans l'agriculture montrent des divergences dans la perception des risques et des bénéfices liés au génie génétique. Les OGM peuvent bénéficier aux pays pauvres comme riches, mais ils soulèvent des questions de sécurité sanitaire et environnementale, et sont un sujet de préoccupation pour les citoyens. Ces inquiétudes sont reflétées par le Protocole récent sur la Biosécurité, qui se réfère de façon appuyée au principe de précaution. Ce protocole n'est pas forcément en accord avec les engagements des pays dans le cadre des accords de l'Organisation mondiale du commerce (OMC). Après un examen des questions de politique commerciale en jeu, est ici présentée une évaluation empirique des conséquences économiques de l'adoption de cultures transgéniques par un certain nombre de pays, alors que d'autres en limiteraient l'importation. En sont tirées quelques leçons politiques aussi bien pour les pays en question que pour l'OMC.

*Cunningham, C./Unnevehr, L. (2000), Market Segmentation for Genetically Modified Corn and Soybean Exports, in: Lesser, William (ed.), Transitions in Agbiotech: Economics of Strategy and Policy, University of Connecticut and University of Massachusetts, Amherst, Food Marketing Policy Center, p. 638-650 (http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=2196&ftype=.pdf)*[12]

This paper examines the evidence regarding the segmentation of export markets for corn and soybeans into GMO and non-GMO varieties and products. First, we examine EU policy which is evolving in a piecemeal fashion across countries, GMO varieties, and end-use markets. Thus EU importers face a difficult challenge in matching supplies with end use markets, and may choose to demand non-GMO product whenever possible, to avoid any problems with market acceptance. Next, we examine trade flows, which differ between the corn and soybean markets. U.S. corn

[12] This paper has also been presented at the conference "Transitions in Agbiotech: Economics of Strategy and Policy" held in Washington, DC, June 24-25, 1999.

exports to the EU have virtually disappeared following the introduction of GMOs, as the EU is able to supply their diminishing import demand from many other sources. U.S. soybean and soybean meal exports to the EU remain a significant share of U.S. exports and of the EU market. There are fewer substitutes and fewer alternative sources for soybeans. These changes in demand are reflected at the local level in Midwestern grain markets, which we examine through the trade press and informal interviews with grain handlers. Two major processors have a specific program to handle and process non-GMO soybeans. They will also accept only EU approved varieties of corn in this coming marketing year. Many elevators are advertising on the internet for non-GMO corn and soybean contracts with growers. These contracts vary in the price premiums offered and in the need for verification that a crop is truly non-GMO. Premiums and markets for non-GMO soybeans appear more robust than those for corn, following the pattern of EU demand. The costs of segmented markets for specialty grains provide a high estimate of the marketing costs of segmentation. Actual costs may be lower due to the higher volume in non-GMO segments and the declining costs of market coordination with use of the internet. On the other hand, if verification of non-GMO status becomes more important to end-users, that could substantially increase marketing costs. A priori analysis of market segmentation cannot predict whether we will eventually see premiums for non-GMO product or not. Shifts in supply and demand curves are expected in both GMO and non-GMO markets. Adoption of GMOs and the evolution of policy in other countries that are major actors in world corn and soybean markets will also influence the outcome. It will be interesting to watch markets respond to the challenges presented by new technologies and changing demands over the next few years.

*Weatherspoon, D./Oehmke, J./Wolf, C./Naseem, A./Maredia, M./Hightower, A. (1999), North-North-South Ag-Biotech Policy: Implications for Growth and Trade, Michigan State University, Department of Agricultural Economics, Staff Paper #99-51 (http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=1781&ftype=.pdf)*

This paper examines the impact of European Union policy on genetically modified organisms on trade flows and economic growth. Restrictive European Union Policies on biotech production and consumption result in: an effective export subsidy of capital to the South; new trade flows; North America being a dominant producer of biotech products; and the European Union being the dominant producer of traditional agricultural products.

*Lence, S./Hayes, D. (2004), Welfare Impacts of Cross-Country Research Spillovers, Paper presented at the 8th conference of the International Consortium on Agricultural Biotechnology Research (ICABR) on "Agricultural Biotechnology: International Trade and Domestic Production", held at Ravello (Italy), July 8 – 11, 2004 (http://www.economia.uniroma2.it/conferenze/icabr2004/papers/Lence.zip)*

The present study focuses on the welfare implications of intellectual property protection (IPP) in agriculture, when the associated knowledge has commercial application in more than one country. Attention is paid to the realistic case where countries provide different IPP levels. A model is developed to determine who benefits from, and who should pay for the associated research. A key contribution is the acknowledgement that in many cases the technology used in

agriculture is subject to spillovers. This fact has some important implications for welfare analysis and for policy prescriptions on where the burden of paying for the research should lie.

*Pardey, P./Koo, B./Nottenburg, C. (2004), Creating, Protecting, and Using Crop Biotechnologies Worldwide in an Era of Intellectual Property, University of Minnesota, Department of Applied Economics, Staff Paper P04-4 (http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=13156&ftype=.pdf)*

Proponents tout the positive incentive-to-innovate effects of intellectual property rights (IPRs), while others maintain that the expanding subject matter and geographical extent of IPRs are stifling crop research, especially research and development (R&D) dealing with developing-country crop concerns. Much of this debate relies on anecdotes and misleading or incomplete evidence on the extent and nature of the IPRs pertaining to crop technologies, including the jurisdictional extent of the property rights and their practice. In this paper we review the evidence on the scope of agricultural R&D worldwide, provide new data on the structure of crop-related IPRs, and summarize trends on the uptake of proprietary bioengineered crops.

*Eaton, D./Van Tongeren, F. (2004), Mixed Incentive Effects of IPRs in Agriculture, Paper presented at the 8th conference of the International Consortium on Agricultural Biotechnology Research (ICABR) on "Agricultural Biotechnology: International Trade and Domestic Production", held at Ravello (Italy), July 8 – 11, 2004*
*(http://www.economia.uniroma2.it/conferenze/icabr2004/papers/Eaton.zip)*

This paper address the question of which factors are important in determining the effectiveness of intellectual property right (IPR) systems in the plant breeding sector. We propose a framework for analysing the effects of intellectual property rights (IPRs) in plant breeding that explicitly incorporates the transaction costs associated with acquiring and enforcing these rights. Based on in-depth interviews with a number of plant breeding companies, PVP is identified as an important factor influencing decision-making. But the effectiveness of PVP depends largely on transactions costs that are affected considerably by the design and implementation of IPR systems, leading to relevant policy recommendations.

*Léger, A. (2003), Strengthening of Intellectual Property Rights in Mexico: A Case Study of Maize Breeding, Paper presented to the Annual Meeting of the American Agricultural Economics Association (AAEA), held in Montreal, Canada, July 27-30, 2003 (http://www.agrar.hu-berlin.de/wisola/fg/ihe/Mitarbeiter/Article%20DIW2.pdf)*

This exploratory study attempts at identifying the impacts of strengthening Intellectual Property Rights (IPR) on the Mexican maize breeding industry through empirical research performed with Mexican maize breeders. According to the breeders, (I) IPR would provide incentives for the development of foreign inventions adapted to the local needs and conditions; (II) Plant Breeders' Rights

would support the diffusion of germplasm and information, while patents would restrict it; and (III) stronger IPR would foster the performance of private breeding. The potential causes behind the few impacts identified and the general low level of use breeders in Mexico make of IPR are discussed: The level of development of the industry, transaction costs related to registration and enforcement and the widespread use breeders make of CGIAR materials are presented as potential explanations. Increased diffusion of protected matters, new domestic institutional arrangements and exercise of negotiation power at the international level are presented as potential methods to increase the benefits from stronger IPR accruing to developing countries. Finally, recommendations for further research activities in this area are presented.

*Goldsmith, P./Ramos, G./Steiger, C. (2002), Intellectual Property Protection and the International Marketing of Agricultural Biotechnology: Firm and Host Country Impacts, in: Evenson, R./Santaniello, V./Zilberman, D. (eds.), Economic and social issues in agricultural biotechnology, Wallingford/UK, p. 309-324*

There has been much debate about the impact of alternative Intellectual Property Rights (IPR) regimes (tight or loose) on the welfare of Southern economies. So far no work has attempted to directly measure firm and host country impacts from weak IPRs. The objective of this research is to add some empirical clarity of the welfare impacts of weak IPR. Goldsmith et al. use the case study method and the unique setting of the corn and soybean seed business to actually measure how the lack of IPR protection distorts the strategy and investment behaviour of a firm. Due to the agronomic differences between corn and soybeans, corn is naturally protected from IPR pirating while soybeans are not. In a Northern setting, the businesses are run in parallel with similar investments, human resource needs, and marketing strategies. In a Southern setting significant and measurable differences are expected due to the firm's inability to protect its intellectual soybean technology. Methodologically, this manuscript empirically analyzes hypotheses derived from IPR theory, by comparing the business practices of the maize and soybean business units within Pioneer Hi-Bred, Argentina. We hypothesize that there will be sharp differences between the corn and soybean business units in a Southern setting which will reflect the "investment not made" that has been so elusive to other empirical studies. Theory predicts differences in quality and quantity of infrastructure investment, supply chain relationships, resource needs, human resource management, and financial performance. At the firm level it would indicate that there are different business strategies for different IPR environments even though the traded products are identical. Finally, the study measures the impacts on the host country in terms of human capital, under investment, reduced cash flow, and smaller knowledge spillovers. These impacts plus those on the market for soybean seed will comprise a measure of the economic impact of weak IPR.

*Evenson, R. (2002), Agricultural biotechnology: developing country access, CABI Publishing, Agbiotechnet No. 87*

Developed countries (particularly the USA) have provided both scientific and technological leadership in the agricultural biotechnology field. As of 2002, most adoption of genetically modified (GM) crops has taken place in developed

countries. A few developing countries (notably China, India and Brazil) have developed biotechnology research capabilities, but most developing countries do not have these capabilities. This paper discusses the economic implications of delays in acquiring research capabilities and of delays in acquiring biotechnology products in market transactions. The role of consumer resistance to GM foods and of weak intellectual property rights in obtaining access to research capabilities and to biotechnology product markets is evaluated.

*Evenson, R. (1999), Intellectual Property Rights, Access to Plant Germplasm, and Crop Production Scenarios in 2020, Crop Science, Vol. 39, p. 1630-1635*

The scope of intellectual property rights (IPRs) has been expanded in recent years to cover plant varieties. Plant breeders' rights (PBRs) provide weak protection to private plant breeders in many countries. The United States and a few other developed countries provide patent protection to plant varieties as well as to some genetic resources. In principle, the strengthening of IPRs for plants should encourage more plant breeding and more variety options for farmers. However, developing countries often lack the institutional setting to enable them to realize these options. A second type of IPR providing for "farmers' rights" has been prepared in the Convention on Biodiversity. Negotiating a payment framework for farmers' rights may result in a period of limited international exchange of genetic resources. Policy simulations based on an international economic model confirm that developing countries will be harmed by weak IPRs while developed countries will not be affected. They also confirm that both developing and developed countries will be harmed by reduced exchange of genetic resources associated with protracted negotiations over farmers' rights.

*Traxler, G. (1999), Assessing the prospects for the transfer of genetically modified crop varieties to developing countries, AgBioForum, 2(3&4), p. 198-202*

Although genetically modified varieties (GMVs) have been commercially successful in the United States (US), their future in developing countries (DCs) with smaller markets is uncertain. How likely is it that relatively small countries will gain access to GMV technology? Will the dominance of biotechnology by multinational firms make GMV technology too expensive for small DCs? In this paper we attempt to draw lessons from the US experience to speculate on the prospects for developing countries to gain access to GMV technology. We conclude that small countries could be attractive markets for life science and seed companies if biosafety and intellectual property systems become institutionalized.

*Eaton, D./Van Tongeren, F. (2002), Potential economic impacts of GURT technologies at national and international levels, Agricultural Economics Research Institute (LEI), The Hague*
*(http://www.lei.dlo.nl/publicaties/PDF/2002/6_xxx/6_02_01.pdf)*

This report examines the possible economic impacts from the development and commercial application of genetic use restriction technologies (GURTs). The

economic rationale for GURTs is reviewed and the various benefits and costs are identified. The report argues that GURTs offer the potential to attract increased private sector investment in a number of major crops that have not been successfully hybridised. Increased segmentation of genepools in the breeding sector and the possibilities for a heightened productivity lag are discussed as possible risks. The possible contribution of GURTs to the trends in the seed and agrochemical sector towards vertical integration and horizontal concentration is discussed. The report then examines a number of regulatory issues facing governments in the areas of intellectual property rights, anti-trust and competition laws, and biosecurity, as well as other potentially possible means for restricting GURT application. The report concludes that weighing up the various potential costs and benefits associated with GURT development poses a challenging task for governments, as much of the necessary information is at best only partially available.

*Food and Agriculture Organization (FAO) (2001), Potential Impacts of Genetic Use Restriction Technologies (GURTs) on Agricultural Biodiversity and Agricultural Production Systems, Report submitted to the Convention on Biological Diversity (http://www.fao.org/ag/agp/agps/pgr/itwg/pdf/P1W7E.pdf)*

The report discusses both the environmental and the economic and socio-economic impact of Genetic Use Restriction Technologies (GURTs).

*Giovannetti, M. (2001), Environmental impact of transgenic crops: potential risks associated with "Terminator" gene technology, Paper presented at the 6th International Conference on Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer held at Ravello (Italy) from July 11 to 14, 2001*

The paper deals with environmental risks associated with the release of GMOs and the potential negative impact of the introduction of GM plants that contain the genes for the death of second generation seeds. After considering that the location of transgenes on chromosomes is an unpredictable event, that many of the introduced genes may be unpredictably silenced or activated, and that they may be transferred among different organisms, the paper examines the risks associated with the cultivation of "Terminator" seeds in agriculture. Awareness that scientists and technologists are unable to predict all the possible interactions between transgenes and different components of complex ecosystems should foster long-term studies aimed at evaluating the environmental impact of particularly dangerous genes, such as "Terminator", which interfere so heavily with fundamental life processes. Moreover the paper deals with the impact of the utilisation of "Terminator" seeds on the survival of human populations in developing countries: the introduction of death genes in crops such as rice or wheat could leave the fate of millions of people to the mercy of a few seed companies.

## 2. Impact of GMOs in Developing Countries

*Hareau, G./Mamaril, C./Mills, B.F./Peterson, E./Norton, G.W. (2004), Potential Impacts of Rice Biotechnologies in Asia, Paper presented at the conference on Research Impacts and Decision Strategies for Biotechnologies, Donald Danforth Plant Science Center, March 6, 2004*
*(http://www.agecon.vt.edu/biotechimpact/education/Potential%20Impacts%20of%20Rice%20Biotechnologies%20in%20Asia,03-04.pdf)*

The study analyzes the impact of the introduction on Bt rice in Asia and discusses the distributional effects across the region. It discusses partial equilibrium distributional cross-country effects (focussing on Vietnam and the Philippines) and general equilibrium cross-country effects (focussing on China, India, Indonesia, Bangladesh, Vietnam, Thailand, the Philippines, and Japan).

*Hareau, G./Norton, G.W./Mills, B.F./Peterson, E. (2004), Biotechnology for rice ecosystems of Asia: public sector R&D options and welfare impacts under imperfect competition, Paper presented at the 8th conference of the International Consortium on Agricultural Biotechnology Research (ICABR) on "Agricultural Biotechnology: International Trade and Domestic Production", held at Ravello (Italy), July 8 – 11, 2004*
*(http://www.economia.uniroma2.it/conferenze/icabr2004/papers/Hareau.zip)*

An ex ante evaluation of potential impacts of three transgenic rice technologies in favorable and unfavorable ecosystems in Asia is conducted in a general equilibrium framework. Results indicate that herbicide resistance is likely to produce larger aggregate gains than Bt and drought resistant rice. For countries with larger proportions of unfavorable environments, the drought resistance technology produces larger gains than Bt rice, but in total, the size of the benefits from those two technologies are similar. Rice biotechnologies will have significant cross country effects, and arguments about which ecosystem the public sector should emphasize depend on incentives for private sector involvement.

*Hareau, G./Norton, G.W./Mills, B.F./Peterson, E. (2004), Potential Benefits of Transgenic Rice in Asia: A General Equilibrium Analysis (2004), Paper prepared for presentation at the Annual meeting of the American Agricultural Economics Association, Denver, Colorado, August 1-4, 2004*
*(http://www.agecon.vt.edu/biotechimpact/rice/Hareau%202004%20AAEA%20paper%20-%20final.pdf)*

A general equilibrium model is developed to analyze the welfare effects of transgenic technologies for both the irrigated and non-irrigated rice ecosystems in Asia. The paper focuses on total versus distributional effects and the impacts in favourable versus fragile environments. It concludes that drought resistance, a technology of particular importance to unfavourable environments, is worth as much as Bt rice, a technology of primary importance to favourable environments.

*Anderson, K./Jackson, L.A. (2004), Implications of Genetically Modified Food. Technology Policies for Sub-Saharan Africa, World Bank, World Bank Policy Research Working Paper 3411 (http://econ.worldbank.org/files/38750_wps3411.pdf)*

The first generation of genetically modified (GM) crop varieties sought to increase farmer profitability through cost reductions or higher yields. The next generation of GM food research is focusing also on breeding for attributes of interest to consumers, beginning with "golden rice," which has been genetically engineered to contain a higher level of vitamin A and thereby boost the health of unskilled labourers in developing countries. Anderson and Jackson analyze empirically the potential economic effects of adopting both types of innovation in Sub-Saharan Africa (SSA). They do so using the global economy-wide computable general equilibrium model known as GTAP. The results suggest that the welfare gains are potentially very large, especially from nutritionally enhanced GM wheat and rice, and that—contrary to the claims of numerous interests—those estimated benefits are diminished only slightly by the presence of the European Union's current barriers to imports of GM foods. In particular, if SSA countries impose bans on GM crop imports in an attempt to maintain access to EU markets for non-GM products, the loss to domestic consumers due to that protectionism boost to SSA farmers is far more than the small economic gain for these farmers from greater market access to the EU.

