OUTPUT II: IMPACT OF PAST RESEARCH MONITORED

2.1 Impact of user participation in Natural Resource Management Research - *by: N. Johnson*

In 1999, the CGIAR Systemwide Program on Participatory Research and Gender Analysis (PRGA) initiated a study of the impact of user participation in natural resource management. An economist from BP1 was contracted to work on the design and implementation of the project. Following are 1) a summary of the study and findings, 2) a description of the conceptual framework and hypotheses and 3) the summary and conclusions. Further information is available in the publications listed below.

2.1.1 Executive Summary

This study assesses the impacts of incorporating user participation and gender analysis in natural resource management research. Four types of benefits and/or costs are considered: (1) impact on the technology developed and its adoption, (2) strengthening of human and social capital among participating individuals and communities, (3) establishment or strengthening of feedback links to formal research, and (4) costs of research. A typology of participation at different stages of the research process is used to develop type- and stage- based hypothesis for each of these four impacts. The hypotheses are evaluated in the context of three participatory NRM research/development projects. The three projects are: the design and development of integrated crop management (ICM) sweetpotato technologies by the Centro Internacional de la Papa (CIP) and partners in Indonesia (1994-97); participatory testing of legume based soil fertility technologies by the International Center for Research in the Semi Arid Tropics (ICRISAT) in Malawi (1997-2000); and World Neighbors's (WN) use of farmer experimentation to adapt and diffuse soil conservation practices in Honduras (1981-1989).

Fieldwork and analysis of the three case study projects was done between August 2000 and February 2001. Both qualitative and quantitative data were used, including existing project documentation; open-ended interviews with project staff, farmer participants, and other key informants including community leaders and policy makers; and statistical and econometric analysis of survey data. Staff of the three projects participated actively throughout the process.

The main findings of the study are summarized below by type of impact:

Impacts on technology and adoption. In all cases, farmer input influenced the technology development process. Farmer impact on the technologies developed by the projects was greatest when farmer input came early in the research process (CIP) or when technology testing was done in a collaborative (empowering) way that gave scope for significant farmer contribution (CIP, WN). In all cases, user participation contributed to greater awareness of the technologies among farmers. In two of the three cases (CIP and WN), user participation is linked to increases in adoption of project technologies. In the CIP case, detailed production data show that exposure to the ICM technologies is associated with higher per-hectare income from sweetpotato production.

All cases used some type of gender analysis. In two of the three cases (CIP and WN), gender analysis revealed that women were not important stakeholders in the NRM activities that the projects were promoting. Only in the ICRISAT case were women specifically targeted as beneficiaries and deliberately incorporated into the project as participants. Disaggregation of participant input by gender did not reveal significant gender differences in overall ranking of the technologies tested, however there were some important differences in perception of specific characteristics of the technologies that could be useful in designing gender-sensitive diffusion strategies.

Human and social capital impacts. Large human capital impacts were observed among participants in the two projects that used collaborative participation at the testing stage (CIP and WN). Where technology testing was consultative (functional) (ICRISAT), useful agronomic and economic research results were obtained, but increases in participant capacity and skills were small. Significant human and social capital impacts at the design stage of the research process were not observed, even where empowering participation was used. In general, human capital impacts were more prevalent than social capital impacts. This may be due to the fact that the technologies being developed and diffused were all essentially plot-level and did not require significant collective action for implementation.

Since increases in human capital were only observed among direct participants in the projects, if women do not participate directly in project activities they will not obtain these benefits.

Feedback to formal research. In all cases, feedback to formal research and development institutions was observed. These impacts were stronger for IARCs and NGOs than for NARS. While some of the feedback was technical in nature and influenced institutional research priorities (CIP), most was methodological, such as information about barriers to adoption (ICRISAT), which is likely to benefit future research and extension efforts. In all cases, the projects stimulated some researchers in their own and/or other institutions to adopt more participatory methods. Feedback to formal research occurred with both consultative and collaborative participation.

Costs of research. Incorporation of user participation was generally associated with four types of additional costs: communications/workshops; farmer participant costs; researchers field work costs; and training of researchers. Only in the first case do the costs necessarily imply an increase in overall project expenditure. Farmer costs were observed to replace (and sometimes reduce) researcher/research assistant costs at the design, testing, and diffusion stages. Spending time in the field is a critical part of participatory projects, however researchers must also spend time in the field to get good results in conventional on-farm trials. Some of the observed cost increases may be more associated with quality than with participation. In all projects, researchers increased their own capacity and skills, either via formal training or learning-by-doing. These are essentially start-up costs incurred because the methods for collection and analysis of data from participatory research processes are often new to researchers. Over time, as more researchers gain experience in participatory research methods, these costs should decline. Neither conducting gender analysis nor intentionally incorporating women as project participants (ICRISAT) increased project costs.

Available data only allowed us to make a rough cost effectiveness estimate for the WN project. Cost per hectare of land under soil conservation practices for the WN project was estimated to be US$208. Similar per hectare costs for comparable projects that did not use the same empowering participatory methods were between US$845 and US$6000. The difference is the high and sustained adoption levels achieved by WN.

2.1.2 METHODOLOGY OF CASE STUDIES

Introduction and Objectives

Scope of the Study

Scientists using participatory methods have observed the success of this approach in a variety of situations, and have documented the results in a number of case studies (e.g., Hinchcliffe et al 1999). However, the impacts and costs of using participatory as opposed to more conventional approaches are rarely systematically analyzed or reported. Until we have a better understanding of the tradeoffs associated with using participatory methods, scaling up or institutionalizing participatory approaches will be difficult within agricultural and natural resource management (NRM) research institutions.

By analyzing three research/development projects that used participatory methods in applied research on NRM, this study aims to improve our understanding of the costs and benefits of using participatory research. Using a shared conceptual framework, the incorporation of participatory methods in each case is evaluated in terms of its impact in the following four areas (for more detailed conceptual framework for impact analysis, see p.1-22 in Lilja et al 2000):

(1) Adoption and impact of the technologies developed,
(2) Strengthening of human and social capital among the participating individuals and communities,
(3) Establishment of feedback links to formal research, and
(4) Costs of doing research.

What we seek to evaluate in this study is not the overall impact of a research project that used participatory techniques, but rather the incremental effect on impacts and costs that can be attributed to incorporating stakeholder participation. Therefore, in each case study the impacts are assessed against an appropriate conventional research counterfactual.

Participatory research can be done in many ways, and different methods may have very different implications for outcomes and impacts. Selecting the appropriate approach will require anticipating how participation will impact on both project structure and goals. Based on a typology of participation, we developed a comprehensive set of hypotheses that link the incorporation of different types of participation at different stages of the innovation process to the four impact areas identified above. In each case study, the relevant hypotheses are tested within the context of the specific project. Taken together, the results will provide some empirical evidence upon which to evaluate both project impacts and the usefulness of the typology as a tool for project design, implementation, and evaluation.