*Anderson, K./Jackson, L.A./Nielsen, C. (2004), Genetically Modified Rice Adoption: Implications for Welfare and Poverty Alleviation, World Bank Policy Research Working Paper 3380 (http://econ.worldbank.org/files/38016_wps3380.pdf)*

The first generation of genetically modified (GM) crop varieties sought to increase producer profitability through cost reductions or higher yields, while the next generation of GM food research is focusing on breeding for attributes of interest to consumers. "Golden Rice," for example, has been genetically engineered to contain a higher level of vitamin A and thereby boost the health of poor people in developing countries. This paper analyzes the potential economic effects of adopting both types of innovation in Asia, including its impact on rice producers and consumers. It does so using the global economy-wide computable general equilibrium model known as GTAP. The results suggest the farm productivity gains could be dwarfed by the welfare gains resulting from the potential health-enhancing attributes of golden rice, which would boost the productivity of unskilled workers among Asia's poor.

*Stone, G.D. (2004), Social constraints on crop biotechnology in developing countries, AgBioForum, Vol. 7, No. 1-2, p. 76-79*
*(http://www.agbioforum.missouri.edu/v7n12/v7n12a14-stone.pdf)*

Westerners often see the social components of agriculture in developing countries as constraints on development. However, the same social components play vital roles in facilitating cultivation. Of particular relevance to the future of genetically modified (GM) crops is the importance of the social component of indigenous management skill. Developing world farmers rely on observations of

each others. Fields and on information and interpretations passed among each other. Along with the benefits that genetic modification has the potential to offer, it is important to keep in mind ways in which the technology may also disrupt this social component of agriculture. Two possible forms of disruption are decreased recognizability and accelerated rate of technological change.

*Van Meijl, H./Van Tongeren, F. (2004), International diffusion of gains from biotechnology and the European Union's common agricultural policy, Agricultural Economics, Vol. 31, Issues 2-3, p. 307–316*

This paper analyses the impact of adopting or rejecting genetically modified (GM) crops in the European Union, taking into account the EU Common Agricultural Policy (CAP). In this paper the productivity impact of genetically modified organisms (GMOs) differs across crops, taking factor biased technology change into account. The transfer of knowledge across countries is modelled as a process of endogenous knowledge spill-overs. Analysis with a multi-region applied general equilibrium model shows that the CAP protects farm income and production despite non-adoption of the more productive GM crops in the EU. The EU will forgo substantial benefits in terms of economic welfare if it bans GM imports.

*Elbehri, A./McDonald, S. (2003), Transgenic cotton and crop productivity: A general equilibrium analysis for West and Central Africa, Paper presented at the 7th International ICABR Conference held in Ravello, Italy, from June 29 to July 3, 2003 (http://www.gtap.agecon.purdue.edu/resources/download/1517.pdf)*

The authors examine the economic impact of Bt cotton adoption by West and Central Africa (WCA). In an ex ante assessment, the economy-wide impact of Bt cotton adoption in WCA and the productivity-enhancing effects on the cotton sector is estimated. Given the significant implications for the global cotton sector, they apply a multi-regional computable general equilibrium model of production and trade (GTAP model). The productivity gains from Bt cotton adoption are assessed using several farm-level impact studies and a 2001 multi-country cost of production survey for cotton by the International Cotton Advisory Council. Two no-adoption scenarios for WCA (with cotton productivity loss from recent trends and without) are contrasted with a partial Bt cotton adoption case, under an international environment where Bt cotton is also adopted elsewhere. The analysis shows that under the no Bt cotton adoption and current declining productivity trends, the cotton sector in WCA shows lower output and declining export shares compared to other regions. Even without total factor productivity loss, the pesticide-based cotton production system also results in eroding relative performance as other Bt adopting countries improve their world market positions. When WCA adopts Bt cotton, the cotton sector performs substantially better than under the status quo, and compares favorably with other regions.

*Cabanilla, L./Abdoulaye, T./Sanders, J. (2003), Economic Cost of Non-adoption of Bt Cotton In West Africa: With Special Reference to Mali, Paper presented at*

*the 7th International ICABR Conference held in Ravello, Italy, from June 29 to July 3, 2003*

This paper provides an ex-ante analysis of the potential benefits (both at the farm and national levels) of the introduction of Bt cotton in West Africa (with special reference to Mali). It uses a linear programming model to determine farm-level benefits and uses these results to aggregate national benefits. Cost of introduction is not explicitly tackled but a review of the experience in other countries indicates that the most practical approach to the introduction of the technology is to create an environment that allows the private sector to locally adapt and later market the technology for profit. This approach effectively addresses poor countries' financial and human resource constraints in technology adoption. Data used in estimating farm-level benefits were based on farmer interviews, expert opinion and, published country reports of yield and cost advantages of Bt cotton. The farm model used in the analysis explicitly took into consideration the food security requirement of the household. It also considered three states of nature to reflect different degrees of insect infestation. Aggregation of national benefits, were based on results from the farm-level analysis. Results from the analysis indicate that farm income from Bt cotton could be from two to three times higher per hectare compared to non-Bt cotton. Farm income is also more stable due to more effective control of insects. Translated at the national and regional levels, the aggregate benefits to farmers are estimated as $68 million in Mali, $41 million in Burkina Faso, $53 million in Benin, $39 million in Cote d'Ivoire and $8 million in Senegal. The reduction in insecticide use is an added environmental benefit. Assuming a 100% adoption rate, and a 3-liter per hectare reduction in insecticide application, Mali would be applying 1.5 thousand tons less insecticides, Burkina Faso 900 tons, Benin 1.1 thousand tons, Cote d'Ivoire 843 thousand tons and Senegal 165 thousand tons. Failure to utilize this improved technology will lead to increasing yield losses and/or higher insecticide costs, and, ultimately lead to loss of market share.

*Nuffield Council on Bioethics (2003), The use of genetically modified crops in developing countries*
*(http://www.nuffieldbioethics.org/fileLibrary/pdf/gm_crops_paper_final.pdf)*

This discussion paper is a follow-up to the Council's 1999 Report, Genetically modified crops: the ethical and social issues. The Paper reassesses the recommendations and conclusions in the light of recent developments in science and policy. The potential costs and benefits of the use of GM crops in developing countries are assessed. In eight case studies on different GMO applications the paper gives an overview over the use if GM crops in developing countries and gives information on their impact. It concludes that the possible costs, benefits and risks associated with particular GM crops must be assessed on a case by case basis. The Paper also discusses the impact of European regulations on GM crops in developing countries, and makes recommendation about policy, regulation and trade. Issues raised by food aid, micronutrient-enriched GM crops and the impact of GM crops on biodiversity are also considered.

*Evenson, R. (2003), GMOs: Prospects for increased crop productivity in developing countries, Yale University, Economic Growth Center, Center Discussion Paper No. 878 (http://www.econ.yale.edu/growth_pdf/cdp878.pdf)*

Genetically Modified Crops (GMO foods) have been widely available to farmers since 1996. The Gene Revolution, based on recombinant DNA (rDNA) genetic engineering techniques, is seen by proponents as both supplanting Green Revolution varieties, based on conventional plant breeding techniques, and potentially enabling "disadvantaged" production environments, unreached by Green Revolution varieties to achieve productivity improvements. This paper argues that the private firms supplying GM crop products have generally had little interest in selling products in disadvantaged production environments. The paper also argues that present rDNA techniques allow only static gains from specific "trait" improvements. But these GM products can be installed on Green Revolution varieties where continued dynamic varietal improvement is possible. As a consequence, the Gene Revolution complements the Green Revolution, and because trait incorporation expands area planted to Green Revolution varieties, there is potential for productivity improvement in disadvantaged environments.

*Bouis, H./Chassy, B./Ochanda, J. (2003), Genetically modified food crops and their contribution to human nutrition and food quality, Trends in Food Science & Technology, Volume 14, Issues 5-8, May-August 2003, p. 191-209*

The author discusses the potential contribution of GM technology to improve human nutrition and food quality and conducts a case study on the potential of breeding of iron- and beta-carotene-dense rice to help alleviate malnutrition.

*International Union of Nutritional Sciences (IUNS)/International Union for Toxicology (IUTOX) (2003), Genetically Modified Foods for Human Health and Nutrition, Vol. 14, Issues 5-8, May-August 2003, p. 169-338*

The purpose of this monograph is to provide an independent analysis of the scientific basis for assessing the benefits and risks of genetically modified (GM) crops and food, specifically in relation to their current and future impacts on human health and nutrition worldwide. In 2000, two of ICSU's member unions, the International Union of Nutritional Sciences (IUNS) and the International Union for Toxicology (IUTOX) initiated this project on GM food (GMF) and GM crops for human health and nutrition. Four other ICSU member unions and two ISCU scientific committees, representing a breadth of scientific interests, joined in the project. A monograph with ten specialized chapters was prepared to provide the basis for the Summary report and conclusions. Chapter 1 considers the role of science in the development and application of transgenic (genetic modification) technologies, in relation to the needs and concerns of society in general. Chapters 2 to 4 review topics pertaining to GM crops and food quality and human nutrition, improving agricultural practices, and industrial products and processes; Chapters 5 to 7 review GM fish, livestock, poultry, and microorganisms. Each of chapters 2 to 7 reviews current knowledge on the expected or potential contribution of genetic modification technology, outcomes and impacts of the use of GM organisms (GMOs), standards of use, methods for the

evaluation of outcomes and impacts, and knowledge gaps. Chapter 8 reviews the scientific basis for risk assessment of GMOs. Economic and social issues pertaining to the use and control of GMOs are reviewed in Chapter 9, and public attitudes towards GMFs are discussed in Chapter 10. Overall conclusions are outlined in Chapter 11. The monograph is intended to serve the increasing dialogue between society and science and thus contribute to ongoing discussions about the application of the technological innovations that make GMFs possible.

*Jackson, L.A. (2002), Who Benefits from Quality Labelling? Segregation Costs, International Trade and Producer Outcomes, University of Adelaide/Australia, Centre for International Economic Studies (CIES), CIES Discussion Paper No. 0231 (http://www.adelaide.edu.au/cies/0231.pdf)*

This paper analyses the impact of quality based labelling on product prices, factor allocation and the resulting effects on producers within the context of an international trading system. A general equilibrium model, calibrated to 1998 data, describes United States and European Union labelling regimes for genetically modified agricultural products. The results indicate that the labelling choice of trade partners have large distributive impacts within national economies, as well as across countries and highlight the importance of using general equilibrium framework to understand the system wide impacts of segregation and quality labelling.

*Jackson, L.A. (2002), Is Regulatory Harmonization Efficient? The Case of Agricultural Biotechnology Labelling, University of Adelaide/Australia, Centre for International Economic Studies (CIES), CIES Discussion Paper No. 0206 (http://www.adelaide.edu.au/cies/0206.pdf)*

This research uses a general equilibrium framework to examine the impacts of labelling policies on genetically modified (GM) agricultural products in the international trading system. The research focuses on the case of the policy debate between the United States and the European Union. Numerical calibrations of the general equilibrium model using 1998 data are used to examine four scenarios: both countries labelling, neither country labelling and the two cases when countries pursue mixed strategies. Results indicate that the benefits of countries pursuing mixed strategies outweigh the benefits of harmonized labelling policies. Countries that introduce labelling regulations restrict access to their agricultural markets. However, the benefits consumers obtain from having access to information about GM content compensate for the trade inefficiencies introduced by differing national labelling regulations.

*Srinivasan, C./Thirtle, C. (2003), Impact of terminator technologies for developing countries: A framework for economic analysis, Environment and Development Economics, Vol. 8, No. 1, p. 187-205*[13]

[13] This article has also been published in the book *Evenson, R./Santaniello, V./Zilberman, D. (eds.) (2002), Economic and social issues in agricultural biotechnology, Wallingford/UK, p. 159-180* and in the book *Swanson, Timothy (ed.) (2002), Biotechnology, Agriculture, and the*

The terminator gene can render seeds sterile, so forcing farmers to purchase fresh seed every year. It is a technological solution to the problem of market failure that could increase the appropriability of R&D investment more effectively than intellectual property rights legislation or patents. This paper shows that appropriability should be more than tripled and that this leads to greater private R&D investment, which may be expected to double or triple. This would bring open-pollinating varieties into line with F1 hybrids, for which seed cannot be saved. In turn, the increased investment should raise yield increases to levels similar to those for hybrid crops. Thus, there are benefits to set against the possible ecological and environmental costs and the clear distributional and social consequences. The paper discusses the way the seed market is developing, the possible impacts, especially from a developing country viewpoint, and considers the policy changes that are needed.

*Goeschl, T./Swanson, T. (2003), The development impact of genetic use restriction technologies: a forecast based on the hybrid crop experience, Environment and Development Economics, Vol. 8, No. 1, p. 149–165 (http://www.landecon.cam.ac.uk/cre/timo/ede+.pdf)*[14]

Advances in biotechnology have made available gene-manipulation techniques that enable the protection of genetic material from unauthorized use and the prevention of self-supply of commercial seeds by farmers—in order to allow enhanced appropriation of the values of innovation in agricultural R&D. These techniques have become known as Genetic Use Restriction Technologies (GURTs). This paper forecasts the potential impact of wide-spread adoption of GURTs by the providers of HYV seeds on the yield development in developing countries. To do so, it assesses (1) the effects of enhanced appropriation through GURTs on the technological expansion at the yield frontier and (2) the effects of technological protection of value-adding traits through GURTS on the diffusion of yield gains from the frontier to developing countries. These assessments are based on a particular hypothesis, which is that GURTs will replicate across most staple crops the experiences that were made with a previous use restriction technology (hybridization) in only a few crops. The estimation of impacts is carried out as a simulation and is based on expansion and diffusion parameters estimated for hybrid seeds over a 38-year period. It shows that the impact of GURTs on developing countries' yields will vary considerably. Specifically, those countries that currently have the lowest yields would be most adversely affected in their future yield development by the wide-spread use of GURTs.

*Swanson, T./Goeschl, T. (2002), The impact of GURTs on developing countries: a preliminary assessment, in: Swanson, Timothy (ed.), Biotechnology,*

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*Developing World, Edward Elgar Publishing, Cheltenham/UK and Northampton, MA/USA, p. 150-176.*

[14] This paper has also been published in *Swanson, Timothy (ed.) (2002), Biotechnology, Agriculture, and the Developing World, Edward Elgar Publishing, Cheltenham/UK and Northampton, MA/USA, p. 177-179* and in *Evenson, R./Santaniello, V./Zilberman, D. (eds.) (2002), Economic and social issues in agricultural biotechnology, Wallingford/UK, p. 182-192.*

*Agriculture, and the Developing World, Edward Elgar Publishing, Cheltenham/UK and Northampton, MA/USA, p. 177-179*

This book chapter sets out the basic framework for the analysis of the expected distributional impacts of Genetic Use Restriction Technologies (GURTs). It identifies the primary factor determining the expected impact of GURTs as the individual country's biotechnology capabilities, present or incipient. Nearly 100 different developing countries are classified by reference to the anticipated impact of the new technology. This exercise points to the importance of a further study, as it is found that nearly half of the developing countries will have their benefits determined by the rate of diffusion that exists under the new technology. The authors therefore examine another system directed to the same purpose: the hybrid crop variety study conducted by Goeschl/Swanson 2003. The authors further discuss the interrelationship between the appropriation system and the level of public spending and conclude with a consideration with policy implications of the advent of GURTs.

*Fisher, W. (2002), The Impact of "Terminator Gene" Technologies on Developing Countries, in: Swanson, Timothy (ed.), Biotechnology, Agriculture, and the Developing World, Edward Elgar Publishing, Cheltenham/UK and Northampton, MA/USA, p. 137-149 (http://www.law.harvard.edu/faculty/tfisher/terminator.html)*[15]

This article deals with the potential effects of the use of Genetic Use Restriction Technologies (GURTs) that could be used for protecting intellectual property. To assess the likely effects of these technologies on the societies and economies of developing countries, one needs first to understand the roles played by Intellectual Property Rights (IPRs) in those countries. Accordingly, the article first briefly reviews and evaluates the types of IPRs currently available for new plant varieties. It then evaluates potential roles of 'terminator' genes as supplements or substitutes for those IPRs and discusses their likely economic impact.

*Goeschl, T./Swanson, T. (2001), Genetic use restriction technologies and the diffusion of yield gains to developing countries, Journal of International Development, Vol. 12, Issue 8, p. 1159 – 1178*

The focus of this paper is the analysis of genetic use restriction technologies (GURTs) from the perspective of the diffusion of crop improvements to developing countries. One of the possible consequences of genetic use restriction technologies is a distinct downward shift in the growth trajectories of agricultural productivity in developing countries by restricting the flow of innovations to which these countries have had access in the past. In this case, developing countries are likely to face cumulative losses in agricultural productivity growth as a result of widespread adoption of GURTs by crop innovators. This paper presents the results of a study on hybrid crops, a

[15] This article was also published in 1999 in *Costs and Benefits to the Livelihoods of the Rural and Urban Poor Arising from the Application of So-Called "Terminator Genes" and Similar Technologies in Developing Countries, Report to the United Kingdom Department for International Development.*

precursor technology, to establish the negative effect of use restriction technologies on diffusion and discusses the implications of widespread use of GURTs for developing countries.

*Nielsen, C./Robinson, S./Thierfelder, K. (2002), Trade in genetically modified food: a survey of empirical studies, International Food Policy Research Institute, TMD Discussion Paper No. 106 (http://www.ifpri.org/divs/tmd/dp/papers/tmdp106.pdf)*

The paper surveys models that can be used for analyzing the market effects of GM technology. The results depend on a number of important issues such as the cost of market segmentation and labelling, the nature of the productivity shock to producers of GM products, and the extent of any adverse reaction to GM products by consumers. It concludes that through market linkages, the benefits of the new technology tend to be spread widely, with adopters generally gaining more than non-adopters. In particular, developing countries will benefit if they can adopt the new technologies, and get mixed results if they are non-adopters.

*Spillane, C. (2002), Agricultural biotechnology and developing countries: Proprietary knowledge and diffusion of benefits, in: Swanson, Timothy (ed.), Biotechnology, Agriculture, and the Developing World, Edward Elgar Publishing, Cheltenham/UK and Northampton, MA/USA, p. 67-134*

This book chapter surveys the current state of play in regard to the public and private roles in agricultural biotechnology in order to estimate the likely distributional effects of the use of Genetic Use Restriction Technologies (GURTs). The author demonstrates the many different fora within which the legal and institutional issues have been negotiated, and how these various discussions that have occurred about the respective roles of the private and the public sector in agricultural R&D. He further sets forth a wide range of policy alternatives that have been discussed in this regard.

*Pray, C./Govindasamy, R. (2002), The Importance of Intellectual Property Rights in the International Spread of Private Sector Agricultural Biotechnology, Paper presented at the 6th International ICABR Conference held in Ravello, Italy, from July 11-14, 2002 (http://www.economia.uniroma2.it/conferenze/icabr/papers/Paper/Pray2.zip)*

The purpose of this study is to provide an overview of the current status of research and commercial use of genetically modified (GM) crops worldwide and to quantify the importance of various policies – particularly intellectual property rights – to the spread of biotechnology research and commercial products. Data collected for this paper show that most of the applied agricultural biotech research is conducted by the private sector of which a substantial portion is by multinational corporations. Econometric analysis of this data finds that plant breeders rights and the ability to patent plants are associated with the spread of applied biotech research. Case studies of Argentina, Brazil, China and South Africa provide evidence that the benefits from GM crops primarily go to farmers and consumers rather than multinationals. Taken together the econometric analysis and case studies suggest that if policymakers in developing countries

strengthen intellectual property rights and allow the use of plant biotechnology, small farmers and consumers could increase their incomes.

*Albrecht, J. (2002), Biotechnology and micronutrient deficiencies in developing countries. A comparative economic assessment of Golden Rice, International Consortium on Agricultural Biotechnology Research (ICABR)*
*(http://www.economia.uniroma2.it/conferenze/icabr/papers/Paper/Albrecht.zip)*

Five interventions to combat vitamin A deficiency in developing countries are compared in a model with different income groups: gardening and education programs, food fortification, vitamin A supplementation, Golden Rice and Golden Rice ++ (i.e. a new variety with more provitamin A and higher yields for rice farmers). In the model, the entitlement approach is linked to Malthusian variables and a micronutrient threshold level under which the productivity of agricultural labourers is reduced. For each income category, the ranking order of the five interventions is different. Supplementation is the most effective intervention but this is not a long-term option, as it should be complemented with other strategies to reduce micronutrient deficiencies and the need for supplementation. For the lowest income group, Golden Rice is a more attractive strategy than gardening and fortification. For the higher income groups, gardening and fortification are more effective in terms of vitamin A delivery. With inclusion of all the costs to make each program effective and working for the period 2003-2020, the overall cost-effectiveness of Golden Rice strongly exceeds that of gardening and fortification.

*Robertson, R./Unnevehr, L. (2001), Golden Rice: What Benefits Can Be Realized?, Paper presented at the 6$^{th}$ International Conference on Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer held at Ravello (Italy) from July 11 to 14, 2001*

The intention of the developers of Golden Rice was to address vitamin A deficiency in less developed countries and the technology has been donated to the International Rice Research Institute in order to facilitate its adaptation and dissemination. It has received widespread media attention as an example of the potential benefits from biotechnology. However, there are several socio-economic questions to be resolved before these benefits can be realized. This paper will explore those questions and review what previous studies indicate about the answers. First, with respect to the nutritional issue, the paper will review the evidence regarding the incidence and effects of vitamin A deficiency, and the impact of past intervention programs. How many consumers in what sub-populations are affected by vitamin A deficiency? What are the effects of deficiency? How many are estimated to live where rice is an important staple? As vitamin A deficiency is particularly acute for small children with limited variety in their diets, we will use a publicly available data set on child malnutrition from the Philippines to examine what small children eat and to estimate what would happen if they substituted golden rice for the rice they currently consume. This will provide one example of potential benefits. Then, the paper will explore production and marketing scenarios. Can this trait be incorporated into existing modern varieties? Will it have similar yield, costs of

production, and adaptability in intensive irrigated areas of Asia? What hypothetical percentage of Asian area would supply golden rice to the estimated number of vitamin A deficit rice consumers? In order to reach vitamin A deficient consumers, will this rice need to be grown by those who eat it? Will consumers who need it purchase it in the marketplace? If the niche is primarily weaning foods, then how will it reach that market? What kinds of supporting nutrition education programs might be needed to facilitate acceptance? Finally, the paper will conclude with a discussion of the potential social welfare gains in Asia from development and adoption of golden rice. We will compare rough estimates of the costs to society (e.g. costs of further research and development to have varieties that will grow under Asian conditions; costs of testing to ensure consumer and environmental safety; any inward shift of supply curve if higher production costs or if environmental costs) with the benefits to society from reduced morbidity and mortality. Are benefits likely to outweigh costs? Will the CB ratio for this be greater than other potential interventions?

*Nielsen, C./Robinson, S./Thierfelder, A. (2001), Genetic Engineering and Trade: Panacea or Dilemma for Developing Countries, World Development, Vol. 29, No. 8, p. 1307-1324*

Advocates of the use of genetic engineering techniques in agriculture contend that this new biotechnology promises increased productivity, better use of natural resources and more nutritious foods. Opponents are concerned about potentially adverse implications for the environment and food safety. In response to consumer reactions against genetically modified (GM) foods, in some countries crop production is being segregated into GM and non-GM varieties. This analysis finds that world markets for maize and soybeans adjust well to these changes in important trading partner countries.

*Paarlberg, R. (2001), The politics of precaution. Genetically modified crops in developing countries, Johns Hopkins University Press, Baltimore/Maryland*

The book looks at the policy choices regarding GM food made by four important developing countries: Kenya, Brazil, India, and China. Of these, so far only China has approved the planting of GM crops. Paarlberg identifies five policy areas in which governments of developing countries can either support or discourage GM crops: intellectual property rights, biosafety, trade, food safety, and public research and investment. He notes that highly cautious biosafety policies have so far been the key reason that Kenya, Brazil, and India have hesitated to plant GM crops. These cautious policies have been strongly reinforced by international market forces and international diplomatic and NGO pressures. China has been less cautious toward GM crops, in part because there is less opportunity in China for international organizations or independent critics of GM crops to challenge official policy.

*Evenson, R. (2001), From Green Revolution to Gene Revolution, Paper presented at the 6th International Conference on Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer held at Ravello (Italy) from July 11 to 14, 2001*

This paper reviews a recently completed study of the green revolution. It shows that, for several crops, the diffusion of high-yielding (quantitative) plant types depended on (qualitative) traits. These traits included host plant resistance (HPR) to plant diseases and to insect pests, and host plant tolerance (HPT) to abiotic stresses (drought, submergence, etc.). The incorporation of traits in the green revolution was achieved utilizing conventional breeding and wide crossing methods. The first generation techniques available in the gene revolution enable breeders to incorporate HPR and HPT traits through genetic engineering techniques. The gene revolution in its early stages thus constitutes a continuation of green revolution strategies with expanded opportunities for achieving trait expression. The distributional implications, both within countries and between countries, of HPR-HPT trait incorporation have been important. As more HPR-HPT traits have been incorporated into successive generations of varieties, access to high-yield crop germplasm has been expanded to more areas and eco-systems. This expansion has had favourable income and nutritional consequences. The natural congruity of first generation biotechnology products thus also has favourable income and nutritional prospects. A detailed study of rice biotechnology developments will be used to show how biotechnology can produce favourable distributional consequences and how a disparity in access to biotechnology methods between developed and developing countries is very unfavourable to developing countries.

*Marra, M. (2001), Agricultural Biotechnology: A Critical Review of the Impact. Evidence to Date, in: Pradey, Philip G. (ed.), The future of food. Biotechnology Markets and Policies in an International Setting, Washington D.C., IFPRI, p. 155-184*

Marra systematically scrutinizes all the empirical evidence available in the public domain of the impacts of the first generation of transgenic crops in the United States and elsewhere. The types of potential benefits are described and discussed as well as the systematic biases introduced into some of the estimates because input quantities are not set at the relevant technology-specific optimum. Overall, the evidence indicates these technologies are profitable for farmers although the impacts vary by year and location. Transgenic cotton (containing DNA from soil bacteria that produce proteins to control the types of caterpillars that attack cotton plants) shows reduced pesticide use in most years in most U.S. states; pest-resistant corn shows small but significant yield increases in most years across the U.S. Corn Belt (and for some places in some years the increase is substantial); and, despite evidence of small yield losses in Roundup Ready soybean varieties in many U.S. states, other cost savings seem to more than offset the lost revenue from the yield discrepancy. Evidence of the effects of transgenic crops in other countries is provided as well.

*DFID Plant Sciences Research Programme (2000), Proceedings of the international workshop on "Transgenic Potatoes for the Benefit of Resource-Poor Farmers in Developing Countries" held in Manchester/UK, 5-9 June 2000 (http://www.dfid-psp.org/publications/Transgenic-pots-2000/index.html)*

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*Srinivasan, C.S./Thirtle C. (2000), Policy arena: genetically modified organisms and smallholders in the developing world, Journal of International Development 12(8), p. 1131-1132*

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*Binenbaum, E:/Nottenburg, C./Pardey, P./Wright, B./Zambrano, P. (2000), South-North Trade, Intellectual Property Jurisdictions, and Freedom to Operate in Agricultural Research on Staple Crops, International Food Research Institute (IFPRI), Environment and Production Technology Division (EPTD), EPTD Discussion Paper No. 70 (http://www.ifpri.org/divs/eptd/dp/papers/eptdp70.pdf)*

A biotechnology revolution is proceeding in tandem with international proliferation of intellectual property regimes and rights. Does the intellectual property impede agricultural research conducted in, or of consequence for, developing countries? This question has important spatial dimensions that link the location of production, the pattern of international trade, and the jurisdiction of intellectual property. Our main conclusion is that the current concerns about the freedom to operate in agricultural research oriented towards food crops for the developing world are exaggerated. Rights to intellectual property are confined to the jurisdictions where they are granted, and, presently, many of the intellectual property (IP) rights for biotechnologies potentially useful to developing-country agricultural producers are valid only in developed countries. IP problems might arise in technologies destined for crops grown in developing countries unencumbered by IP restrictions, if those crops are subsequently exported to countries in which IP is likely to prevail. Thus freedom to trade is also part of the IP story. However, using international production and trade data in the 15 crops critical to food security throughout the developing world, we show that exports from developing to developed countries are generally dwarfed by production and consumption in the developing world, the value of these exports is concentrated in a few crops and a few exporting countries, and the bulk of these exports go to Western Europe. Thus for now, most LDC researchers can focus primarily on domestic IPR in determining their freedom to operate with respect to food staples. Undue concern with current freedom to operate is diverting attention from the lack of financial and technical support necessary for the effective generation, evaluation, adaptation, and regulation of newly available technologies by public and international nonprofit breeders in LDCs, given the continued inability of private-sector research to fill the gap.

*Maredia, M. (1998), The Economics of Biosafety: implications for biotechnology in developing countries, Michigan State University, Department of Agricultural Economics, Staff Paper 98-5*
*(http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=590)*

There is a growing body of literature on the safe use of biotechnology and the need for an international biosafety protocol and national regulations to facilitate the safe development and transfer of biotechnology. Most of these studies, however, address

the issue of biosafety from a scientific, legal, environmental and organizational perspective. The purpose of this paper is to add to this discussion by providing an economic perspective on regulating products of agricultural biotechnology, with special emphasis on implications for developing countries who are under increasing pressure to put a biosafety framework in place. The paper provides a brief discussion on the economic rationale for biosafety regulations, explains the economic benefits and costs of biosafety, and discusses the appropriate form of biosafety policy and the effects of regulation on resource allocation. The benefits of biosafety discussed include - the reduction of possible human and environmental risks of biotechnology products and "accident" costs to the society; increased predictability for a research organization of the expected time and money to get a new product on the market; making the products of biotechnology accessible to a country; and the provision of certainty and stability to the social framework, necessary for the development of biotechnology research and development activities. Developing countries should balance these potential benefits with the tangible costs of biosafety regulation to the biotechnology organizations and the society. To a biotechnology organization, biosafety will increase the research lag, production costs, transaction costs and marketing costs. Given the scarcity of human and physical resources, setting up a biosafety system also poses opportunity costs to the society. The following issues need careful examination in designing a biosafety policy in a developing country: the goal of biosafety policy; the appropriate means of controlling risk; the impact of biosafety on scientific development and private investments; the impact of biosafety on the international transfer of technology and international trade; the incidence of biosafety costs; and the size of biosafety system.

### a) Country Specific Studies on the Impact of GMOs

*Dirección Nacional de Mercados Agroalimentarios/Food and Agriculture Organization (2004), Costos invrementales de la segrecación de maíz y soja no OVM en Argentina, documento preparado por el Instituto de Economía y Sociología del INTA, Buenos Aires, junio de 2004, CD-ROM*

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Country: Argentina

*De Leon, A./Manalo, A./Guilatco, F.C./Gloriani-Barzaga, N.(2004), The Cost Implications of GM Food Labeling in the Philippines, Philippine Bureau of Food and Drugs (BFAD)/USAID*
*(http://www.bcp.org.ph/downloads/Cost%20Implications%20of%20GM%20Food%20Labeling%20in%20the%20Philippines.pdf)*

In this study, the impact of mandatory GM food labelling in the Philippines was evaluated from the standpoint of all stakeholders concerned, focusing on two GM products, soybean and corn, which are found in the daily diet of Filipinos. A significant portion of the study examined the cost implications of mandatory labelling of GM food products to the farmers, traders and manufacturers, the government, and consumers.

Country: Philippines

*De Leon, A./Manalo, A./Guilatco, F.C./Gloriani-Barzaga, N. (2004), The Cost Implications of GM Food Labeling in the Philippines, International Service for the Acquisition of Agri-biotech Applications (ISAAA), Crop Biotech Brief, Vol. 4, No. 2 (http://www.isaaa.org/kc/Publications/pdfs/briefs/Brief4-2.pdf)*

This paper is a summary version of the previous one.

Country: Philippines

*Kuta Danladi, D. (2004), GM technology to benefit farmers in Nigeria, AgBiotech Net, Vol. 6*
*(http://www.agbiotechnet.com/reviews/Database/feb04/html/ABN120.htm)*

Nigeria, with favourable agro-climatic conditions and an estimated cultivable land area of 71.2 million hectares, can produce food crops exceeding the volume required to feed its over 120 million people and export the excess to diversify its revenue base. Despite this potential, Nigeria remains a low-income food-deficit country due mainly to low agricultural productivity. The bulk of the agricultural production in Nigeria is done by resource-poor rural farmers, who practice unimproved crop husbandry, grow crop varieties that can not tolerate/resist water stress, insect pests, diseases, nematodes and other field and post-harvest constraints. Though many farmers are interested in adopting herbicide technology in weed management, the need to combine different types of costly herbicides for effective control of broad range of weeds discourages them from the technology. A recent survey has demonstrated several needs for GM intervention, including rice varieties that can tolerate water stress and glyphosate herbicide; cowpea cultivars that can resist insect pests; plantain/banana clones that are nematode-resistant; cassava genotypes with broad resistance to viral diseases. These demands have stimulated the interest of the Nigerian government in the acquisition of biotechnology capability in the country. Already, a National Biotechnology Policy has been formulated and relevant biotechnology agencies and laboratory are being established to promote the exploitation of biotechnology for the benefit of farmers in Nigeria.

Country: Nigeria

*Pray, C./Bengali, P./Ramaswami, B. (2004), Costs and Benefits of Biosafety Regulation in India: A Preliminary Assessment, Paper presented at the 8th ICABR Conference, Ravello (Italy), 8-11 July*
*(http://www.economia.uniroma2.it/conferenze/icabr2004/papers/Pray.C.zip)*

The paper presents the costs incurred and estimated by firms and government research institutes in India to obtain regulatory approval of GM crops, specifically Bt cotton. The direct costs include the costs of research and laboratory trials need to fulfill information requests by the regulators and also the government's costs of the bureaucracy for implementing the regulatory rules. The indirect costs or opportunity costs are farmers' foregone incomes and the biotech industry's foregone profits if regulation prevented the sale of safe and profitable technology.

After describing the Indian current regulatory system and an economic framework for evaluating food safety and environmental regulation and enforcement, we present preliminary findings on costs. We then analyze the impact of direct costs on biotech research done by private and public research institutes, the structure of seed industry and the impact of indirect costs on social welfare. We finally run alternative policy scenarios to suggest that improving the efficiency of the system – reducing the years required for approval and the costs of research required – would have a large positive income impact on both farmers and seed companies.

Country: India

*Mentaberry, A. (2003), Transgenic crops in the Argentinean agriculture, In: Vasil, I. K. (ed.), Plant biotechnology 2002 and beyond, Dordrecht/Netherlands, p. 205-209*

This paper covers the trends and status of transgenic crops in Argentina, highlighting the regulatory systems for the release of genetically modified crops and the non-economical benefits of transgenic crop production in the country. The future trends in the further adoption of transgenic plant varieties in Argentina are briefly discussed based on the generally supportive public attitude towards scientific and technological advancement.