A final objective of the study is to look at the implications of participatory research for different stakeholder groups, particularly women and the poor. In each case, the methods of gender analysis used in a project are identified, and the impacts desegregated by gender.

This project does not seek to reach general conclusions about which type of participation is appropriate in what area; nor will we have the last word on whether or not the targeting of women is cost effective. Much more experience in both the implementation and evaluation of participatory research methods in many contexts will be needed before these kinds of questions can be answered in any definitive way. What we hope to provide in this study is a set of examples with sufficient diversity that a broad range of researchers, research managers, and others can find similarities to their own work. It is through their representativity of processes rather than their combined statistical power that these studies will be useful in beginning to understand and evaluate the impacts and costs of using participatory methods in agricultural and NRM research.

Conceptual Framework for Impact Analysis of Participatory Research: Types of Participation and Their Implications for Impact

Types of Participatory Research

The expected impacts of incorporating stakeholder participation in research are contingent upon the nature of the approach used. Lilja and Ashby (1999a) develop a typology of participation based on who makes decisions that permits analysis at different stages of the research process. However, the research process is understood as being iterative rather than linear. The typology defines the two decision-makers as “scientists” and “farmers.” A generic term “farmers” is used to describe any target group and the term “scientists” for outside agencies, extension systems, or formal research agencies. Underlying this typology is the assumption that differences in who makes a decision will result in differences in what decision is made. This need not be the case; however, cases where the assumption holds are the most appropriate for participatory research methods. The following is extracted from their framework.

Stages of innovation

The innovation process can be divided into three stages – design, testing, and diffusion.

- In the **design stage**, problems or opportunities for research are identified and prioritized, and potential solutions to priority problems are determined. The outcome of the decisions made at this stage is an array of potential solutions. They can be any of the following: a completely new solution is invented and needs to be tested; a new application of an existing solution is identified as having potential, but needs to be tested; or an existing solution can be used, but needs to be promoted.
- The **testing stage** is when potential solutions chosen for testing are evaluated. Decisions are made about who does the testing, and about where and how it is done. This stage results in recommendations to intended users about the innovation or technology for mass distribution.
- The **diffusion stage** involves building the awareness of recommended solutions among future users. It involves decisions about when, to whom, and in what way to build awareness, supply new inputs, and teach new skills to future users. The outcome of decisions made at this stage is full or partial adoption, or no adoption.

Farmer participation at different stages of innovation can have different impact on the technology or innovation design, as well as on the potential adoption or acceptance among the intended users. Farmer participation early in the design stage helps reduce the likelihood that the technologies being developed are ultimately unacceptable to farmers. Their participation in planning and setting goals may help steer the research in a more focused fashion and more directly towards farmers' priority needs. Commonly, farmer participation steers research into completely unanticipated directions. Similarly, who participates at different design stages may lead to different priorities being identified for different beneficiaries.

Who makes the key decisions in the participatory process?

In characterizing the participation in an innovation process we are concerned with organized communication between or among the groups. By organized communication we mean a well-defined procedure (such as informal surveys, group interviews, transect walks, and formal surveys). Organized communication is not an ad-hoc opportunistic event. We also differentiate between **one-way communication**, which is always scientist initiated and where farmers respond to scientists' inquiries, and **two-way communication**, which may be scientist- or farmer-initiated, and scientists make sure that farmers understand their opinions and ideas or their proposals and objectives, and vice versa.

"Who makes decisions" is one way of deciding the balance of power in a participatory process. We define five different types of participatory approaches depending on who makes the decision at various stages in the innovation process. A different type of participation is possible at each of the three stages of innovation (this builds on the previously known work on "categories" of participation, for example see Biggs and Farrington 1991.)

(1) **Conventional (non-participatory)**: Scientists make the decisions alone without organized communication with farmers.
(2) **Consultative**: Scientists make the decisions alone, but with organized communication with farmers. Scientists know about farmers' opinions, preferences, and priorities through organized one-way communication with them. Scientists may or may not let this information affect their decision. The decision is not made with farmers nor is it delegated to them.
(3) **Collaborative**: The decision is shared between farmers and scientists, and involves organized communication among them. Scientists and farmers know about one another's opinions, preferences, and priorities through organized two-way communication. The decisions are made jointly; neither scientists nor farmers make them on their own. No party has a right to revoke the shared decision.
(4) **Collegial**: Farmers make the decisions collectively in a group process or through individual farmers who are involved in organized communication with scientists. Farmers know about scientists' opinions, preferences, proposals, and priorities through organized two-way communication. Farmers may or may not let this information affect their decision.
(5) **Farmer experimentation**: Farmers make the decisions individually or in a group without organized communication with scientists.

Why does it matter who makes the decisions in the participatory process? If outsiders or scientists make all the key decisions without farmer participation in the early stage of an innovation process, farmers cannot influence many features of the innovation that are fixed by those decisions. The outcome of the participatory research is different when scientists and farmers plan together in the early stage and share key decisions, hence increasing the likelihood that the farmers' top priority is addressed. Participatory research has a very different outcome if farmers make all the planning decisions and only consult scientists late in the process when problems arise.

Implications for Impact

The expected impacts of incorporating participatory research approaches at different stages of the innovation process are described in the following sections. Again, we are interested in the impact of stakeholder participation on economic benefits from technology adoption; the impacts of human and social capital benefits from participation; and feedback to research and the cost of research. The second and third impacts are examples of **process** impacts that occur as a result of the participation itself rather than as a result of the technologies developed via participatory research methods. In the case of process impacts, the type of interaction between scientists and farmers directly affects the kinds of impacts that occur. Therefore, the hypotheses related to these impacts vary by type as well as by stage.

Technology impacts

The economic benefits associated with technologies developed using participatory research are dependent on many factors including the specific technologies, agroecological environment, input supply, and farmer and household characteristics. However, some general hypotheses about how stakeholder involvement at different stages might influence the adoption are given below.

Design stage:

(H1) *The proportion of the targeted beneficiary group that could potentially be reached by the project increases because the priority topic chosen for research is more relevant to the needs and priorities of targeted farmers.*

Testing stage:

(H2) *The number of potential adopters within the target group increases because the specific technology[1] selected for recommendation is more appropriate given farmers' criteria and constraints.*

Diffusion stage:

(H3) *The probability increases that potential adopters for whom the technology is appropriate will be aware of it, and that adopters will be willing and able to adopt and recommend it to others.*

Social and human capital impacts (among beneficiaries)

It is hypothesized that through the process of interacting with researchers, the human and social capital of participating individuals and communities can be strengthened. These impacts would only be anticipated as a result of empowering participation, meaning collaborative or collegial.