Country: Argentina

*Trigo, E.J./Cap, E.J. (2003). The impact of the introduction of transgenic crops in Argentinean agriculture, AgBioForum, 6(3), 87-94*

Since the early 1990s, Argentinean grain production underwent a dramatic increase in grains production (from 26 million tons in 1988/89 to over 75 million tons in 2002/2003). Several factors contributed to this "revolution," but probably one of the most important was the introduction of new genetic modification (GM) technologies, specifically herbicide-tolerant soybeans. This article analyses this process, reporting on the economic benefits accruing to producers and other participating actors as well as some of the environmental and social impacts that could be associated with the introduction of the new technologies. In doing so, it lends attention to the synergies between GM soybeans and reduced-tillage technologies and also explores some of the institutional factors that shed light on the success of this case, including aspects such as the early availability of a reliable biosafety mechanism and a special intellectual property rights (IPR) situation. In its concluding comments, this article also posts a number of questions about the replicability of the experience and some pending policy issues regarding the future exploitation of GM technologies in Argentina.

Country: Argentina

*Contini, E./Sampaio, M.J. (2003), Biotechnology potential impact in Brazil, Paper presented at the 7$^{th}$ International ICABR Conference held in Ravello, Italy, from June 29 to July 3, 2003*

The legal prohibition of the commercial use of glyphosate tolerant soybeans in 1998 which induced a kind of "moratorium" and the new environmental biosafety measures to control experimental and commercial use of GMO crops in Brazil have economic consequences for the farmers and for the agribusiness. Some important crops could be cultivated in large scale such as soybeans, which events have been available since 1998, or corn and cotton, available since 2000. This paper deals with the following questions are: what would be the benefits to the farmers if they could be planting transgenic crops? What is the Brazilian economy loosing due to a less competitive crop production in comparison with other exporting countries such as Argentina and China? The potential benefits will be estimated for two crop groups: a) cotton, corn and soybeans and b) papaya and beans, with are in the final research stage. For soybeans we will deduce from the total benefits the actual area cultivated with GMO although illegal. To estimate the adoption rate of each GMO and the potential benefits we will utilize information from other countries. Information on cultivated areas of each crop, decease and pest control costs and other parameters will be obtained from official Brazilian agencies. Initial cost impact of certification, identity preservation and labelling will also be considered.

Country: Brazil

*Avila, A.F./Quirino, T.R./Contini, E./Rech Filho, E.L. (2001), Social and economic impact ex-ante evaluation of Embrapa's biotechnology research products. Paper presented at the the 5th International Conference on "Biotechnology, Science and Modern Agriculture: a New Industry at the Dawn of the Century" held at June 15-18, 2001 at Ravello, Italy (http://www.embrapa.br/unidades/uc/sge/ImpactoBiotecnologia.pdf)*[16]

The study discusses the potential benefits of GMO research conducted by the Brazilian public agricultural research institute EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária). The authors give rather vague estimations on the impacts of the introduction of biotechnology innovations for five commodities (soybeans, cotton, potatoes, papaya and beans). They distinguish between the social and environmental effects on producers, consumers, processing and distribution systems and other effects. The likely benefits are estimated to be substantial so that the amount spent annually through the Embrapa biotechnology program (around US$14.4 millions, in 2000) will generate high returns for the Brazilian society. Only the economic impacts expected from the new transgenic varieties of beans are estimated to be enough to compensate these investments.

Country: Brazil

*Anderson, K./Yao, S. (2003), China, GMOs, and world trade in agricultural and textile products, Pacific Economic Review, Vol. 8, No. 2, p. 157-169*[17]

[16] This paper was also published in *Evenson, R./Santaniello, V./Zilberman, D. (eds.) (2002), Economic and social issues in agricultural biotechnology, Wallingford/UK, p. 287-307.*

China has always strived for self-sufficiency in farm products, particularly staple foods. Its rapid industrialization following its opening up to global markets during the past two decades has been making that more difficult, and its accession to the WTO may add to that difficulty. New agricultural biotechnologies could ease that situation. However, the adoption and spread of some of those biotechnologies in agriculture have raised concerns, particularly over the environmental and food safety effects of genetically modified organisms (GMOs). This paper focuses on possible implications of the GMO controversy for China, since it is prospectively not only a major producer and consumer of GM farm products but also a potential exporter of some of them. It explores the potential economic effects of China not adopting versus adopting GMOs when some of its trading partners adopt that technology. The effects are shown to depend to a considerable extent on the trade policy stance taken in high-income countries opposed to GMOs and/or to liberalization of China's trade in textiles and apparel.

Country: China

*Huang, J./Hu, R./Wang, Q./Keeley, J./Falck-Zepeda, J. (2002), Agricultural Biotechnology Policy and Impact in China, Economic and Political Weekly [India], 37 (27) (Review of Science Studies), 6-12 July, p. 2756-61 (http://www.ids.ac.uk/ids/env/PDFs/China%20PaperEPW.pdf)*

China is developing the largest plant biotechnology capacity outside North America and an impressive list of genetically modified (GM) crops under trial. However, underlying these achievements is a growing concern among policy-makers about the impact of the global biotechnology debate on China's agricultural trade. Like many other developing countries, it has now to address serious questions on the future of biotechnology in the country.

Country: China

*Zhao, F./Wahl, T./McCluskey, J. (2001), Biotechnology and the WTO: Implications for US-China Grain Trade, Paper presented at the 6th International Conference on Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer held at Ravello (Italy) from July 11 to 14, 2001*

China's is exploring the adoption of GMO wheat, rice, and corn. Adoption of these crops in the US has been mixed because of consumer reaction, both domestic and in some importing countries. The potential effects of a ban of GMO imports is potentially devastating to GMO producers and the companies that own the technologies. The WTO agreement allows bans that are based upon internationally accepted science, but the debate on the implications for GMO continues. China has suggested that it will ban the imports of GMO crops if other

[17] This article was published in 2001 as a discussion paper of the Centre for International Economic Studies (CIES), University of Adelaide/Australia (CIES Discussion Paper 0126, http://www.adelaide.edu.au/cies/0126.pdf) and presented as a paper at the 4th Annual Conference on Global Economic Analysis, Purdue University, West Lafayette, 27-29 June 2001.

countries are allowed to do so. The November 1999, US-China bilateral WTO agreement eliminates trade barriers on agricultural products. However, the potential effects on trade in GMO products is unclear. To examine these effects on China and US grain markets, a multi-region, multi-commodity partial equilibrium model is estimated. The effects of alternative trade liberalization scenarios, including restrictions on trade in GMO crops and the effects on US biotechnology firms, are examined.

Country: China, USA

*Chauvet, M./Gonzalez, R.L./Massieu, Y. (2001), GMOs and Social Consequences in Mexico, Paper presented at the 4th International Symposium "Perspectives of the Agri-food System in the new Millennium" held in Bologna (Italy), 5-8 September 2001*

Despite agricultural biotechnology is developed at industrialized societies, in the lesser developed countries like Mexico, agricultural biotechnology is present. The purpose of this paper is to identify and discuss the social consequences of biotechnology. It gives a general background about transgenic crops in Mexico and specific cases of them: tomato, cotton, corn and potato. Perspectives from social networks theory is used in the analysis. We argue that it is very important that transgenic plants in Mexico are aimed to solve Mexican agriculture problems and not only to benefit multinational agro biotechnology company's interests. To achieve this, it is necessary for the country to have scientific and institutional capabilities in order to assess, for each crop and ecosystem, the possible socio-economic, ecological and health impacts. It has to exist, also, a monitoring activity of transgenic crops' evolution, which can help new research about them.

Country: Mexico

**b) Country and Crop Specific Studies on the Impact of GMOs**

Cotton

*Qaim, M./De Janvry, A. (forthcoming), Bt Cotton and Pesticide Use in Argentina: Economic and Environmental Effects, Accepted for publication in Environment and Development Economics*
*(http://www.einaudi.cornell.edu/conf/2003/gmopoverty/pdf/Qaim_on_Argentina.pdf)*

This paper analyzes the effects of Bt cotton on pesticide use and agricultural productivity in Argentina. Based on farm survey data, it is shown that the technology reduces application rates of toxic chemicals by 50%, while significantly increasing yields. Using a production function and damage control framework, the effectiveness of Bt versus chemical pesticides is estimated, and technological impacts are predicted for different farm types. Results show that gross benefits could be highest for smallholder farmers, who are not currently using the technology. The durability of the advantages is analyzed by simulating resistance development in different pest populations over time. Biological models that have been calibrated with Argentine parameters suggest that rapid resistance buildup and associated pest outbreaks are unlikely if minimum non-Bt

refuge areas are maintained. Promoting a more widespread diffusion of Bt cotton under these conditions would therefore amplify the efficiency, equity, and sustainable environmental gains.

Country: Argentina
Crop: Cotton

*Qaim, M./De Janvry, A. (2004), Cheaper GM Seeds Could Boost Adoption, Farm Benefits and Company Profits: The Case of Bt Cotton in Argentina, International Service for the Acquisition of Agri-biotech Applications (ISAAA), Crop Biotech Brief, Vol. 4, No. 1 (http://www.isaaa.org/kc/Publications/pdfs/briefs/Brief4-1.pdf)*

This article summarizes the findings of Qaim/de Janvry 2003.

Country: Argentina
Crop: Cotton

*Qaim, M./De Janvry, A. (2003), Genetically Modified Crops, Corporate Pricing Strategies, and Farmers' Adoption: The Case of Bt Cotton in Argentina, American Journal of Agricultural Economics, Vol. 85, No. 4, p. 814-828*

This article analyzes adoption and impacts of Bt cotton in Argentina against the background of monopoly pricing. Based on survey data, it is shown that the technology significantly reduces insecticide applications and increases yields; however, these advantages are curbed by the high price charged for genetically modified seeds. Using the contingent valuation method, it is shown that farmers' average willingness to pay is less than half the actual technology price. A lower price would not only increase benefits for growers, but could also multiply company profits, thus resulting in a Pareto improvement. Implications of the sub-optimal pricing strategy are discussed.

Country: Argentina
Crop: Cotton

*Qaim, M./Cap, E.J./De Janvry, A. (2003), Agronomics and sustainability of transgenic cotton in Argentina, AgBioForum, 6(1&2), p. 41-47 (http://www.agbioforum.org/v6n12/v6n12a10-qaim.htm)*

Transgenic Bt cotton can halve pesticide application rates in Argentina while significantly increasing yields. Yield effects are bigger than in other countries, due to the current low levels of insecticide use. Although smallholder farmers are not currently using the technology, gross benefits are predicted to be highest for them. Biological model simulations show that rapid resistance buildup in pest populations appears to be unlikely if minimum non-Bt refuge areas are maintained.

Country: Argentina
Crop: Cotton

*Roca, C. (2003), Impacto económico de la soja y el algodón transgénicos en Argentina, Asociación Semilleros Argentinos*

*(http://www.argenbio.org/h/biblioteca/pdf/impacto-economico.pdf)*

Country: Argentina
Crop: Cotton, Soybean

*Traxler, G./Godoy-Avila, S. (2004), Transgenic cotton in Mexico, AgBioForum, Vol. 7, No. 1-2, p. 57-62 (http://www.agbioforum.org/v7n12/v7n12a11-traxler.pdf)*

We examine the farm-level impact of Bt cotton in Coahuila, Mexico. Bt cotton was introduced in Mexico in 1996. It has been an important tool in reducing pesticide use by more than 50% and generating annual benefits of US$2.7 million. About 85% of benefits accrued to farmers and 15% to seed suppliers. Adopting farmers spent $100 less on pest control and had $295/ha higher net revenue than non-adopting farmers. The average holding of adopting farmers was 14 ha. Bt cotton has been a valuable technology for certain areas in Mexico. Cotton profitability and competitiveness have increased, and the risk of crop failure from insect infestation has been reduced. Victory over the pink bollworm, once the dominant insect pest, would not have been possible without Bt cotton. Because Bt cotton protects only against a certain spectrum of the pest population, national adoption stands at 33%.

Country: Mexico
Crop: Cotton

*Traxler, G./Godoy-Avila, S./Falck-Zepeda, J./Espinoza-Arellano, J. (2003), Transgenic cotton in Mexico: economic and environmental impacts, In: Kalaitzandonakes, N. (ed.), The economic and environmental impacts of agbiotech: a global perspective, New York, USA, Kluwer-Plenum Academic Publishers*

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Country: Mexico
Crop: Cotton

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

The authors examine the impact of the adoption of Bt cotton in the Comarca Lagunera region in northern Mexico in 1997 and 1998. They 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. The 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 technology. 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.

Country: Mexico
Crop: Cotton

*Falck-Zepeda, J./Traxler, G./Godoy-Avila, S./Espinoza-Arellano, J. (2001), Analysis of the Distribution Welfare From the Introduction of Transgenic Cotton Varieties in Mexico: A Case Study of the Coahuila-Durango Region, Paper presented at the 6th International Conference on Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer held at Ravello (Italy) from July 11 to 14, 2001*

Abstract available at http://www.economia.uniroma2.it/conferenze/icabr01/abstract/Falck.htm

Country: Mexico
Crop: Cotton

*Bennett, R./Morse, S./Ismael, Y./Shankar, B. (2005), Reductions in Insecticide Use from Adoption of BT Cotton in South Africa: Impacts on Economic Performance and Toxic Load to the Environment, Journal of Agricultural Science*, *Vol. 142, p. 1-10*

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Country: South Africa
Crop: Cotton

*Shankar, B. (2005), Pesticide Productivity and Transgenic Cotton Technology: The South African Smallholder Case, Journal of Agricultural Economics, Vol. 56, No. 1 (Accepted for publication, forthcoming)*[18]

[18] This paper has been presented as *Shankar, Bhavani/Thirtle, Colin (2003), Pesticide overuse and Bt cotton – evidence from South Africa* at the 7th International ICABR Conference held in Ravello, Italy, from June 29 to July 3, 2003 (http://www.economia.uniroma2.it/conferenze/icabr2003/papers/Environment/Shankar.zip) under the title "Pesticide Productivity and Transgenic Cotton Technology: The South African Smallholder Case" as a working paper of the

This paper empirically investigates how the productivity of pesticides differs in Bt versus non-Bt technology for South African cotton smallholders and the implications for pesticide use levels in the two technologies. This is accomplished by applying a damage control framework to farm-level data from Makhathini flats, KwaZulu-Natal. Contrary to findings elsewhere, notably China, that farmers tend to over-use pesticides and that transgenic technology benefits farmers primarily by enabling huge reductions in pesticide use, the econometric evidence here indicates that non-Bt smallholders in South Africa underuse pesticide and that the main contribution of the new technology is to enable them to realize the lost productivity resulting from under-use. By providing a natural substitute for pesticide, the Bt technology enables the smallholders to circumvent credit and labour constraints associated with pesticide application. Thus the same technology that greatly reduces pesticide applications but only mildly affects yields when used by large-scale farmers in China and elsewhere, benefits South-African smallholder farmers primarily via a yield-enhancing effect.

Country: South Africa
Crop: Cotton

*Bennett, R./Morse, S./Ismael, Y. (2003), The benefits of Bt cotton to small-scale producers in developing countries – the case of South Africa, Paper presented at the 7th International ICABR Conference held in Ravello, Italy, from June 29 to July 3, 2003*
*(http://www.economia.uniroma2.it/conferenze/icabr2003/papers/Economic_Impact/Bennett%20R..zip)*

Results of a large-scale survey of resource-poor smallholder cotton farmers in South Africa over three years (the first such study in Sub-Saharan Africa) show that adopters of the genetically-modified variety Bt (Bacillus thuringiensis) cotton have reaped the benefits of adoption in terms of higher yields, lower pesticide use and less labour for pesticide application. Despite the higher cost of the Bt seed, Bt adopters achieved substantially higher gross margins per hectare over the three years, including one very wet year unfavourable to growing cotton. The pattern of adoption and performance showed that, after the first year of adoption, the smallest producers benefited from adoption of the Bt variety as much, if not more, than the larger producers. Indeed, the results suggest that the Bt variety helped to reduce the risk of crop failure, to which the smallest growers may be most vulnerable. Moreover, there is evidence from hospital records (showing cases of insecticide poisonings) to suggest that there have been substantial benefits to human health with the decline in use of bollworm insecticides due to adoption of the new variety.

Country: South Africa
Crop: Cotton

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Deptartment of Agricultural & Food Economics, University of Reading, UK (http://www.apd.rdg.ac.uk/AgEcon/research/workingpapers/JAE%20submission%20BS%20Jun%2003.pdf).

*Beyers, L./Gouse, M./Hadley, D./Piesse, J./Thirtle, C. (2003), GM and polluting inputs in South African Agricultural production: A non-parametric analysis of potential input reduction, Paper presented at the 7th International ICABR Conference held in Ravello, Italy, from June 29 to July 3, 2003*

Genetically modified crops are rapidly becoming important in South Africa, with commercial releases of Bt cotton to both smallholders and commercial farmers, yellow maize to commercial farmers and white maize to smallholders. Applying standard data envelopment analysis (DEA) programming techniques to farm-level data for the available samples gives comparative estimates of technical and scale efficiencies. However, all inputs are assumed to be reduced in the same proportion when restrictive, simple radial measures are used. This is not appropriate for Bt seed varieties, which are expected to result in biased input reductions. Pesticide inputs particularly should be reduced and also labour. To measure the input reductions, radial measures are adjusted for slack variables and non-radial measures are used. The results suggest that the input reductions are seriously biased, so that simple radial measures are misleading and that there are consistent differences between the gains to smallholders, relative to commercial farmers, with the smallholders achieving greater percentage gains. Estimates of the extent to which crop protection inputs can be reduced vary from 7% to 29%.

Country: South Africa
Crop: Cotton, Maize

*Kirsten, J./Gouse, M. (2003), The Adoption and Impact of Agricultural Biotechnology in South Africa, in: Kalaitzandonakes, N. (ed.), The economic and environmental impacts of agbiotech: a global perspective, New York, USA, Kluwer-Plenum Academic Publishers*[19]

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Country: South Africa
Crop: Cotton, Maize

*Kirsten, J./Gouse, M. (2002), Bt Cotton in South Africa: Adoption and the Impact on Farm Incomes Amongst Small-scale and Large-scale Farmers, Paper presented at the 6th International Conference on "Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer" held at Ravello (Italy) from July 11 to 14, 2002*

South African farmers have met the introduction of insect-resistant cotton with reactions varying between blind enthusiasm, cautious pessimism and downright disregard. This paper focus on the reasons and effects of Bt cotton adoption by large-scale and small-scale farmers in South Africa. In an analysis using data on large-scale farmers, factors such as area planted, age, education and credit did

[19] This paper has also been published as Working Paper of 2002-09 of the Department of Agricultural Economics, Extension and Rural Development of the University of Pretoria, South Africa (http://www.up.ac.za/academic/ecoagric/fulltext/2002-25.pdf).

not render significant results as reasons of adoption. The authors announced that later studies will focus more on this aspect. For this paper they propose that the perceived and real benefits as indicated by seed agents and observed through own cotton production experience can be accepted as partial reasons for adoption of the new technology. Compared to small-scale farmers the increased yield benefit is not that important to large-scale farmers. Although more than 50% of large-scale farmers indicated increased yield as a benefit, it is seen more as a bonus. The big advantage for large-scale farmers is that insect-resistant cotton gives them the peace of mind and the managerial freedom to go on with other farming activities. Despite a higher seed cost and the additional technology fee, both large-scale and small-scale farmers realise net incomes per hectare due to the higher yield and savings on pesticide chemicals. In addition to the monetary measures of success in adopting Bt cotton, we also explored the technical efficiency of the large-scale cotton producers. For this purpose, the data envelopment analysis (DEA) model that has been widely applied to efficiency measurement problems, was used in this study. Results indicate that the adopters are far more technically efficient, on average, than the non-adopters.

Country: South Africa
Crop: Cotton

*Kirsten, J./Gouse, M./Jenkins, L. (2002), Bt cotton in South Africa: adoption and impact on farm incomes amongst small- and large-scale farmers, Virginia Tech University, Blacksburg, VA, Information Systems for Biotechnology (ISB), ISB News Report, p. 7-9 (http://www.isb.vt.edu/news/2002/oct02.pdf)*

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Country: South Africa
Crop: Cotton

*Ismael, Y./Bennett, R./Morse, S. (2002), Benefits from Bt cotton use by smallholder farmers in South Africa, AgBioForum, Vol. 5, No. 1, p. 1-5 (http://www.agbioforum.org/v5n1/v5n1a01-morse.pdf)*

This paper describes the results of research conducted in the Makhathini region, Kwazulu Natal, Republic of South Africa, designed to explore the economic benefits of the adoption of Bt cotton for smallholders. Results suggest that Bt cotton had higher yields than non-Bt varieties and generated greater revenue. Seed costs for Bt cotton were double those of non-Bt, although pesticide costs were lower. On balance, the gross margins (revenue – costs) of Bt growers were higher than those of non-Bt growers.

Country: South Africa
Crop: Cotton

*Beyers, L./Ismael, Y./Piesse, J./Thirtle, C. (2002), Can GM-Technologies Help the Poor? The Efficiency of BT Cotton Adopters in the Makhathini Flats of Kwazulu-Natal, in: Agrekon, Vol. 41, No. 1, p. 62-74*[20]

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Country: South Africa
Crop: Cotton

*Ismael, Y./Bennett, R./Morse, S. (2001), Can farmers in the developing countries benefit from modern technology? Experience from Makhathini Flats, Republic of South Africa, International Service for the Acquisition of Agri-biotech Applications (ISAAA), Crop Biotech Brief, Vol. 1, No. 5*
*(http://www.isaaa.org/kc/Publications/pdfs/briefs/brief1-5.pdf)*

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Country: South Africa
Crop: Cotton

*Ismael, Y./Bennett, R./Morse, S. (2001), Biotechnology in Africa: The adoption and economic impacts of Bt cotton in the Makhathini flats, Republic of South Africa, Paper presented at the AfricaBio conference "Biotechnology in Africa", held 26th-27th September, 2001, in Johannesburg/South Africa*
*(http://www.agbioworld.org/biotech_info/topics/agbiotech/africa.pdf)*

The research intends to shed some light on the polarised debate about the use of agricultural biotechnology in the developing world, especially in Africa. The research reported here charts the pattern of smallholder adoption and the agronomic/economic impact in the first two seasons of the release of a genetically-modified (GM) crop – Bt cotton – in the Republic of South Africa. The paper discusses a number of issues concerning the uptake of the technology. The farmers who adopted the Bt cotton variety benefited from the technology. The increased in yields and reduction in pesticide outweighed the higher seed cost, so that the gross margins were also considerably higher for adopters especially in the wet second season.. The result gives considerable cause for cautious optimism regarding the economic impact of Bt cotton. However, further years of data are required before final judgement of the economic benefits of the GM crop can be made.

Country: South Africa
Crop: Cotton

*Barwale, R.B./Gadwal, V.R./Zehr, U./Zehr, B. (2004), Prospects for Bt cotton technology in India, AgBioForum, Vol. 7 No. 1-2, p. 23-26*
*(http://www.agbioforum.org/v7n12/v7n12a04-zehr.pdf)*

[20] This paper was also presented at the ISNAR Consultation "Biotechnology and Rural Livelihood — Enhancing the Benefits" held in The Hague/Netherlands in 2001.

Cotton is a very important crop in India; farmers there face the challenge of losses due to various insect pests. The first genetically modified crop in India, Bt cotton, has been introduced to address bollworm infestation. The process of introduction of Bt cotton took six years of experimentation, during which time agronomic, environmental, and biosafety data was generated and reported. The trials conducted prior to commercialization clearly established the superior performance of Bt cotton, as demonstrated by increased yields and reduction in application of pesticides. Transgenic technology is suitable for the Indian farmer despite small farm holdings. The area under Bt cotton is projected to increase rapidly in the coming years.

Country: India
Crop: Cotton

*Stone, G.D. (2004), Biotechnology and the Political Ecology of Information in India, Human Organization, Vol. 63, No. 2*
*(http://www.artsci.wustl.edu/~anthro/research/StoneHumanOrg2004.pdf)*

The move of crop biotechnology into the south raises issues about effects on cultural agricultural practices. The case of recently introduced genetically modified cotton in India is used to explore how crop biotechnology can affect change in processes underlying local practice. The particular focus is agricultural skilling—acquiring information and adopting management practices derived from that information—based on both environmental learning and cultural transmission. Impediments to skilling include inconsistency, unrecognizability, and overly rapid technological change; these processes may lead to agricultural deskilling, which has similarities to and differences from industrial deskilling. India's first genetically engineered crop, Bt cotton, has recently been released into an unsustainable situation plagued by deskilling, yet biotechnology has brought new disruptions of information flows and thus of the skilling process. The India case shows how susceptible to political manipulation the cultural agricultural practices become when skilling is disrupted.

Country: India
Crop: Cotton

*Stone, G.D. (2002), Biotechnology and Suicide in India, Washington University, St. Louis*
*(http://www.artsci.wustl.edu/~anthro/research/biotech_suicide.html)*

The article explores the potential contribution of the market introduction of Bt cotton in India to the incidence of mass suicide in the Warangal District of Andhra Pradesh, India. Stone argues that the suicides can be attributed to the indebtedness of cotton farmers who are spending more and more money on agricultural inputs and who are victims of excessive interest rates. He points out that, even if the suicides can not be attributed to the use of Bt cotton alone, the rising costs for agricultural technology applications like Bt cotton can contribute to tragedies like the one that has happened in Andra Pradesh. Stone further argues that Warangal farmers need much tighter regulation at the point-of-sale (the input

vendors) and that the protection of privately owned intellectual property rights to agricultural technologies like Bt cotton could aggravate social problems in the Warangal district, if it comes at the expense of the point-of-sale regulation that the farmers need. He points out that the socioeconomic effects of biotechnology applications depend on the degree to which they are consistent with agricultural sustainability. According to Stone, this consistence is achieved rather by public sector research than by private sector research. For instance, cotton varieties that are resistant to economically more important pests than bollworm could be more beneficial to farmers in Andra Pradesh than Bt cotton. The author concludes by stating that anthropological perspectives are sorely needed in the debate about the impacts of biotechnology applications in developing countries.

Country: India
Crop: Cotton

*Pemsl, D./Orphal, J. (2003), Bt Cotton – Productivity Considerations from India and China, Paper presented at the conference "Deutscher Tropentag 2003" on International Research on Food Security, Natural Resource Management and Rural Development at the University of Göttingen (Germany), October 8-10, 2003 (http://www.cottonipmasia.org/source/Article/Bt-Cotton%20Productivity.pdf)*

Previous studies, which assess Bt cotton, claim a sharp reduction in pesticide use accompanied by significant human health and environmental benefits. But none of these studies captures long-term productivity effects or the stochastic nature of main parameters. A recent study on Bt cotton productivity in India does not even consider the production costs and product prices at all. Moreover, the validity to generalize study results from one region is questionable and analyses mainly based on short-term empirical studies might lead to wrong conclusions about the net benefits of Bt crops. The analysis presented in this paper uses farm level data from Bt case studies in China and India. Based on plot level input data for cotton, production functions are estimated separately for each country. A damage control function following the approach of Lichtenberg and Zilbermann is incorporated to account for the special nature of the Bt trait that is not directly yield increasing but prevents pest induced crop loss. To adequately assess the farm level economic viability of the Bt technology it is necessary to account for uncertainty of main parameters. Some variables fluctuate following an underlying probability distribution (e.g. pest pressure and precipitation which determine the required irrigation or pesticide application and hence influence production costs). These variables are included as stochastic parameters in the simulation of gross margins. The approach presented here complements existing analyses by including uncertainty aspects in the assessment of Bt cotton productivity.

Country: India, China
Crop: Cotton

*Qaim, M. (2003), Bt Cotton in India: Field Trial Results and Economic Projections, World Development Vol. 31, No. 12, p. 2115–2127*

The performance of Bt cotton in India is analyzed on the basis of field trial data from 2001. The amounts of pesticides applied during the trials were reduced to one-third of what was used in conventional cotton, while—under severe pest pressure—yield gains were 80%. Productivity effects are modeled econometrically with a damage-control specification. The first approval for the commercial cultivation of Bt hybrids was given in 2002. By 2005, the technology is expected to cover one-quarter of total Indian cotton area. Medium-term projections show sizeable welfare gains for the overall economy, with farmers being the main beneficiaries.

Country: India
Crop: Cotton

*Qaim, M./Zilberman, D. (2003), Yield effects of genetically modified crops in developing countries, Science, Feb 7, 2003, Vol. 299, Issue 5608, p. 900-903*

On-farm field trials carried out with Bacillus thuringiensis (Bt) cotton in different states of India show that the technology substantially reduces pest damage and increases yields. The yield gains are much higher than what has been reported for other countries where genetically modified crops were used mostly to replace and enhance chemical pest control. In many developing countries, small-scale farmers especially suffer big pest-related yield losses because of technical and economic constraints. Pest-resistant genetically modified crops can contribute to increased yields and agricultural growth in those situations, as the case of Bt cotton in India demonstrates.

Country: India
Crop: Cotton

*Zhang, B.-H./Wang, Q.-L./Wang, K.-B./Zhou, D./Liu, F. (2003), Bt cotton in India, Current Science, Vol. 86, No. 6, 25 March 2004, p. 758-760*

This article critically comments on *Qaim, M./Zilberman, D. (2003), Yield effects of genetically modified crops in developing countries, Science 299, p. 900-902.*

Country: India
Crop: Cotton

*Hossain, F./Pray, C./Lu, Y./Huang, J./Fan, C./Hu, R. (2004), Genetically Modified Cotton and Farmers' Health in China, International Journal of Occupational and Environmental Health, Vol. 10, No. 3, p. 296-303*
*(http://www.ijoeh.com/pfds/1003_Hossain.pdf)*

This study provides the first evidence of a direct link between the adoption of a genetically modified (GM) crop and improvements in human health. Estimation of the impact of Bacillus thuringiensis (Bt) cotton adoption on pesticide use from data from a survey of cotton farmers in northern China, 1999–2001, showed that Bt cotton adoption reduced pesticide use. Assessment of a health-production function showed that predicted pesticide use had a positive impact on poisoning

incidence. Taken together, these results indicate that the adoption of Bt cotton can substantially reduce the risk and the incidence of poisonings.

Country: China
Crop: Cotton

*Huang, J./Hu, R./Van Meijl, H. /Van Tongeren, F. (2004), Biotechnology boosts to crop productivity in China: trade and welfare implications, Journal of Development Economics, Vol. 75, Issue 1, p. 27-54*[21]

Genetically modified (GM) cotton is widely adopted and the list of GM technologies in trials is impressive in China. At the same time there is an active debate on when China should commercialize its GM food crops. This paper provides an economy-wide assessment of some of the issues surrounding the adoption and commercialization of biotechnology. Based on unique data from empirical micro-level study and field trials in China and a modified GTAP model, our results indicate that the development of biotechnology has an important impact on China's production, trade and welfare. Welfare gains far outweigh the public biotechnology research expenditures. Most gains occur inside China, and can be achieved independently from biotech-unfriendly polices adopted in some industrialized countries.

Country: China
Crop: Cotton, Rice

*Huang, J./Hu, R./Fan, C./Pray, C./Rozelle, S. (2003), Bt cotton benefits, costs and impacts in China, Institute of Development Studies (IDS), Brighton (England), IDS Working Paper 202 (http://www.ids.ac.uk/ids/bookshop/wp/wp202.pdf)*

The overall goal of this paper is to reexamine findings of earlier efforts that analysed the effect of Bt cotton adoption in 1999 with two follow-up surveys conducted in 2000 and 2001. Our survey data on yields and econometric analyses indicate that the adoption of Bt cotton continues to increase output per hectare in 2000 and 2001 and that the yield gains extend to all provinces in our sample. More importantly, Bt cotton farmers also increased their incomes by being reducing use of pesticides and labour inputs. Finally, survey data shows that Bt cotton continues to have positive environmental impacts by reducing pesticide use. We provide evidence that farmers have less health problems because of reduced pesticide use. We conclude with evidence that China is not unique and that there are lessons for other developing countries in their experience.

Country: China
Crop: Cotton

[21] This paper is an uptdated version of Huang, Jikun/Hu, Ruifa/van Meijl, Hans/van Tongeren, Frank (2003), Economic impacts of genetically modified crops in China, in: Proceedings of the 25th International Conference of Agricultural Economists (IAAE) in Durban, South Africa, 16-22 August 2003. It has also been published by the Agricultural Economics Research Institute (LEI), The Hague, Netherlands (http://www.lei.dlo.nl/publicaties/PDF/2002/8_xxx/8_02_06.pdf).

*Huang, J./Hu, R./Pray, C./Qiao, F./Rozelle, S. (2003), Biotechnology as an alternative to chemical pesticides: a case study of Bt cotton in China, Agricultural Economics, Vol. 29, p. 55–67*

The overall goal of this study is to determine the extent by which genetically engineered (GE) crops in China can lead to reductions of pesticide use, the nature and source of the reductions, and whether or not there are any non-pecuniary externalities. One of the first studies of the effect of plant biotechnology on poor farmers, the study is based on a data set collected by the authors in 2000 in North China. The paper's descriptive, budget and multivariate analysis find that Bt cotton significantly reduces the number of sprayings, the quantity of pesticides used and the level of pesticide expenditures. All Bt cotton varieties—both those produced by foreign life science companies and those created by China's research system are equally effective. In addition to these input-reducing effects, the paper also demonstrates that such reductions in pesticides also likely lead to labour savings, more efficient overall production, as well as positive health and environmental impacts.

Country: China
Crop: Cotton

*Pemsl, D./Waibel, H./Gutierrez, A.P. (2003), Productivity analysis of Bt cotton: a modelling approach, Paper presented at the 7th International ICABR Conference on Productivity, Public Goods and Public Policy: Agricultural Biotechnology Potentials, Ravello (Italy), June 29 to July 3, 2003*
*(http://www.economia.uniroma2.it/conferenze/icabr2003/papers/Economic_Impact/Pemsl.zip)*

Bt cotton varieties are considered an effective method to control the cotton bollworm, a major pest of cotton. To assess the impact of Bt varieties on cotton productivity a methodology is required that accounts for the short-term and long-term effects of the Bt trait in the cotton production system. In this paper the results from a village level case study of 150 farmers in Shandong province, China, are used to assess the short-term productivity of Bt cotton. The first step is the estimation of a production function with damage control function and the computation of marginal factor productivity of the two damage abatement agents, Bt trait and chemical pesticides. The paper concludes that the econometric procedure may not capture the true input-output relationships due to factors that are difficult to measure empirically in the context of small-scale cotton farming in China. Hence it is submitted that a bio-economic modelling approach might be more appropriate especially to assess the long-term productivity effects of Bt cotton.

Country: China
Crop: Cotton

*Frisvold, G./Reeves, J.M. (2003), International impacts of Bt cotton adoption, Paper presented at the 7th International ICABR Conference on Productivity, Public*

*Goods and Public Policy: Agricultural Biotechnology Potentials, Ravello (Italy), June 29 to July 3, 2003*

This study uses a 3-region mathematical programming model to estimate the impacts of Bt cotton adoption in the United States and China, the two dominant growers of Bt cotton. The impacts of Bt cotton adoption on world price, cotton purchasers, and cotton producers in the U.S., China and the Rest of World are assessed. Bt cotton can reduce adopter pest control costs and increase yields. Yet, greater production at an aggregate level lowers prices received by all producers. Cotton purchasers globally gain from Bt cotton adoption, as do adopters in the U.S, and China. In contrast, there are significant losses to non-adopters in the Rest of World. The model results illustrate how US commodity programs shelter US producers from the price-reducing effects of domestic and overseas adoption. Given provisions of the new US farm bill, further overseas adoption will continue to have minimal impacts on US producer returns, but more significant impacts on US commodity program outlays.