Design stage:

(H4) *Collaborative: Farmers/communities improve their ability to interact with outsiders, to articulate and evaluate their opinions and priorities, and to negotiate joint solutions with other stakeholders who may have different opinions.*

(H5) *Collegial: Farmers/communities improve their ability to interact with outsiders, particularly their ability to attract the interest and support of researchers for farmers' problems and priorities.*

Testing stage:

(H6) *Collaborative: Farmers/communities enhance their own testing and evaluation skills with an increased knowledge of scientific methods of experimentation and*

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[1] For the sake of grammatical simplicity, in the text we will refer to "a research topic identified" or "a technology tested or recommended." In reality however, participatory research processes often identify more than one priority problem, possible solution or appropriate technology.

evaluation, and improve their ability to negotiate joint recommendations with other stakeholders who may have different opinions.

(H7) *Collegial: Farmers/communities enhance their own testing and evaluation skills with an increased knowledge of scientific methods of experimentation and evaluation, and improve their ability to convince researchers of the validity and relevance of farmers' results.*

Diffusion stage:

(H8) *Collaborative/collegial: Farmers/communities learn what is involved in mass diffusion of technology, particularly the complexity of adoption decisions and the importance of complementary inputs such as seed, credit, or information.*

A final hypothesis relates to the fact that, in many cases, participatory projects involve farmers working together with other farmers as well as with researchers.

(H9) *The increased communication among farmers may result in better information and in information sharing among farmers and within the broader community, strengthening community social capital.*

Feedback to formal research impacts

The previous section looked at the process impacts of participation on the beneficiaries. In this section, we look at the benefits for the formal research process, specifically on researchers' access to information about farmers. These impacts can occur with any type of participatory research, either functional or empowering.

Design stage:

(H10) *Consultative: Researchers learn about farmers' priorities and solutions.*

(H11) *Collaborative: Researchers understand farmer priorities and solutions—including any new shared priorities or solutions that farmers and researchers identify as a result of working together—and incorporate them into their work.*

(H12) *Collegial: Researchers learn about farmers' priority problems and solutions by observing their decisions about problems, solutions, and innovations.*

Testing stage:

(H13) *Consultative: Researchers learn farmer criteria for evaluating technologies.*

(H14) *Collaborative: Researchers understand farmer criteria and methods for testing and evaluation of technology—including any new shared criteria or methods that farmers and researchers identify as a result of working together.*

(H15) *Collegial: Researchers learn about farmers' testing and evaluation methods and criteria by observing their actions.*

Diffusion stage:

(H16) *Consultative: Researchers learn about the factors that affect farmers' adoption decisions and what these imply for the diffusion process.*

(H17) *Collaborative: Researchers learn about farmer-to-farmer diffusion practices and about what kinds of information and skills both farmers and extension workers need to support this spontaneous diffusion.*

(H18) *Collegial: Researchers may learn about spontaneous farmer-to-farmer diffusion through observation of farmer activities.*

Finally, a general hypothesis that would apply at all stages is that:

(H19) *Researchers begin to understand that working with farmers may require new types of skills such as facilitation and conflict resolution that were not as important when research was carried out entirely on-station.*

This would be expected to increase as participation moves from functional to empowering.

Cost of research impacts

As with the impact on economic benefits, the impact of participation on research organizations' costs is largely an empirical question. Several general hypotheses are possible, however.

(H20) *Moving from conventional to consultative or collaborative forms of participation generally increases formal research organizations' costs at the particular stage where it is incorporated; however, it may reduce cost at subsequent stages.*

(H21) *Collegial research reduces research costs to formal research organizations at the stage where it is implemented because costs are transferred to farmers.*

(H22) *Participation without compensation increases farmers' costs unless it relies exclusively on those farmers (often a small and unrepresentative group) who already experiment on their own with new technologies and practices.*

Gender Analysis in Participatory Research

Technological, policy, or other changes often have different impacts on different stakeholder groups. One group that is often differentially affected is women. The systematic disaggregation of data and analysis by gender is referred to as gender analysis. Gender analysis and the targeting of women can be carried out in both participatory and non-participatory research. Three common methods of doing gender analysis in the context of agricultural research and technology development are[2]

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[2] Extracted from Lilja and Asbhy 1999b.

(1) **Diagnostic gender analysis**. Gender differences in the client group(s) for the research are described, and different problems or preferences are diagnosed. This information is not taken into account in priority setting, design of solutions for testing, or their evaluation and adoption. Diagnostic gender analysis may conclude that gender differences are not an important criterion for designing the research; or it may identify gender differences as an obstacle to adoption of technical solutions for men or women members of the client group.

(2) **Design-oriented gender analysis**. In addition to describing gender differences in the client group with respect to their problems and preferences, different research and development (R&D) paths are designed that take into account gender-based constraints, needs, and preferences. Design-oriented gender analysis may result in men and women developing and adopting different technologies, which may require different dissemination approaches.

(3) **Transfer-oriented gender analysis**. In addition to describing gender differences in the client group with respect to their problems and preferences, different adoption and dissemination paths are designed to overcome access to, and adoption of, a given technology known or assumed to be of similar importance to men and women. Transfer-oriented gender analysis results in the same technologies being disseminated to men and women in different ways.

If diagnostic gender analysis results in the conclusion that gender differences are important, the project can choose to target women specifically. Targeting can occur in either the development of the technology, or in the design of the dissemination strategy. In participatory research, attention to gender can go beyond targeting women as beneficiaries to deliberately incorporating women into the research process. Design-oriented gender analysis would be consistent with the incorporation of women at the design and testing stages. In transfer-oriented gender analysis, women could be incorporated at the dissemination stage.

Different ways of targeting women as beneficiaries and/or participants have different implications for impact. Specifically, if women are not participants, then they will be excluded from the process impacts described in the previous section. Whether or not women must be participants in order to be beneficiaries of technology impacts is an empirical question that will be examined in each of the cases. The cost impacts of including women will also be examined.

Selection of Cases

Criteria for Selection

Three cases were selected for analysis of the costs and impacts of incorporating farmer participation in NRM research. Several criteria were used to select the projects. The first criterion was to identify projects that had documented impact or that had been operating long enough to generate intermediate or final impacts. Additional criteria were to include a range of geographical areas, types of NRM technologies, and implementing organizations. The cases are part of an inventory of projects doing participatory research on natural resource management (NRM inventory, www.PRGAprogram.org) The projects selected are outlined below.

The Centro Internacional de la Papa (CIP) development of integrated crop management (ICM) technologies and practices for farmer field school (FFS) for sweet potato in Indonesia (1990s)

During 1995-97, CIP, with support from UPWARD[3], and in collaboration with public and private sector groups, implemented a project to develop a protocol for a sweet potato ICM-FFS in Indonesia. Collaborators were Mitra Tani, a local nongovernmental organization (NGO); the National Research Institute for Legume and Tuber Crops; and Duta Wacana Christian University. Project activities were implemented in major sweet potato growing areas in East and Central Java, where it is grown as an important cash crop throughout the year, mostly in rotation with rice. The project strategy relied on participatory approaches and methods at all stages: needs assessment and project design; R&D of ICM technologies and practices; design of farmer learning protocols applying the FFS approach; pilot-scale implementation of the sweet potato ICM-FFS; and monitoring and evaluation. To institutionalize the sweet potato ICM-FFS model that was developed, and allow for large-scale farmer learning and implementation, staff from the National IPM Program (NIPMP) and 30 local NGOs underwent FFS facilitators' training; NIPMP staff in June 1997, NGO staff in April 1998. These local extension organizations implemented and funded follow-up programs, and a second research project was initiated to evaluate their activities during a 2-year period (1998-99). Mitra Tani carried out the work, with methodological and financial support from CIP and UPWARD.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) work on models for the participatory testing of soil fertility technologies in Southern Africa (1990s)

The ICRISAT Mother–Baby (MB) trial model is an upstream participatory research methodology designed to improve the flow of information between farmers and researchers about technology performance and appropriateness under farmer conditions (Snapp 1999b). The methodology was initially developed and implemented to test soil fertility management technologies in Malawi that were legume-based, and was later

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[3] The Users' Perspectives for Agricultural Research and Development (UPWARD) is a CIP-affiliated network of Asian researchers conducting participatory R&D projects in root crop systems.

expanded to Zimbabwe. The trial design consists of two types, mother and baby trials. The mother trial is researcher-designed and conforms to scientific requirements for publishable data and analysis. A baby trial consists of a single replicate of one or more technologies from the mother trial. A single farmer manages each baby trial on his or her own land. A typical implementation of the methodology would include a single mother trial and numerous baby trials within a village. The MB trial methodology has three goals. The first is to generate data on which to assess technology performance under realistic farmer conditions. The second is to complement the agronomic trial data with farmers' assessments of the adoption potential of technologies. This information helps researchers understand how the technologies fit into farmers' broader farming and livelihood strategies. The third goal is to encourage farmers to actively participate in the trials, and is expected to stimulate farmer experimentation with, and adoption of, new technologies and practices.

World Neighbors (WN) soil conservation work in Honduras (1980s and early 1990s)

This project, supported by WN, the Coordinating Association of Resources for Development (ACORDE), and the Ministry of Natural Resources of the Government of Honduras, promoted improved soil conservation practices in south central Honduras from 1981-1989. The project worked in 41 communities in three municipalities – Guinope, San Lucas, and San Antonio de Flores – in the state of El Paraiso. The project's approach went beyond strictly increasing agricultural productivity through the adoption of soil conservation practices, to improving economic, social, and ecological conditions via agriculture (Plan del Programa). Although the project was primarily one of development, it had a significant capacity building component, teaching farmers the principles of soil conservation technologies, training them to experiment and adapt technologies, and imparting knowledge about selection and improvement of genetic materials for green manure. The project carried out these activities in the context of community groups, and trained local farmers to take over extension jobs after several years. The purpose of these activities was to build social as well as human capital, while strengthening organizational capacity and the capacity and commitment to share knowledge within the community. The project methodology was that described in Bunch (1982) that advocates a combination of 80% practical training and 20% theory. Significant increases in adoption were observed in the study areas during the course of the project. According to WN reports, nearly 1400 farmers tripled their basic grains' yields as a result of adopting soil conservation practices. Subsequent follow-up studies indicate that further adaptation and adoption continue (Bunch and Lopez 1999). Increases in productivity were also observed, as were increases in farmer experimentation, and the exchange of information among farmers. After several years working mainly on agriculture with men, the project added a component for women. This focused on sanitation, home gardens, and food preparation.

Representativity of Cases and Types of Participation

To assess the representativity of the three cases, they can be compared with an inventory of participatory NRM research cases which was complied by the PRGA (www.prgaprogram.org). According to an analysis of the cases, the majority are from

Africa (38%) followed by Asia (34%) and Latin America (22%) (see Johnson, Lilja and Ashby, 2001 for a thorough analysis of the inventory cases). The most common resource in those cases was soils, and this is also the major focus of the three cases in this impact study. Of the three study cases, one (WN) was NGO supported; the others are International Agricultural Research Center (IARC) cases. The important actor that is missing here is the National Agricultural Research System (NARS). In each of the cases, NARS were partners in the implementation, but did not undertake the work directly. This is also consistent with the findings of the analysis of the inventory. Two of the three study cases are managed by CGIAR centers. CG centers were also the dominant organizational type in the inventory (37% of cases), however it is likely that that the predominance of CGIAR work in this area is overstated due to the fact that CGIAR organizations (PRGA, CIAT) compiled the inventory.

The type of organization appears to be associated with project design and implementation. The NGO project is essentially an extension program that incorporates farmer testing and experimentation as a dissemination mechanism. In the IARC projects, in addition to working with farmers on a specific technology, methodologies were developed for systematically implementing similar work with other farmers. In these cases, the methodology itself is an output, not just the specific technologies developed in given field sites.

Table II-1 represents an attempt to place the cases within the framework of the typology presented in the previous section.

Table II-1. Types of participation used in the three case studies[a].

Stage	Conventional (non-participatory)	Functional Consultative	Empowering		Farmer Experimentation
			Collaborative	Collegial	
Design	WN, ICRISAT	CIP	CIP		-
Testing	-	ICRISAT	CIP, WN		-
Diffusion	(ICRISAT)	(CIP)	CIP, WN		CIP, WN ICRISAT

a. WN = World Neighbors – Honduras, CIP = Centro Internacional de la Papa – Indonesia, and ICRISAT = International Crops Research Institute for the Semi-Arid Tropics – Southern Africa. Parentheses indicate an activity that is planned, but remains to be executed.

Overall, the table shows that at the design stage, participation tends to be slightly more consultative, with farmers giving input, but researchers making decisions. Only in the case of CIP did stakeholder participation substantially change researchers' agendas, budgets, and work plans. Where significant research expenditures will occur, it appears that control still rests with the researcher, largely reflecting the sectoral nature of R&D funding. Cases in the inventory also tended to be more consultative.

As mentioned earlier, classifying project activities as either testing or diffusion was difficult. It appears that traditional, planned diffusion now begins in the testing stage, where researchers hope that by involving farmers in trials, both participating and non participating farmers will gain awareness of the technologies. This change may be related to the fact that the information-intensity of NRM practices requires farmers to learn something about how the technologies work. It may not be possible to adopt a technology off-the-shelf with no adaptation. Traditional diffusion may occur at the level of the methodology for facilitating adaptation rather than the technology itself. This is a subject that will be examined in more detail in the context of the case studies.