Country: China, USA
Crop: Cotton

*Huang, J./Hu, R./Rozelle, S./Qiao, F./Pray, C. (2002), Transgenic varieties and productivity of smallholder cotton farmers in China, Australian Journal of Agricultural and Resource Economics, Vol. 46, No. 3, p. 367-387*[22]

Genetically modified cotton varieties have greater production efficiency for smallholders in farming communities in China. We also find that the adoption of Bacillus thuringiensis (Bt) cotton varieties leads to a significant decrease in the use of pesticides. Hence, we demonstrate that Bt cotton appears to be an agricultural technology that improves both production efficiency and the environment. In terms of policies, our findings suggest that the government should investigate whether or not they should make additional investments to spread Bt to other cotton regions and to other crops.

Country: China
Crop: Cotton

*Lu, Y./Pray, C./Hossain, F. (2002), An econometric analysis of the reduction in pesticide poisoning due to Bt cotton use in China, Paper presented at the 6th International ICABR Conference, held in Ravello (Italy), July 11-14, 2002 (http://www.economia.uniroma2.it/conferenze/icabr/papers/Paper/Pray3.zip)*

This study provides the first evidence of a direct link between the adoption of a GM crop and improvements in human health. The authors modeled the linkage as a health production function with farmers' reports of poisonings as the dependent variable and pesticide use, farmers' characteristics, and environment as independent

[22] This article has also been published as a book chapter under the title "Smallholders, Transgenic Varieties and Production Efficiency: the Case of Cotton Farmers in China" in: Evenson, R.E./Santaniello, V./Zilberman, D. (eds.), Economic and Social Issues in Agricultural Biotechnology, CABI Publishing, Wallingford/UK, p. 393-407.

variables. We hypothesized that the main impact of Bt cotton on poisoning would be through its impact on pesticide use. Therefore, we first estimated the impact of Bt cotton adoption on pesticide use using data from a survey of 400 cotton farmers in northern China. Our estimates showed that Bt cotton use reduced pesticide use. We then estimated the health production function and found that predicted pesticide use had a positive impact on poisoning. Adding a Bt cotton variable to the health function we found that it have a small negative impact on poisonings in addition to its impact through pesticide use. This probably picks up the separate impact of the number of times farmers sprayed. Taken together these results indicate that the adoption of Bt will lead to a major reduction in the risk and the incidence of poisonings. The marginal impact of one more hectare of Bt cotton use on the probability of farmers having pesticide poisoning was calculated using the logit specification of the health function. We found that an increase in one hectare reduces the probability of poisoning by 12.5 percent. Using data from the poisson specification, we calculated that the marginal decrease in the number of poisonings due to increasing Bt cotton adoption by one hectare was 0.15. This evidence strongly suggests that when assessing the debate on GM crops policy makers should put more weight on the well documented risks of pesticide poisoning rather than the speculative risks of Bt to consumer's and farmer's health and to the environment. It also suggests that the recent decisions of Indonesia and India to adopt Bt cotton technology are well justified and that other cotton growing countries should also consider using this technology.

Country: China
Crop: Cotton

*Pray, C./Huang, J./Hu, R./Rozelle, S. (2002), Five years of Bt cotton in China – the benefits continue, The Plant Journal, Vol. 31, Nr. 4, p. 423-430*

Bt cotton is spreading very rapidly in China, in response to demand from farmers for technology that will reduce both the cost of pesticide applications and exposure to pesticides, and will free up time for other tasks. Based on surveys of hundreds of farmers in the Yellow River cotton-growing region in northern China in 1999, 2000 and 2001, over 4 million smallholders have been able to increase yield per hectare, and reduce pesticide costs, time spent spraying dangerous pesticides, and illnesses due to pesticide poisoning. The expansion of this cost-saving technology is increasing the supply of cotton and pushing down the price, but prices are still sufficiently high for adopters of Bt cotton to make substantial gains in net income.

Country: China
Crop: Cotton

*Pray, C./Ma, D./Huang, J./Qiao, F. (2001), Impact of Bt cotton in China, World Development, Vol. 29, Nr. 5, p. 813-825*

Bt cotton is spreading very rapidly in China, in response to demand from farmers for technology that will reduce both the cost of pesticide applications and exposure to pesticides, and will free up time for other tasks. Based on surveys of hundreds of farmers in the Yellow River cotton-growing region in northern China

in 1999, 2000 and 2001, over 4 million smallholders have been able to increase yield per hectare, and reduce pesticide costs, time spent spraying dangerous pesticides, and illnesses due to pesticide poisoning. The expansion of this cost-saving technology is increasing the supply of cotton and pushing down the price, but prices are still sufficiently high for adopters of Bt cotton to make substantial gains in net income.

Country: China
Crop: Cotton

*Price, G./Lin, W. (2001), The Distribution of Benefits Resulting from Biotechnology Adoption, Paper presented at the 6th International Conference on Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer held at Ravello (Italy) from July 11 to 14, 2001*[23]

The purpose of this study is to estimate the distribution of benefits from adopting Bt cotton and herbicide-tolerant soybeans in 1997. The stakeholders considered are U.S. farmers and consumers, the technologies' innovators, and producers and consumers in the rest of the world (ROW).

Full abstract available at
*http://www.economia.uniroma2.it/conferenze/icabr01/abstract/Price.htm*

Country: USA, rest of the world
Crop: Cotton, Soybean

*Falck-Zepeda, J./Traxler, G./Nelson, R. (2000), Surplus distribution from the introduction of a biotechnology innovation, American Journal of Agricultural Economics, Vol. 82, Issue 2, p. 360-369*

The authors examine the distribution of welfare from the introduction of Bt cotton in the United States in 1996. The welfare framework explicitly recognizes that research protected by intellectual property rights generates monopoly profits, and makes it possible to partition these rents among consumers, farmers, and the innovating input firms. They calculate a total increase in world surplus of ST0.3 million for 1996. Of this total, the largest share (59%) went to U.S. farmers. The gene developer, Monsanto, received the next largest share (21%), followed by U.S. consumers (9%), the rest of the world (6%), and the germplasm supplier, Delta and Pine Land Company (5%).

Country: USA, rest of the world
Crop: Cotton

*Falck-Zepeda, J./Traxler, G./Nelson, R. (2000), Rent Creation and Distribution From Biotechnology Innovations: The Case of Bt Cotton and Herbicide-Tolerant Soybeans in 1997, Agribusiness, February 2000, Vol. 16, Issue 1 , p. 21-32*

[23] This paper has also been published as Price, Gregory/Lin, William/Falck-Zepeda, José/Fernandez-Cornejo, Jorge (2003), Size and Distribution of Market Benefits From Adopting Biotech Crops, United States Department of Agriculture (USDA), Economic Research Service, Technical Bulletin No. 1906 (http://www.ers.usda.gov/publications/tb1906/tb1906.pdf).

The authors examine the distribution of welfare from the second-year planting of Bt cotton in the United States in 1997. We also provide preliminary estimates of the planting of herbicide-tolerant soybeans in 1997. For Bt cotton, total increase in world surplus was $190.1 million and US farmer share of total surplus was 42%. The gene developer, Monsanto, received 35% and the rest of the world 6% of the total world surplus. Delta and Pine Land received 9%, whereas US consumers received 7%. For herbicide-tolerant soybeans, total world surplus was $1,061.7 million. US farmers' surplus was 76%, Monsanto's was 7%, US consumers received 4%, and seed companies captured 3% of total surplus.

Country: USA, rest of the world
Crop: Cotton, Soybean

*Traxler, G./Falck-Zepeda, J. (1999), The distribution of benefits from the introduction of transgenic cotton varieties, AgBioForum 2(2): 94-98*

Some concern has been expressed about the potential for abuse of monopoly power in the marketing of genetically modified (GM) seeds in the United States (US). Are the firms marketing GM seeds extracting all of the benefits generated by their products? We attempt to partition the benefits from the introduction of Bacillus thuringiensis (Bt) cotton in the United States among United States domestic and rest of the world consumers of cotton lint, the gene-supplying firm, the germplasm-supplier, and US cotton farmers. The benefit calculations were based on comparisons of pest control costs and yields for Bt and conventional cotton varieties. We estimate that an average of more than $200 million per year in benefits were generated by the use of Bt cotton. In each year, US farmers received the largest single share of benefits, ranging from 42% to 59% of total surplus generated. The combined share of Monsanto and the seed firms ranged from 26% to 44%.

Country: USA, rest of the world
Crop: Cotton

Soybean

*Chang, C.-C./Hsu, S.-H./Wu, C.-H. (2004), An Economy-wide Analysis of GM Food Labeling Policies in Taiwan, AAEA Annual Meeting, Denver/CO, USA (http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=14277&ftype=.pdf)*

Abstract

Country: Taiwan
Crop: Soybean, Maize

*De Leon, A./Manalo, A./Guilatco, F.C./Gloriani-Barzaga, N. (2004), The Cost Implications of GM Food Labeling in the Philippines, Philippine Bureau of Food and Drugs (BFAD)/USAID (http://www.bcp.org.ph/downloads/Cost%20Implications%20of%20GM%20Food%20Labeling%20in%20the%20Philippines.pdf)*

Abstract

Country: Philippines
Crop: Soybean, Maize

*De Leon, A./Manalo, A./Guilatco, F.C./Gloriani-Barzaga, N. (2004), The Cost Implications of GM Food Labeling in the Philippines, International Service for the Acquisition of Agri-biotech Applications (ISAAA), Crop Biotech Brief, Vol. 4, No. 2 (http://www.isaaa.org/kc/Publications/pdfs/briefs/Brief4-2.pdf)*

This paper is a summary version of the previous one.

Country: Philippines
Crop: Soybean, Maize

*Qaim, M./Traxler, G. (forthcoming), Roundup Ready Soybeans in Argentina: Farm Level and Aggregate Welfare Effects, Accepted for publication in Agricultural Economics*[24]

Although adoption rates of genetically modified crops have been staggering in some countries, there is still comparatively little evidence about biotechnology impacts under diverse agroecological and institutional conditions. These knowledge gaps lead to an overly precautious attitude among policy makers and the public. This paper analyses the effects of Roundup Ready (RR) soybeans in Argentina, the country with the second biggest transgenic area worldwide. Based on recent survey data, it is shown that the technology increases total factor productivity by 10% on average, with cost savings being somewhat more pronounced for smaller than for larger farms. The reduction in use of toxic herbicides and of tillage operations entails positive environmental repercussions. Aggregate welfare effects are computed over the 1996–2001 period with a three-region, partial equilibrium model, comprising Argentina, the US, and the rest of the world. In 2001, RR soybeans created more than 1.2 billion US$ of economic surplus at the global level. The largest share went to consumers (53%), followed by seed and biotechnology firms (34%), and agricultural producers (13%). Due to comparatively weak intellectual property protection, and thus only small technology mark-ups in seed prices and widespread adoption, Argentinean soybean growers receive 90% of the benefits in that country. This demonstrates that farmers in developing countries can gain considerably when they obtain access to suitable foreign innovations through technology spillovers.

Country: Argentina
Crop: Soybean

*Trigo, E./Lopez, A./Chudnovsky, D./Cap, E. (2004), Los transgénicos en la agricultura argentina. Una historia con final abierto, Trade Knowledge Network/International Institute for Sustainable Development (IISD)/ International*

[24] This article has been presented as a paper at the 6th International ICABR Conference held in Ravello, Italy, July 11-14, 2002. The paper can be downloaded at http://www.economia.uniroma2.it/conferenze/icabr/papers/Paper/qaim.zip.

*Centre for Trade and Sustainable Development (ICTSD)/ Centro de Investigationes para la Transformación (CENIT)*
*(http://www.tradeknowledgenetwork.org/pdf/tkn_transgenic_argentina_es.pdf)*

This study looks at the impacts, mostly in terms of economic effects, but also to some extent looking at social and environmental effects, of Argentina's unprecedented mass adoption of genetically modified soy. It also examines the regulatory system in Argentina for approval of such crops, assessing its strengths and weaknesses.

Country: Argentina
Crop: Soybean

*Penna, J.A./Lema, D. (2003), Adoption of Herbicide Tolerant Soybeans in Argentina: An Economic Analysis, in: Kalaitzandonakes, N. (ed.), The economic and environmental impacts of agbiotech: a global perspective, New York, USA, Kluwer-Plenum Academic Publishers*

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Country: Argentina
Crop: Soybean

*Roca, C. (2003), Impacto económico de la soja y el algodón transgénicos en Argentina, Asociación Semilleros Argentinos*
*(http://www.argenbio.org/h/biblioteca/pdf/impacto-economico.pdf)*

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Country: Argentina
Crop: Soybean, Cotton

*Brookes, G. (2003), The farm level impact of using Roundup Ready soybeans in Romania, Brookes West, Kent, UK*
*(http://www.pgeconomics.co.uk/pdf/GM_soybeans_Romania.pdf)*[25]

Romania has the third highest soybean area in Europe with about 75,000 hectares in 2003. Roundup Ready soybeans have been grown in commercial scale since 1999 and its use has increased to 55%-60% by 2003. Farmers planting genetically modified soybeans in Romania, particularly Roundup Ready soybeans, have experienced an average impact on yield by 31%. The significant yield improvement is due to improved weed control. Most of the farmers also benefited from a 2%-3% improvement in the price received for their soybeans from improved harvest quality due to less weed impurities. Apart from higher yields, Brookes found additional benefits associated with the use of GM soybeans: increased convenience and management flexibility for farmers, small savings from harvest costs as less time is spent on harvesting, and improved

[25] This paper has also been presented at the 8th ICABR International Conference on Agricultural Biotechnology: International Trade and Domestic Production" held in Ravello (Italy), July 8 - 11, 2004.

weed control and hence reduced use of herbicides in the production of follow-on corn crops.

Country: Romania
Crop: Soybean

*Price, G./Lin, W. (2001), The Distribution of Benefits Resulting from Biotechnology Adoption, Paper presented at the 6th International Conference on Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer held at Ravello (Italy) from July 11 to 14, 2001*[26]

Abstract

Country: USA, rest of the world
Crop: Soybean, Cotton

*Falck-Zepeda, J./Traxler, G./Nelson, R. (2000), Rent Creation and Distribution From Biotechnology Innovations: The Case of Bt Cotton and Herbicide-Tolerant Soybeans in 1997, Agribusiness, February 2000, Vol. 16, Issue 1 , p. 21-32*

Abstract

Country: USA, rest of the world
Crop: Soybean, Cotton

Rice

*Huang, J./Hu, R./Rozelle, S./Pray, C. (2005), Insect-Resistant GM Rice in Farmers' Fields: Assessing Productivity and Health Effects in China, Science 308(5722), 29 April, p. 688-690*

Although no country to date has released a major genetically modified (GM) food grain crop, China is on the threshold of commercializing GM rice. This paper studies two of the four GM varieties that are now in farm-level preproduction trials, the last step before commercialization. Farm surveys of randomly selected farm households that are cultivating the insect-resistant GM rice varieties, without the aid of experimental station technicians, demonstrate that when compared with households cultivating non-GM rice, small and poor farm households benefit from adopting GM rice by both higher crop yields and reduced use of pesticides, which also contribute to improved health.

Country: China
Crop: Rice

[26] This paper has also been published as Price, Gregory/Lin, William/Falck-Zepeda, José/Fernandez-Cornejo, Jorge (2003), Size and Distribution of Market Benefits From Adopting Biotech Crops, United States Department of Agriculture (USDA), Economic Research Service, Technical Bulletin No. 1906 (http://www.ers.usda.gov/publications/tb1906/tb1906.pdf).

*Huang, J./Hu, R./Van Meijl, H./Van Tongeren, F. (2004), Biotechnology boosts to crop productivity in China: trade and welfare implications, Journal of Development Economics, Vol. 75, Issue 1, p. 27-54*[27]

Abstract

Country: China
Crop: Rice, Cotton

*Zimmermann, R./Qaim, M. (2004), Potential health benefits of Golden Rice: a Philippine case study, Food Policy, Vol. 29, Issue 2, p. 147–168*

Golden Rice has been genetically modified to produce beta-carotene in the endosperm of grain. It could improve the vitamin A status of deficient food consumers, especially women and children in developing countries. This paper analyses potential impacts in a Philippine context. Since the technology is still at the stage of R&D, benefits are simulated with a scenario approach. Health effects are quantified using the methodology of disability-adjusted life years (DALYs). Golden Rice will not completely eliminate the problems of vitamin A deficiency, such as blindness or increased mortality. Therefore, it should be seen as a complement rather than a substitute for alternative micronutrient interventions. Yet the technology could bring about significant benefits. Depending on the underlying assumptions, annual health improvements are worth between US$ 16 and 88 million, and rates of return on R&D investments range between 66% and 133%. Due to the uncertainty related to key parameters, these results should be treated as preliminary.