Use of Gender Analysis

All three of the projects undertook diagnostic gender analysis. In two of the cases, CIP and WN, it was decided that women did not play a significant role in the principal activity being addressed in the project. World Neighbors responded by implementing a separate set of activities for women focused on nutrition and health. Women were not excluded from the soil conservation activities, but self-selection of participants resulted in few women being involved.

Some Issues in Empirical Analysis

Before presenting each case study in detail, this section discusses some of the common empirical challenges associated with analyzing the impact of participatory NRM research. Each case study had to address the issues in some way in the empirical analysis.

Controlling for Selection Bias

Selection bias is an issue in any analysis where the treatment groups (study communities) were not randomly selected. When projects choose to work with specific individuals or communities, they may be doing so for reasons that may also be associated with the observed impacts. For example, interventions based on local collective action are often implemented in communities that have high levels of social capital. Failure to account for this could result in a project taking credit for social capital when in fact social capital contributed to the project’s success. Further, even if the project did have a measurable impact on such a community, it would be difficult to extrapolate about what the impact of a similar project might be in an area where social capital is not so high. Knowing how communities were selected is important so that appropriate control communities can be identified. The ideal situation is to collect pre- and post-project data for many replications of the project in different types of communities as well as in sites where no intervention occurred. This allows us to look at changes associated with the project and to control for the influence of other factors on observed outcomes. Without this, extrapolating beyond the specific project site(s) is difficult.

In addition to researcher-selection bias, self-selection bias is also likely to occur in participatory projects. Because participation is voluntary, people can choose to participate or not. In any given situation, the people who choose to participate are likely to be different from those who choose not to do so. For example, the type of individual who wants to volunteer his or her time to be part of a local agricultural research group is likely to be someone who already has an interest in experimentation, or someone who has a high level of commitment to working for the good of the community. The consequences of self-selection bias are similar to those of researcher-selection bias. However, it is harder to control for because the criteria for selection are largely unobservable and uncorrelated with observable characteristics such as age, education, or income. Extrapolation of impacts from self-selected participants to the broader population may not be appropriate.

Identifying the Appropriate Counterfactual

As mentioned earlier, the goal of this analysis is to look at the impact of incorporating stakeholder participation on the costs and impacts of developing and disseminating NRM innovations. This implies that the counterfactual is the impact that would have occurred if the project had used only conventional methods. In this study, the conventional research and/or extension counterfactual is only used when comparing technology impacts and research costs. We are making the assumption that non-participatory projects do not have impacts on human or social capital or on the research process. These impacts—which we refer to as process outcomes—result from the interaction of researchers and farmers; thus they could not occur in a non-participatory project.

The extent to which this counterfactual can be achieved in each case study varies. In some cases, participatory methods were either not part of the original project plan or resulted in major changes in project activities. In these cases, we have enough information to use the original project plan to construct a hypothetical counterfactual. In other cases, we will need to identify an appropriate comparison with a project that addressed a similar problem in a similar community using non-participatory methods. This may be another project by the same or a different organization.

The Definition of Technology and Adoption

In every project farmers were encouraged to experiment and make changes to the technologies. This was an important goal of the projects. However, it complicates impact assessment because it is not always clear whether an innovation is really an adapted version of a project technology or something entirely unrelated. This type of outcome is common, and getting at the causality of these impacts may require more qualitative and participatory methods of data collection than conventional impact studies that have clearly defined technologies and definitions of adoption.

2.1.3 THE IMPACTS AND COSTS OF USER PARTICIPATION IN NRM RESEARCH: A COMPARATIVE ANALYSIS OF THREE CASES

In this section, all empirical impacts observed in the three case studies are discussed separately, by stage of research process (see table II-34 for summary). Given the types of participation in the cases, the main hypotheses that we can test relate to consultative participation versus conventional research methods at the design and testing stages, and collaborative participation at the dissemination stage. The remainder of this paper is organized around the three stages of the research process-design, testing and diffusion..

For each stage, relevant hypotheses for all four impacts are assessed. A summary of the comparative analysis is presented in table II-34. The concluding section assesses the usefulness of the typology of participation and the conceptual framework developed for this analysis.

User Participation in Project Design

The CIP project was the only one that involved user participation in project design where key problems and potential solutions are identified. In both ICRISAT and ACORDE-WN, project staff made these decisions, drawing on past experiences and in consultation with other R&D professionals.

Technology Impacts

The hypothesis regarding participation at the design stage is not type-specific, which means that impact would be expected to increase as participation of farmers increased. It was hypothesized that participation at the design stage would lead to an increase in the proportion of the targeted beneficiary group that could potentially be reached by the project because the priority topic chosen for research would be more relevant to the needs and priorities of targeted farmers (H1). The findings in these case studies support this hypothesis with regard to impacts on the size of the potential beneficiary group.

In the case of CIP, user input in the design stage led to significant changes in the focus and activities of the project, most importantly the shift from IPM to ICM. Analysis of both production data and opinions of FFS and non-FFS participants show that ICM aspects of the work were indeed most relevant to farmers, and contributed to the benefits that farmers obtained.

Where farmers did not participate at the design stage, topics initially selected for research were less relevant to users' immediate needs. In the ICRISAT case, evidence supports the researchers' conclusion that soil fertility was the problem; however, the technologies chosen for testing (the legume intercrops and rotations) were found not consistent with users' preferences and constraints. Researchers selected the technologies based on their agronomic performance, although they knew that they had not been accepted in the past. Lack of adoption was in part the motivation for seeking farmer input via the MB trial methodology. Useful information for research was obtained as a result of the project; however, adoption remains low.

The WN project was similar to the ICRISAT case in that it worked with existing technologies whose adoption had been low. However, in ACORDE-WN's case, the project's flexible implementation and intensive focus on farmer capacity building and adaptation overcame some initial inconsistencies between user needs and project technologies. The conclusion from these three studies is that if adoption is the goal in the short run, then involving users in the early stages can help identify technologies that are relevant and appropriate. If users are not involved at the beginning, it may mean that farmers either spend more time later in adapting technologies or they simply do not adopt them.

Impacts with regard to women are mixed; however, there is no support for the assumption that not including gender explicitly hindered a project's ability to achieve its stated NRM objective. Diagnostic gender analysis was carried out in the CIP case, and it was found that women generally played a small and secondary role in sweet potato production. Therefore they were not targeted in subsequent project activities. Some women did ultimately participate in the SP ICM FFS as implemented by the NIPMP, and the results of the impact assessment do not show gender differences in the economic benefits of participation.

The ICRISAT case did not conduct gender diagnostic analysis; however, it was assumed that cultural aspects of agriculture (e.g., men's vs. women's crops) would make this project relevant to women. Women played a part in the project activities, and appeared to have benefited economically to the same extent that men did.

In the WN case, no formal diagnostic gender analysis was done. However, again project staff knew that women were not involved in agricultural production and therefore did not include them in NRM project activities. In this case, we did not find examples of women benefiting directly from the technologies or practices promoted by ACORDE-WN. Including women in the design stage of the NRM component of this project would likely have resulted in a very different project, perhaps not focusing on soil conservation or even crop agriculture. Not including women does not appear to have diminished the impacts with regard to the project-stated soil conservation objectives.

Although these studies support the hypothesis that farmer participation at the design stage increases the size of the potential beneficiary group, no support was found for the implicit assumption that the magnitude of benefits increases as participation moves from functional to empowering. The CIP did a consultative assessment of constraints and opportunities in sweet potato production. They also did data collection and interpretation, and pilot field schools to test the methodology for sweet potato collaboratively. Given the iterative nature of the project, the usefulness of consultative work done just at the beginning is difficult to compare with the ongoing collaborative activities. However, clearly some of the lessons from participation, such as the importance of non-pest issues or the opportunity for improving efficiency of nutrient management, emerged in both consultative and collaborative analysis. In fact, the consultative analysis may even have identified more constraints. Farmer-researchers were initially reluctant to believe some of the researchers' conclusions from needs' assessment, such as the importance of economic analysis or the possibility that current nitrogen fertilizer use was excessive. Over time, and as a result of experimentation activities, they were convinced. Collaborative participation was important in refining the issues and in developing and testing technologies, but regarding their contribution to identifying problems and priorities, collaborative participation at the design stage did not appear to be better than consultative, and may even have been less effective.

Human and Social Capital Impacts

It was assumed that human and social capital impacts would only occur with empowering participation, which we define here as collaborative or collegial. Using collaborative participation at the design stage was expected to improve participants' ability to interact with outsiders, to articulate and evaluate their opinions and priorities, and to negotiate joint solutions with other stakeholders who may have different opinions. Here we can assess whether these impacts occurred in the collaborative aspects of the CIP case. Because no women participated in the collaborative research activities, gender-differentiation of benefits cannot be assessed. We can look at whether any impacts were observed among the participants in the consultative aspects, and test the assumption that no impacts occur with functional participation.

Because the principal participants in the CIP collaborative activities at the design stage—the farmer-researchers—were also the participants in collaborative activities at subsequent stages, separating the two effects is difficult. A way of doing so is to look at progress over time. Project staff observed that farmer-researchers were initially hesitant to advance opinions, and that the content of their input was often simplistic. As their experience with experimentation and sharing information grew, they became much more confident and more capable of managing complex concepts, activities, and interactions. This suggests that their involvement in design-stage activities alone was not sufficient to increase their capacity. However, combining design and testing stages led to significant impacts. This finding does not support the hypothesis that collaborative participation at the design stage has human and social capital benefits.

Regarding impact on the participants in the consultative activities, the individuals who participated in these activities were not an explicit focus of the data collection. Some were involved because they later participated in the FFS, but as a group the farmers who collected field data or who answered questions in the consultative needs' assessments exercises were not systematically evaluated. We can state that in all our interactions with farmers, the farmer-researchers were significantly different from others in terms of their ability to express themselves, to answer and ask questions, and to explain complex issues. They were also more likely to experiment, and to be sought out by others for advice. Further, the village leaders and other key informants specifically mentioned changes in the human capacity of farmer-researchers, but said nothing about these impacts with regard to other farmers. These observations are consistent with the assumption that there are no human and social capital impacts with functional participation at the design stage.

Feedback to Formal Research Impacts

Similar to the human and social capital benefits among participants, we would also expect to find benefits to the knowledge and capacity of researchers as a result of their interactions with farmers. With consultative participation, researchers would be expected to learn about farmers' existing problems and their priorities for solutions. In collaborative participation, researchers and farmers interact so that although researchers still ultimately learn about farmers' priorities and constraints, these may have evolved as a result of the interactions with researchers. Further, in collaborative participation, researchers incorporate farmers' perspectives in their work because authority for identifying final priorities, problems, and solutions is shared. Impact can be observed among researchers at the project, program, or institutional levels.

The results from the CIP case support the general hypothesis that user participation increases researchers' knowledge of user priorities and constraints. The project contributed to changes in CIP research priority decisions regarding sweet potato weevil in Asia, the importance of scab, and the the need to screen germplasm for important commercial characteristics like starch content. The ICM concept is also widely used within the center.

Support for the hypothesis that the nature of feedback impacts differs by type of participation is less strong. As reported earlier, the initial information generated from consultative and collaborative participation at the design stage was very similar. As mentioned above, researchers drew some conclusions from their consultative work that did not emerge initially in the collaborative work. Over time, as the collaborative interaction between researchers and farmers continued, new priority topics and problems emerged, partly as a result of new knowledge and perspectives gained through interaction, confirming that collaboration can influence farmers' priorities and criteria.

Cost of Research Impacts

It was hypothesized that costs increase as participation moves from conventional to consultative or collaborative participation, although they may be reduced later. Participation is also hypothesized to increase farmers' costs. In general the results of these three cases support these hypotheses; however, the magnitudes of the differences may not be as large as is often assumed. For example, ICRISAT invested in participatory activities with researchers from different institutions to identify problems and select technologies. It may have been possible to include farmers with little additional cost, and their input could have resulted in changes in technologies and/or implementation strategies. In the CIP case, the financial costs of the consultative and collaborative work were not so different. The consultative was shorter in duration with more high-cost researcher time. There is no evidence that conducting diagnostic gender analysis increased costs. CIP's collaborative design-stage work lasted longer—2 to 3 years, but this also included many of the testing stage activities—and involved more farmer and field assistant time. The CIP case suggests that even at the collaborative stage some research costs, such as managing data collection, can be passed on to farmers, which raises their costs, but lowers total project costs even when farmers are compensated. This impact was previously hypothesized to occur only in collegial participation.

User Participation at the Testing Stage

At the testing stage, where solutions are tested and evaluated and recommendations made, all three projects used some form of user participation. The ICRISAT project used consultative, and the CIP and ACORDE-WN projects used collaborative.

Technology Impacts

The size of the potential pool of potential adopters is determined at the design stage through the selection of the problem to be addressed and the type of solutions to be considered. At the testing stage, user involvement is hypothesized to contribute to increased adoption by helping ensure that the technology or technologies ultimately selected for dissemination are appropriate for the largest number of people either in general or in specific beneficiary groups. The cases provide some support for this hypothesis.