Country: Philippines
Crop: Rice

*Zimmermann, R./Qaim, M. (2002), Projecting the benefits of Golden Rice in the Philippines, Zentrum für Entwicklungsforschung (ZEF), Bonn/Germany, ZEF Discussion Paper 51 (http://www.zef.de/download/zef_dp/zef_dp51.PDF)*[28]

Golden Rice has been genetically engineered to produce beta-carotene in the endosperm of the grain. It could improve the vitamin A status of deficient food consumers, especially women and children in the developing world. This paper analyses the potential impacts in a Philippine context. Since the technology is still at the stage of R&D, benefits are simulated within a scenario approach. The health effects are quantified using the methodology of disability-adjusted life years (DALYs). Golden Rice will not completely eliminate the problems of vitamin A deficiency, such as blindness or increased mortality rates. So it should be seen

[27] This paper is an uptdated version of Huang, Jikun/Hu, Ruifa/van Meijl, Hans/van Tongeren, Frank (2003), Economic impacts of genetically modified crops in China, in: Proceedings of the 25th International Conference of Agricultural Economists (IAAE) in Durban, South Africa, 16-22 August 2003. It has also been published by the Agricultural Economics Research Institute (LEI), The Hague, Netherlands (http://www.lei.dlo.nl/publicaties/PDF/2002/8_xxx/8_02_06.pdf).

[28] This paper has also been presented at the 6th International Conference on Agricultural Biotechnologies on "New Avenues for Production, Consumption and Technology" Transfer held in Ravello, Italy, July 11-14, 2002.

as a complement rather than a substitute for alternative interventions. Yet, the technology will reduce related health costs significantly. In monetary terms, annual gains will lie between $23 million and $137 million, depending on the underlying assumptions. A preliminary cost-benefit analysis shows high returns on R&D investments. Micronutrient-enriched crops are an efficient way to reduce deficiency problems among the poor, and related research projects should receive higher political priority.

Country: Philippines
Crop: Rice

*Dawe, D./Robertson, R./Unnevehr, L. (2002), Golden Rice: what role could it play in alleviation of vitamin A deficiency?, Food Policy, Vol. 27, Issues 5–6, p. 541–560*

Golden rice (GR) is a new rice variety that has been genetically modified to contain beta-carotene, a source of vitamin A. This modification was undertaken as a strategy to address VAD, which is widespread in less developed countries of Asia. Children's food intake data from a poor rural region of the Philippines are used to simulate the potential impact of GR on vitamin A intake. The potential impact, coverage of deficient subpopulations, and costs of GR are compared to two other interventions, food fortification and supplementation. While investments in future development of GR compare favourably with other interventions in terms of costs and coverage, GR would deliver amounts of vitamin A that are modest, and unlikely to fulfil requirements. Thus, it should be viewed as a complement to existing interventions. To have greatest impact at a cost comparable with wheat fortification, GR varieties should be suited for widespread adoption in Asia and should deliver as much beta-carotene as possible.

Country: Philippines
Crop: Rice

*Hareau, G./Mills, B.F./Norton, G.W./Bosch, D. (2002), The Economic Impact of Genetically Modified Organisms in Small Developing Countries, Paper prepared for presentation at the Annual Meeting of the American Agricultural Economics Association, Long Beach, CA, July 28-31, 2002*
*(http://www.agecon.vt.edu/biotechimpact/rice/Hareau%20et%20al_2002.pdf)*

The expected benefits from herbicide resistant transgenic rice in Uruguay are estimated with stochastic simulation techniques. Economic surplus methods that account for private profits are used to measure the magnitude and distribution of the benefits between producers and a multinational firm. Further, the adoption rate of transgenic rice is endogenous in the model and depends on the expected profitability of the technology. The results show that the potential benefits from the technology are relatively small because of the small production base. Multinational firms are, therefore, unlikely to develop locally adapted transgenic rice varieties without strategic partnerships with local institutions.

Country: Uruguay

Crop: Rice

*Hareau, G. (2002), The Adoption of Genetically Modified Organisms in Uruguay's Agriculture: An Ex-Ante Assessment of Potential Benefits, Virginia Polytechnic Institute*
*(http://scholar.lib.vt.edu/theses/available/etd-07262002-142338/unrestricted/GGHareau_Thesis.pdf)*

The present study analyzes the economic impact of the introduction of Genetically Modified Organisms (GMOs) in Uruguay's agriculture. Using a partial equilibrium framework the impacts of transgenic varieties are simulated for two crops, rice and potatoes, in small open and closed economies respectively. The model accounts for the presence of market imperfections created by the monopolistic behaviour of the genes' patent owner. The change in economic surplus generated after the adoption of the new technology is projected to be positive, although the seed markup charged by the monopolist reduces the surplus compared to a perfectly competitive market. Total deadweight losses and domestic losses are found to increase with the seed premium, as additional monopolist profits are extracted out of the country. Adoption decreases with the seed premium, further reducing the domestic consumer and producer surplus. The results of the study suggest an active role for national technology policies and for the agricultural R&D system in Uruguay to generate conditions that attract the technology's owner to a small market while at the same time reducing the potential losses that monopoly power creates.

Country: Uruguay
Crop: Rice, potato

<u>Maize</u>

*Demont, M./Tollens, E./Fogarasi, J. (2005), Potential Impact of Biotechnology in Eastern Europe: Transgenic Maize, Sugar Beet and Oilseed Rape in Hungary, Centre for Agricultural and Food Economics, Katholieke Universiteit Leuven, Working Paper No. 92*

In January 2005, the Hungarian farm ministry announced that it would not allow Monsanto's MON 810 maize to be planted or imported until tests had established whether transgenic crops contaminated other cultures. The present study is the first attempt to estimate the size and distribution of the ex ante welfare effects of transgenic crops in Hungary developing a partial equilibrium model following a counterfactual approach for the agricultural season 2003. Our model and data are conservative, such that the results have to be interpreted as lower estimates of the true impact. For uncertain parameters, we include subjective prior distributions. In 2003, maize, sugar beet and oilseed rape were planted on an area of respectively 1,150,000 ha, 53,000 ha and 71,000 ha in Hungary. Total benefits of Bt maize resistant to the European corn borer amount to an estimated 3 million euros, of which 76% accrues to the farmers and 24% to the seed industry. The adoption of Bt maize resistant to the Western corn rootworm translates into a total welfare increase of 16 million euros, of which farmers gain

65% and the industry 35%. The introduction of herbicide tolerant maize potentially generates 14 million euros, of which 73% is shared by the farmers and 27% is extracted by the industry. Herbicide tolerant sugar beet involves a welfare gain of 3 million euros, of which 50% flows to farmers and 50% to the seed industry. The adoption of herbicide tolerant oilseed rape could potentially engender a total benefit of 0.8 million euros, of which 61% is absorbed by Hungarian farmers and 39% is captured by the seed industry. We then conduct a stochastic sensitivity analysis through Monte Carlo simulation techniques to analyze the robustness and sensitivity of the model to the underlying parameter estimates and assumptions.

Country: Hungary
Crop: Maize, Rape, Sugar Beet

*Gouse, M./Pray, C./Kirsten, J./Schimmelpfennig, D. (2004), Impact of Bt White Maize on Small-scale Farmers in South Africa, Paper presented at the 8th conference of the International Consortium on Agricultural Biotechnology Research (ICABR) on "Agricultural Biotechnology: International Trade and Domestic Production", held at Ravello (Italy), July 8 – 11, 2004 (http://www.economia.uniroma2.it/conferenze/icabr2004/papers/Pray.zip)*

This paper reports some initial findings of ongoing research focussing on the performance of insect resistant white maize under small-scale, subsistent farmer conditions in South Africa. South Africa was at the start of 2004 still the only country in the world were as staple food i.e. white maize was released for commercial production. Initial results suggest that small-scale, resource-poor farmers in southern Africa could benefit from a genetically engineered staple food created initially for large-scale farmers in developed countries.

Country: South Africa
Crop: Maize

*Jensen, H./Meyers, W./White, W./Batres-Marquez, S.P. (2004), Benefits and Costs of "Golden Maize" in South Africa: An Ex-ante Assessment Method, Paper presented at the 8th ICABR Conference, Ravello (Italy), 8-11 July (http://www.economia.uniroma2.it/conferenze/icabr2004/papers/Meyers.zip)*

This paper presents the basic analytic plan and preliminary data for an ex-ante assessment of the introduction of biofortified maize to combat vitamin A deficiency. We use the approach used by Zimmermann and Qaim (2002) to study biofortified rice (Golden Rice) in the Philippines, and adapt it to a different product and context. We also hope to greater weight to nonocular, systemic manifestations of vitamin A deficiency, i.e., severe infection and anemia. Using available survey data, we will assess benefits to subgroups of the population, particularly small producers, since crop genetic enhancement is expected to be most effective in enhancing the vitamin A status of the rural poor.

Country: South Africa
Crop: Maize

*Beyers, L./Gouse, M./Hadley, D./Piesse, J./Thirtle, C. (2003), GM and polluting inputs in South African Agricultural production: A non-parametric analysis of potential input reduction, Paper presented at the 7th International ICABR Conference held in Ravello, Italy, from June 29 to July 3, 2003*

Abstract

Country: South Africa
Crop: Maize, Cotton

*Kirsten, J./Gouse, M. (2003), The Adoption and Impact of Agricultural Biotechnology in South Africa, in: Kalaitzandonakes, N. (ed.), The economic and environmental impacts of agbiotech: a global perspective, New York, USA, Kluwer-Plenum Academic Publishers*[29]

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Country: South Africa
Crop: Maize, Cotton

*Owuor, G./Smale, M./De Groote, H. (2004), Crop Biotechnology for Africa: Who Will Gain From Adopting Bt Maize in Kenya? Paper prepared for presentation at the Annual meeting of the American Agricultural Economics Association (AAEA), Denver/CO, USA, August 1-4, 2004*
*(http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=14463&ftype=.pdf)*

Bt maize in Kenya is a promising biotechnology innovation for poor households. Econometric prediction from a trait-based model of variety adoption indicates that the choice of host variety has equity and efficiency implications related to heterogeneity in maize growing environments and pest pressures, as well as the differences among farm households in terms of wealth, income, and market access.

Country: Kenya
Crop: Maize

*De Groote, H./Mugo, S./Bergvinson, D./Odhiambo, B. (2004), Debunking the myths of GM crops for Africa: The case of Bt maize in Kenya, Paper presented at the Annual Meetings of the American Agricultural Economics Association, August 4, Denver, Colorado*
*(http://www.syngentafoundation.com/pdf/IRMA_GM_crops_africa_bt_maize_kenya_paper.pdf)*

Empirical evidence from research on Bt maize in Kenya puts to rest most concerns raised against GMOs, most importantly that the technology would not respond to the needs of poor farmers, but would be expensive and benefit only agro-business, and that it might decrease biodiversity. However, research results

[29] This paper has also been published as Working Paper of 2002-09 of the Department of Agricultural Economics, Extension and Rural Development of the University of Pretoria, South Africa (http://www.up.ac.za/academic/ecoagric/fulltext/2002-25.pdf).

indicate that contamination of local varieties is likely through farmers' seed selection practices and dissemination. Moreover, possible buildup of insect resistance requires careful monitoring and evaluation after release. Using an economic surplus model, the welfare effects of the *Insect Resistant Maize for Africa (IRMA)* project are assessed in an ex ante analysis for two different scenarios with different adoption rates. Apart from the aggregate welfare effects, the benefits for producers and consumers are estimated separately.

Country: Kenya
Crop: Maize

*De Groote, H./Overholt, W./Ouma, J.O./Mugo, S. (2003), Assessing the impact of Bt maize in Kenya using a GIS model, Paper presented at the 25th conference of agricultural economists, held at Durban, South Africa, 16-22 August 2003 (http://www.iaae-agecon.org/conf/durban_papers/papers/002.pdf)*

The Insect Resistant Maize for Africa (IRMA) project is currently developing Bt maize for Kenya. So far, Bt genes with resistance to *Chilo partellus*, *Chilo orichalcociliellus*, *Eldana Sacharina*, and *Sesamia calamistis*, four of the five major stemborers were successfully incorporated into elite CIMMYT maize inbred line (CML216) and tested in insect bioassays in Kenya. Participatory Rural Appraisals showed that stem borers are indeed a major pest problems for farmers. Four seasons of on-farm crop loss assessment showed an average crop loss of 13.5%, or 0.4 million tons, valued at US$ 80 million. If the project manages to find a Bt gene that is effective to the fifth stemborer, *Busseola fusca*, adoption rates are likely to be high, and therefore the returns. Under standard assumptions, the economic surplus of the project is calculated at $ 208 million over 25 years (66% of which is consumer surplus) as compared to a cost of $5.7 million. Geographically, the project should focus on the high production moist-transitional zone. However, if such gene cannot be found, Bt maize technology would only be effective in the low potential areas, and adoption rates would be fairly low, although benefits would still exceed costs.

Country: Kenya
Crop: Maize

*Odame, H./Kameri-Mbote, P./Wafula, D. (2003), Governing modern agricultural biotechnology in Kenya: implications for food security, Institute of Development Studies (IDS), IDS Working Paper 199 (http://www.ids.ac.uk/ids/bookshop/wp/wp199.pdf)*

This report reviews governance issues of modern biotechnology. The study used two case studies of transgenic sweet potato and Bt maize to examine how governance issues influence household and national food security in the country. The report argues that for biotechnology to engender food security in Kenya in the context of globalisation and international governance, the national context for biotechnology has to be facilitative. More specifically, there is need to synchronise biotechnology development with national development imperatives taking into account structural limitations that could negate gains made through biotechnology activities. Five key findings emerge from this report. First,

alleviating rural poverty and food insecurity in Kenya requires changes at the local, national and international levels because of the inter-connectedness of agricultural systems and development in general. Second, developments in agricultural biotechnology will require slow and careful policy planning and implementation in order to improve food security of smallholders and reduce possible negative and socio-economic impacts of technology. Third, the Kenyan public sector will continue to play an important role in the biotechnology development because this area of research is crucial to the national and local interests. Fourth, the transfer of agricultural biotechnology to developing countries as advocated by international agencies and their national collaborators is a risky undertaking, particularly when it proceeds faster than the capacity of the state to cope with the management of new knowledge. Fifth and finally, while recognising that agricultural biotechnology has potential to alleviate food insecurity in rural Kenya, its programmes must be strongly linked to the interests of smallholders and institutions that support local participation.

Country: Kenya
Crop: Maize, Sweet potato

*Chang, C.-C./Hsu, S.-H./Wu, C.-H. (2004), An Economy-wide Analysis of GM Food Labeling Policies in Taiwan, AAEA Annual Meeting, Denver/CO, USA (http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=14277&ftype=.pdf)*

The development of agricultural biotechnology offers the opportunity to increase crop production, lowers farming costs, improves food quality and could reduce costs to consumers. For the food importing economies, the import quantities as well as prices will be affected through world market as the production technology of GM crops is adopted by the exporting countries. Many sectors will be affected by the use of these crops through vertical (or backward) and horizontal (or forward) linkages. The purpose of this paper is to develop an economy-wide quantitative assessment of the economic impacts of the introduction of GM products with and without labeling. The modeling framework used in this analysis is TAIGEM (Taiwan General Equilibrium Model), a multi-sectoral computable general equilibrium (CGE) model of the Taiwan's economy which is derived from ORANI model (Dixon, Parmenter, Sutton and Vincent, 1982). TAIGEM is amended by splitting corn and soybeans into GM and non-GM varieties. It also endogenizes the decision of producers and consumers to use GM vs. non-GM corn and soybeans in their intermediate uses and consumption, respectively. We also consider the consumers' acceptance of GM food so that the mandatory labeling policy can be examined. Our simulation results indicate that the most extreme import ban on GM crops would be very costly in terms of total production values, ranging from NT$ 40 to 90 billions per year.

Country: Taiwan
Crop: Maize, Soybean

*De Leon, A./Manalo, A./Guilatco, F.C./Gloriani-Barzaga, N. (2004), The Cost Implications of GM Food Labeling in the Philippines, Philippine Bureau of Food and Drugs (BFAD)/USAID*
*(http://www.bcp.org.ph/downloads/Cost%20Implications%20of%20GM%20Food%20Labeling%20in%20the%20Philippines.pdf)*

Abstract

Country: Philippines
Crop: Maize, Soybean

*De Leon, A./Manalo, A./Guilatco, F.C./Gloriani-Barzaga, N. (2004), The Cost Implications of GM Food Labeling in the Philippines, International Service for the Acquisition of Agri-biotech Applications (ISAAA), Crop Biotech Brief, Vol. 4, No. 2*
*(http://www.isaaa.org/kc/Publications/pdfs/briefs/Brief4-2.pdf)*

This paper is a summary version of the previous one.

Country: Philippines
Crop: Maize, Soybean

*Gonzales, L. (2002), Likely transcendental effects of agri-biotechnology: The case of Bt hybrid corn in the Philippines, STRIVE Foundation, Los Banos, Laguna, Philippines*

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Country: Philippines
Crop: Maize

*Diaz-Osorio, J. (2003), Economic Effect of the Genetic Modifications Bt and Rr in Corn Crops for Seed Purposes, Poster presented at the conference Deutscher Tropentag 2003 on International Research on Food Security, Natural Resource Management and Rural Development at the University of Göttingen (Germany), October 8-10, 2003* *(http://www.tropentag.de/2003/proceedings/node251.html#tex2html1892)*

The poster looks at the corn production costs for seed not modified genetically and genetically modified Bt (resistance to insects) and RR (resistance to herbicide) corn in Chile. From this comparison, the main differences in the variable costs of production of the two forms of crops are established. This translates into a scenario of the potential economic benefits of the market introduction of GM maize seed in Chile.