The ICRISAT case, where participation was consultative, provides on suggestive, preliminary evidence about possible future impacts. Where farmers carried out trials according to researcher-designed protocols, farmers' perceptions and rankings of the technologies differed from those of researchers. This information could be useful for future technology development or for designing dissemination strategies. Because women participated in the trials, preferences could be disaggregated by gender. Some differences were found, but were not statistically significant. Because testing was consultative, we cannot know whether farmers had any ideas about how the technologies might be adapted to make them more appropriate for their purposes, nor whether gender differences would have mattered here.

Where testing-stage participation was collaborative, farmer input led to changes in the technologies themselves, which were linked to higher levels of adoption. Farmer-researchers in the CIP project made a significant contribution to testing, evaluation, and adaptation. They selected which technologies to test, designed and implemented trials, and evaluated results. In many cases, such as fertilizer use, they may have obtained the same results and interpreted them in the same way as researchers would have done. In others, such as cultural practices or the testing of the FFS methodology, they provided insights that researchers would not have had.

In the case of the ACORDE-WN project, the technologies selected by the project were presented to farmers as a basis on which to begin a self-sustaining process of innovation. High levels of adoption and especially adaptation, both during and after the project, support the hypothesis that farmer involvement in testing and modification is key to achieving high levels of adoption with NRM technologies such as soil conservation practices.

Human and Social Capital Impacts

Since human and social capital impacts were assumed to occur only with empowering participation the relevant hypothesis to test related to the collaborative participation used in the CIP and ACORDE-WN cases. The hypothesis was that farmers/communities would enhance their own testing and evaluation skills with an increased knowledge of scientific methods of experimentation and evaluation, and improve their ability to negotiate joint recommendations with other stakeholders who may have different opinions (H6). The null hypothesis of no impact would be expected for the ICRISAT project. The experience of the three cases is consistent with the hypothesis.

In the cases of CIP and ACORDE-WN, where farmers and researchers carried out experiments collaboratively over a period of several years, human capital benefits to the farmers were significant. As mentioned above, they increased their knowledge and understanding of agroecology and of experiment methods. In the case of the CIP farmer-researchers and the ACORDE-WN farmer-leaders, they also increased their self-confidence and ability to interact with outsiders such as researchers and extension agents. The farmer-researchers and farmer-leaders continue to experiment, and to be sources of information in their communities. No such impacts were found among participants in the ICRISAT case, whose interaction with researchers was significantly less intense. The baby-trial farmers enjoyed participation and benefited directly from the opportunity to work with the field assistant and ask him questions. However, we found no evidence of substantive changes in their understanding of soil fertility management issues or experiment methods. It is important to note that these results reflect the impacts of the MB trail method as observed in Chisepo. ICRISAT's subsequent impact assessment work found that when implemented in a more collaborative manner, the MB method did generate human and social capital impacts.

Although human capital benefits were visible and significant, social capital benefits were less so. In the CIP case, many benefits were widely socialized in the sense that the farmer-researchers shared what they learned with their neighbors. However, this seemed to be due more to already existing habits of and networks for information sharing rather than to new patterns of behavior stimulated by the project. In the ICRISAT case, information sharing increased in the context of the project because participants were specifically instructed to share what they were doing with neighbors—something they were not always doing spontaneously. We found little evidence that this would continue after the project ends. No other group activities were formed in connection with the project activities. In both cases, the lack of externalities or other aspects of the resources and technologies that might require collective action surely contributed to the lack of social capital impacts.

The ACORDE-WN project had impact on social capital variables such as information sharing and community activities. The technologies promoted in this project were also essentially at plot level and therefore did not require collective action for effective implementation. However, the project devoted a lot of time to building individual and group capacity in addition to promoting soil conservation technologies. Despite these efforts, in terms of overall community solidarity, evidence on impacts was mixed, reflecting that these types of impacts are complex and difficult to assess, and that stakeholder differentiation is highly important.

Feedback to Formal Research Impacts

Consultative participation at the testing stage is expected to increase researcher knowledge about farmers' criteria for evaluating technologies. With collaborative participation, the potential benefits go beyond researchers learning about farmers' criteria to include the establishment of new shared criteria and the incorporation of the criteria into their research activities.

Researchers and extension agents in all cases benefited from their interactions with farmers. In the ICRISAT project, researchers not only learned of new criteria—such as the ability of technologies to suppress weed growth—but also learned that farmers give less value to other criteria, such as yield potential, than researchers do. Some evidence showed that women and men may have different criteria, and further project work will focus exclusively on women. Researchers from other institutions have adopted the particular participatory methodology used, the MB trial method, for getting basic farmer input from many farmers.

The CIP approach was much smaller scale, working more intensively with fewer farmers. As mentioned in the previous sections, farmers learned a lot from researchers and were clearly influenced by researcher knowledge and methods. The benefits to researchers from the testing stage activities of this project were not so much related to specific criteria or aspects of technologies, but rather to more conceptual issues concerning the different purposes for which experiments are conducted. Within the project, there were experiments carried out by farmer-researchers to assess new technologies, and experiments with the FFS for learning and demonstration purposes. The project had not initially recognized these as different, with different implications for how they should be presented to participants, what skills were needed from both participants and researchers for implementation, and how the results should be interpreted. The project is influencing CIP's research program at a broader level. An NGO involved in the project has also made radical program changes and now incorporates elements of research in all its activities. Impact on the NARS involved was limited.

In the ACORDE-WN project, intensive interactions occurred between farmers and extension agents concerning how to test, evaluate, and adapt technologies. Because this was an extension-oriented project and the purpose of experimentation was to facilitate adaptation and adoption, systematic data on the experiments and their results were not recorded, analyzed, or published. This limited the extent to which others learned from specific technical findings of the trials. However, a great deal of research and extension attention has been attracted to the methodological aspects of the project, especially at international R&D organizations, mainly because of its high adoption rates. In what attention there has been to farmer adaptation, such as in the case of live barriers, the purpose has been to call attention to the participatory methodology, not the adaptations themselves.

Costs of Research Impacts

It is hypothesized that moving from conventional to consultative or collaborative forms of participation increases research costs, at least in the short term. Long-run cost effectiveness should, however, increase. Farmers' costs also increase unless the project works only with the subset of farmers who already engage in experimentation.

In the case of the ICRISAT MB trials, the main costs associated with supporting the baby trials were enumerator salaries, training for project staff in participatory methods, and research time learning and conducting analysis of the type of data generated by the trial method. In the latter two categories, these are one-time costs associated with the PR methods being new in the Center. Future PR projects using the same staff will not have to bear these costs to the same extent. Therefore, the main recurring cost is enumerator time.