Country: Chile
Crop: Maize

*Commission for Environmental Cooperation of North America (CEC) (2004), Maize and Biodiversity. The Effects of Transgenic Maize in Mexico. Key Findings and Recommendations, Secretariat Article 13 Report*
*(http://www.cec.org/files/PDF//Maize-and-Biodiversity_en.pdf)*

The focus of this report is on the possible impacts of cultivation of current and near-term commercial transgenic maize varieties on landraces of maize and teosintes and the possible introgression and effects of transgenes into those taxonomic entities. Likely future transgenic maize varieties are also considered to ensure the present report serves future policy making and scientific research. In considering the effects of transgenic maize cultivation, the authors aimed to identify and assess both the risks and benefits to interested and affected parties and to maize biodiversity in Mexico. Several of the 10 chapters of the background volume to the report examine issues related to gene flow, both direct and indirect, from transgenic varieties of maize to Mexican landraces and their wild relatives, and the conservation of maize biodiversity near its center of origin. They also deal with the context and background on wild and cultivated maize in Mexico, present a framework for judging potential benefits and risks, on understanding benefits and risks, help our understanding of the biology of maize and community values to improve communication and participation, and discuss managing potential risks and enhancing potential benefits. Other chapters cover the potential effects of transgenic maize on biodiversity, genetic diversity, agriculture, society and culture, and human health. The report further includes information on the distribution of risks and benefits among affected parties.

Country: Mexico
Crop: Maize

*Brush, S./Chauvet, M. (2004), Assessment of Social and Cultural Effects Associated with Transgenic Maize Production, in: North American Commission for Environmental Cooperation, Maize and Biodiversity: The Effects of Transgenic Maize in Mexico*
*(http://www.cec.org/files/PDF//Maize-Biodiversity-Chapter6_en.pdf)*

This book chapter assesses the potential social and cultural effects of transgenic maize on Mexican farmers. Assessing the impact of technological change is never a precise science, and in this case, it is complicated by the highly differentiated agroecological and social rural contexts of Mexico. In the first part, we present an overview of Mexico's agriculture emphasizing its heterogeneity and different types of farms that produce maize. The second part is focused on the potential effects of transgenic maize. The methodology followed is to review the changing nature of maize agriculture in Mexico and the impact of other types of technological change on different types of farms and on maize diversity. The chapter then reviews potential impacts of transgenic maize on farmers' choice and rights, on yield and income, and on cultural values. Three groups of farmers are considered – non commercial, semi-commercial and commercial producers.

Country: Mexico
Crop: Maize

<u>Potato</u>

*Qaim, M. (2000), Welfare prospects of transgenic crops in developing countries, in: Qaim, M./Krattiger, A.F./von Braun, J. (eds.), Agricultural Biotechnology in*

*Developing Countries: Towards Optimizing the Benefits for the Poor, Kluwer Academic Publishers, Boston and Dordrecht, p. 155-173*

Abstract

Countries: Kenya, Mexico
Crops: Sweet potatoes, potato

*Hareau, G. (2002), The Adoption of Genetically Modified Organisms in Uruguay's Agriculture: An Ex-Ante Assessment of Potential Benefits, Virginia Polytechnic Institute (http://scholar.lib.vt.edu/theses/available/etd-07262002-142338/unrestricted/GGHareau_Thesis.pdf)*

Abstract

Country: Uruguay
Crop: Rice, potato

*Massieu, Y./Gonzalez, R.L./Chauvet, M./Castañeda, Y./Barajas R.E. (2000), Transgenic potatoes for small-scale farmers: a case study in Mexico, Biotechnology and Development Monitor 41, p. 6-10*

To evaluate the possible benefits of biotechnology for small-scale potato farmers, a field study based on interviewing these farmers in the mountainous areas of Mexico was undertaken during 1996-99. The objective was to inquire into several aspects of potato agriculture: origin of seed; inputs, costs and yields; production and seed commercialization; agricultural prices; farmers' general agronomic and socioeconomic situation (crop diseases, level of organization with other farmers and possible contacts with public or private institutions); and assessing the possible relevance of new biotechnologically produced varieties. The results of this case study are discussed and some of the assumptions and conclusions made by Quaim (1998) are questioned. In addition, the paper provides information on potato production in Mexico, the CINVESTAV (Centro de Investigacion y Estudios Avanzados, Unidad Irapuato)/Monsanto programme on transgenic potatoes and assumptions from an economic model on transgenic virus resistant potatoes in Mexico.

Country: Mexico
Crop: Potato

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

The study analyzes ex ante the socioeconomic effects of transgenic virus resistance technology for potatoes in Mexico. All groups of potato growers could significantly gain from the transgenic varieties to be introduced, and the technology could even improve income distribution. Nonetheless, public support is needed to fully harness this potential. Different policy alternatives are tested within scenario calculations in order to supply information on how to optimize the technological outcome, both from an efficiency and an equity perspective.

Transgenic disease resistance is a promising technology for developing countries. Providing these countries with better access to biotechnology should be given higher political priority.

Country: Mexico
Crop: Potatoes

*Qaim, M. (1998), Transgenic virus resistant potatoes in Mexico: potential socioeconomic implications of North-South biotechnology transfer, International Service for the Acquisition of Agri-biotech Applications (ISAAA), ISAAA Briefs No. 7 (http://www.agbiotechnet.com/reports/isaaa_briefs/Brief7.pdf)*

This paper is an ex ante assessment of the potential socio-economic impact of the introduction of transgenic virus-resistant potatoes in Mexico. The main beneficiaries of the new technology will be the producers and consumers of Mexico's potato sector, which will be directly impacted by the use of transgenic potatoes. This study evaluates and quantifies the benefit potentials produced by technology improvements through a market equilibrium displacement model; in a further step these benefits are contrasted to the corresponding costs of research and extension. Moreover, the equity implications of the technology are explicitly analyzed. Distribution effects are scrutinized in terms of three different farm sizes. Strategies to disseminate the technology and place it in the hands of small-scale farmers have not yet been identified. It is hoped that the study can provide some impetus in this respect, too. To gain a better understanding of the importance of developing such strategies, the impacts of different policy alternatives on efficiency and equity are juxtaposed within scenario considerations. In addition to the direct benefit potentials of the technology in the Mexican potato sector, the transfer project also produces more indirect institutional benefits in the national agricultural research system (NARS). Because these indirect benefits are difficult to be quantified, they are qualitatively discussed.

Country: Mexico
Crop: Potato

Sweet potatoes

*Odame, H./Kameri-Mbote, P./Wafula, D. (2003), Governing modern agricultural biotechnology in Kenya: implications for food security, Institute of Development Studies (IDS), IDS Working Paper 199 (http://www.ids.ac.uk/ids/bookshop/wp/wp199.pdf)*

Abstract

Country: Kenya
Crop: Sweet potato, Maize

*Qaim, M. (2000), Welfare prospects of transgenic crops in developing countries, in: Qaim, M./Krattiger, A.F./von Braun, J. (eds.), Agricultural Biotechnology in Developing Countries: Towards Optimizing the Benefits for the Poor, Kluwer Academic Publishers, Boston and Dordrecht, p. 155-173*

This paper describes an ex ante analytical framework that can assist in analyzing the potential welfare impacts of specified crop biotechnologies in developing countries. In a case-study approach, the expected effects of virus- and weevil-resistant potatoes in Mexico are scrutinized. Built upon recombinant methods, these technologies are being developed within joint public-private sector research initiatives. The resulting applications will be released in the near future and, because cultivation practices do not need to be altered, they will easily be integrated into existing farming systems. The quantitative results indicate that the innovations are likely to bring about significant welfare gains for agricultural producers and consumers. These examples confirm that biotechnology can offer cost-effective solutions to a wide range of agricultural and food problems in developing countries.

Countries: Kenya, Mexico
Crops: Sweet potatoes, potatoes

*Qaim, M. (2001), A Prospective Evaluation of Biotechnology in Semi-Subsistence Agriculture, Agricultural Economics, Vol. 25, Issue 2-3, p. 165-175*

The paper analyses ex ante the economic implications of transgenic virus- and weevil-resistant sweet potatoes in Kenya. These technologies are being developed within international projects, involving public and private organisations. It is expected that the resistant varieties will significantly reduce the crop losses in farmers' fields. Model calculations show that both innovations are likely to bring about substantial growth in economic surplus. The projected annual gross benefit is 5.4 mUS$ (million US$) for virus resistance and 9.9 mUS$ for weevil resistance. Due to the semi-subsistence nature of sweet potato, the producing households will be the main beneficiaries. However, market consumers will also capture about one-fourth of the aggregate welfare gains. The high profitability of the projects is confirmed by significantly positive returns on research investments. The examples demonstrate the viability of successful research partnerships between the public and private sectors. As most of the basic biotechnology tools available to date are patented by private companies in the North, which often do not have sufficient market incentives to develop end-technologies for the South, more interactions of this kind are required from a development policy perspective. Working with typical semi-subsistence crops is particularly appealing because it immediately targets the poor and avoids conflicts with the private sector's commercial interests.

Country: Kenya
Crop: Sweet potato

*Qaim, M. (1999), The economic effects of genetically modified orphan commodities: projections for sweet potato in Kenya, International Service for the Acquisition of Agri-biotech Applications (ISAAA), ISAAA Briefs No. 13 (http://www.agbiotechnet.com/reports/isaaa_briefs/Brief13.pdf)*

Using an ex ante analytical framework, this paper analyzes the potential economic impacts of the use of transgenic sweet potato varieties in Kenya. It

investigates the potential impacts of both virus and weevil resistance in the Kenyan sweet potato sector. The first step is an analysis of the likely effects of transgenic sweet potatoes at the farm level. The potential yield and income effects are estimated for farms in different agro-ecological environments. The author estimates that rising cash revenues as well as the greater availability of sweet potato for subsistence consumption will contribute significantly to improved food security for rural households. The potential effects of transgenic technologies are also analyzed for the Kenyan sweet potato market as a whole. For this purpose, an economic surplus model with technological progress is employed. The model simulations show that the virus-resistant varieties would produce an aggregate annual benefit of 5.4 million US$, whereas the weevil resistance technology could create welfare gains of 9.9 million US$ per year. For both technologies, about 26 percent of the overall surplus will be captured by food consumers, since the growth in productivity will cause the sweet potato market price to decline. Moreover, the internal rate of return (IRR) of research and development of sweet potato weevil and virus resistance are calculated.

Country: Kenya
Crop: Sweet potato

Banana

*Edmeades, S./Smale, M. (2004), Targeting cultivars and traits to enhance the potential for adoption of a subsistence crop biotechnology: The case of bananas in Uganda, Paper presented at the 8th conference of the International Consortium on Agricultural Biotechnology Research (ICABR) on "Agricultural Biotechnology: International Trade and Domestic Production", held at Ravello (Italy), July 8 – 11, 2004 (http://www.economia.uniroma2.it/conferenze/icabr2004/papers/Edmeades..zip)*

This paper examines the potential for adoption of a subsistence crop biotechnology in Sub-Saharan Africa – cooking bananas in Uganda. Variety demands are derived within an agricultural household model with attributes. The demand for host varieties now being considered for gene insertion is predicted using a Poisson regression system. In general, households with high predicated demand for potential host varieties are larger and poorer, and are less likely to purchase bananas than they are to sell them. They are closer to markets but in some cases taking more time to reach them. The fitted model is also used to simulate changes in variety demand for changes in the level of effective resistance to each and both biotic constraints. Reducing perceived yield losses to either biotic constraint has a statistically significant effect on expected demand, though expected demand responds most sharply to effective insertion of resistance to both.

Country: Uganda
Crop: Banana

*Edmeades, S./Smale, M./Renkow, M./Phaneuf, D. (2004), Variety demand within the framework of an agricultural household model with attributes: the case of bananas in Uganda, International Food Policy Research Institute (IFPRI),*

*Environment and Production Technology Division (EPTD), EPTD Discussion Paper No. 125 (http://www.ifpri.org/divs/eptd/dp/papers/eptdp125.pdf)*

Ugandan smallholder farmers produce the nation's major food crop using numerous banana varieties with distinctive attributes, while coping with important biotic constraints and imperfect markets. This empirical context motivates a trait-based model of the agricultural household that establishes the economic association between household preferences for specific variety attributes (yield, disease and pest resistance, and taste), among other exogenous factors, and variety demand, or the extent of cultivation. Six variety demands are estimated in reduced form, each in terms of both plant counts ("absolute" or levels demand) and plant shares ("relative" demand). Two salient findings emerge from the analysis: 1) the determinants of both absolute and relative demands are variety-specific and cannot be generalized across groups of cultivars; and 2) the determinants of absolute and relative demand are not the same in sign or significance. These findings raise questions about commonly used econometric specifications in the adoption literature. Grouping varieties together masks individual differences, and differences may be important for predicting the adoption of new technologies such as genetically transformed, endemic or local varieties. The development of methods to estimate a complete variety demand system might permit resolution of cross-variety relationships. The purpose of this research is to contribute information of use in identifying suitable local host varieties for the insertion of resistance traits through genetic transformation, and the factors affecting their potential adoption.

Country: Uganda
Crop: Banana

*Edmeades, S. (2003), Variety Choice and Attribute Trade-offs within the Framework of Agricultural Household Models: The Case of Bananas in Uganda, PhD Dissertation, North Carolina State University*

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Country: Uganda
Crop: Banana

*Smale, M./De Groote, H. (2003), Diagnostic research to enable adoption of transgenic crop varieties by smallholder farmers in Sub-Saharan Africa, African Journal of Biotechnology, Vol. 2 (12), p. 586-595*
*(http://www.academicjournals.org/AJB/PDF/Pdf2003/DecemberPDFs2003/Smale%20and%20De%20Groote.pdf)*

Diagnostic research is important in helping to create an enabling environment for promising biotechnology products in smallholder agriculture, *before* rather than *after* release. The biotechnology products that now hold promise for poor people in Sub-Saharan Africa are those that tackle economically important, biotic or abiotic problems not easily addressed through conventional plant breeding or pest control, in crops that serve for food as well as cash, while posing little risk of

endangering trade. Two biotechnology products we have selected for social science research in East Africa, Bt maize in Kenya and pest and disease resistance in the East African highland banana, meet these criteria. Preliminary research suggests that the expression of the trait is much more visible to farmers in maize than in bananas; for either crop, for different reasons, bottlenecks will be encountered in planting materials systems; and despite differing crop reproduction systems, transgenic varieties of either share the same environmental hazard of heightened genetic uniformity in the inserted trait relative to conventionally bred varieties. Aside from the performance of the technology, many factors that have incidence at national, regional, and farm levels will affect the likelihood that farmers will adopt transgenic varieties. Social science research can help pinpoint necessary complementary investments.

Country: Kenya, East Africa
Crop: Maize, Banana

Cassava

*Pachico, D./Gottret, V./Escobar, Z./Perez, S. (2002), Income and employment effects of transgenic herbicide resistant cassava in Colombia: a preliminary simulation, Evenson, R./Santaniello, V./Zilberman, D. (eds.), Economic and social issues in agricultural biotechnology, Wallingford/UK, p. 351-358*[30]

Pachico et. al conduct an ex ante study of the potential 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 raises consumer and producer surplus compared to conventionally bred 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 topography.

Country: Colombia
Crop: Cassava

[30] This article was also presented as a paper at the 6th International Conference on Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer held at Ravello (Italy) from July 11 to 14, 2001 and published under the title *A Preliminary Comparison of the Potential Welfare and Employment Effects of Herbicide Tolerant, High Yielding, or Mechanized Cassava in Different Markets in Colombia* in: Fauquet, C.M./Taylor, N.J. (eds.) (2003), Cassava: An ancient crop for modern times, Proceedings of the 5th International Meeting of the Cassava Biotechnology Network, held at St. Louis/MO (USA), November 1-9, 2001.

Cowpea

*Kushwaha, S./Musa, A.S./Lowenberg-DeBoer, J./Fulton, J. (2004), Consumer Acceptance of GMO Cowpeas in Sub-Sahara Africa, Long Paper #119265, presented at the Annual Meeting of the American Agricultural Economics Association (AAEA), Denver/CO, USA (http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=14082&ftype=.pdf)*

Cowpea is the most important indigenous African grain legume for both home use and as a cash crop. Because of its tolerance to drought it is especially important for the Sahel. Genetic transformation of cowpea with Bacillus thuringiensis (Bt) genes to control pod boring insects has many advantages, but little is known of the potential consumer response. This paper analyzes and reports the results of a survey of 200 consumers in northern Nigeria in early 2003 concerning consumer awareness of and acceptance of biotechnology. Ninety percent of the respondents were aware of GM products. Those respondents who were most concerned about the ethics of genetic transformation were likely to disapprove of such products, while those individuals who identified international radio as an information source were more likely to approve of GM technology.

Country: Nigeria
Crop: Cowpea

Tomato

*Chauvet, M./Massieu, Y./González, R.L. (2001), Transgenic crops in Mexico, Paper presented at the 6th International Conference on Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer held at Ravello (Italy) from July 11 to 14, 2001*

In this paper, the production and testing of GM crops in Mexico is discussed. The authors also conduct a socio-economic impact assessment of the production of genetically modified long shelf tomato.

Country: Mexico
Crop: Tomato

Rape

*Demont, M./Tollens, E./Fogarasi, J. (2005), Potential Impact of Biotechnology in Eastern Europe: Transgenic Maize, Sugar Beet and Oilseed Rape in Hungary, Centre for Agricultural and Food Economics, Katholieke Universiteit Leuven, Working Paper No. 92*

Abstract

Country: Hungary
Crop: Maize, Rape, Sugar Beet

Sunflower

*Fonseca, E.A./López Bilbao, M./Luders, M./Nogués, J./Parsons, A./Regúnaga, M./Sturzenegger, A. (2004), Estudio sobre el impacto economico de la eventual*

*utilización de eventos transgenicos de girasol en Argentina, Asociación Argentina de Girasol, Buenos Aires/Argentina*
*(http://www.asagir.org.ar/OGM/transgenicos.asp)*

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Country:Argentina
Crop: Sunflower

Sugar Beet

*Demont, M./Tollens, E./Fogarasi, J. (2005), Potential Impact of Biotechnology in Eastern Europe: Transgenic Maize, Sugar Beet and Oilseed Rape in Hungary, Centre for Agricultural and Food Economics, Katholieke Universiteit Leuven, Working Paper No. 92*

Abstract

Country: Hungary
Crop: Maize, Rape, Sugar Beet

## Index