How this cost compared to non-participatory projects depends on the nature of those trials. In some cases, on-station trials or carefully managed trials where field assistants regularly visit test plots could be more costly than MB trials (especially on a per trial basis). On the other hand, less intensive methods, such as one we were told of where researchers sent trial kits by bus to extension agents to plant, monitor, and send back results, would clearly be less costly to the research program. Controlling for quality, the actual implementation costs of the MB trials likely were not significantly higher than a non-participatory method.

Farmers were not compensated except for the seed they received from the trial; yet many farmers, both male and female, wanted to be involved initially and stayed involved in subsequent years. This suggests that the trials were not a financial burden for the participants, although some of this may be because the field assistant helped with much of the work. The field assistant said it was easier to work with women because they were more likely to follow the protocol.

In the CIP case, the regular and intensive interaction among researchers and farmer-researchers via workshops added to costs. However, the costs of the actual testing done by the farmer-researchers were not especially high. The farmers were compensated for their time, but they were paid relatively little compared to a researcher or a research assistant. In the early years of the project, farmers were less skilled, but as their experience and capacity grew—largely because of the intensive interaction with researchers—the quality of their experiments improved. As was the case with ICRISAT, use of PR methods is costly at first because new skills must be learned. Once these skills are in place, then the costs decline and quality improves.

The ACORDE-WN project dedicated many more human resources to the communities where they worked, but worked with farmer-extension workers rather than researchers or professional extension agents. This probably lowered costs and increased impact.

However, comparing this project methodology to conventional research trials is difficult because trial data were not kept or analyzed.

User Participation at the Diffusion Stage

The CIP and ACORDE-WN projects used collaborative participation in the diffusion stage, which involves identifying target beneficiaries and designing an extension strategy and/or methodology involving complementary inputs. The ICRISAT project did not have an explicit design component for participatory dissemination. What has been done to date, including production of an extension brochure, is conventional.

Technology Impacts

It was hypothesized that by incorporating users in the design of the dissemination activities, adoption would increase by making sure that those for whom the problem and technology were relevant and appropriate had adequate information, skills, and other inputs necessary to adopt. The experiences of the CIP and ACORDE-WN projects support this hypothesis. In the CIP case, for example, the flexibility of the FFS methodology and the focus on experimentation and skill building made it possible for NGOs to implement it for crops other than sweet potato. In the ACORDE-WN project, the willingness of staff to adjust both technologies and project activities to suit farmer preferences increased farmer interest and participation.

In both the CIP and the ACORDE-WN cases, the key complementary inputs were knowledge and skills. Evidence from the study of spontaneous diffusion in the ICRISAT case suggests that seed availability may be a constraint there. However, little attention was given in that project to farmer knowledge and capacity for adaptation.

None of the projects designed gender-differentiated strategies for diffusion of their NRM technologies. Evidence from studies of spontaneous diffusion in the ICRISAT and CIP cases suggest that women and men receive and diffuse information through different sources. This suggests that if a main part of a project's diffusion strategy is by farmer-to-farmer dissemination, attention to gender may be important in achieving impact.

Human and Social Capital Impacts

Incorporating users into the design of diffusion strategy is expected to increase their understanding of what is involved in mass diffusion of technologies, including the complexity of decision making and the importance of complementary inputs. ***The results of the cases with regard to this impact are mixed.*** In the case of WN, the farmers who were selected to work as promoters and later extension workers learned a great deal about the diffusion of technologies, with many going on to work as extension agents, consultants, and even founders of agricultural service centers. In the CIP case, an attempt to train farmer-researchers to become FFS trainers was not successful. The farmers felt uncomfortable with the process, and much preferred their roles as researchers and resource people. The reason for the different outcomes may be that the CIP farmer-researchers were selected for one purpose (research) and then trained for another (training/facilitation). In the ACORDE-WN case, the farmers were part of a lengthy selection process that included both experimentation and extension activities.

Feedback to Formal Research Impacts

The hypothesis for feedback to research from collaborative participation was that researchers learn about farmer-to-farmer diffusion practices and about what kinds of information and skills both farmers and extension workers need to support spontaneous diffusion (H17**).** Both the CIP and ACORDE-WN case experiences support this hypothesis, with each project making changed to its proposed dissemination strategy based on farmer input.

The impacts regarding the knowledge and skills needed for successful systematic dissemination were much stronger than the ones relating to farmer-to-farmer dissemination. This is especially evident in the ACORDE-WN case, where diffusion beyond the project communities has been limited even 15 years after the project ended. As mentioned earlier, the main "complementary input" needed is information and skills, which it may not be possible to leave to "market forces" in the same way as inputs such as credit or seed production.

Cost of Research Impacts

Costs were hypothesized to increase as participation increased, and this was the case in the projects at least in the short run. However, cost effectiveness appears to have increased because of participation. In the CIP case, running trial FFSs to get farmer feedback and train farmer-researchers was costly, but farmer input led the project to abandon plans to develop its own implementation capacity and work through others, thus reducing project costs and likely enhancing cost effectiveness. It also contributed to the important lesson about farmer-researchers' unsuitability for training/facilitation.

In the ACORDE-WN case, training farmer-extension agents incurred some costs, although much of the early learning was done as part of regular project activities. These farmer-extension agents came to replace outside project staff, which reduced costs and enhanced impacts. Comparisons of cost effectiveness figures show that the project was much more cost effective than other projects promoting similar technologies. In both cases, it must be pointed out that the farmers involved in the design of diffusion strategies had also been involved in other earlier testing stage activities of the projects. This experience clearly increased their effectiveness to contribute in the diffusion stage activities.

Table II-34. Summary of the main impacts of user participation by stage and type

Stage	Main impacts[a]			
	Technology and its adoption	**Human and social capital**	**Feedback to research**	**Costs of research**
Design	Highly important if goal was adoption and/or if subsequent farmer adaptation was unlikely. Empowering participation not necessarily better than conventional. Lack of gender analysis was not a problem for achieving project initial NRM goals, but none of the projects specifically targeted women as beneficiaries of NRM work.	Low, even in empowering participation.	Important impacts within and beyond the projects. Limited impact on NARS. Empowering participation not necessarily better than conventional.	Cost increase compared to conventional, but empowering was not more costly than functional. Diagnostic gender analysis did not increase costs of consultative participation.

Continued.

Table II-34. Summary of the main impacts of participation by stage and type (preliminary results).

Stage	Main impacts[a]			
	Technology and its adoption	**Human and social capital**	**Feedback to research**	**Costs of research**
Testing	Important observed or potential impacts in all cases.	Very high human capital impacts in collaborative, low impact in consultative.	Impacts observed within and beyond the projects.	Recurring costs of participatory trials not significantly different from conventional on-farm trials. Costs increased with collaborative aspects such as workshops, rather than with actual trial costs.
	Collaborative is better than consultative in terms of achieving impact.	Lower impact of testing activities on social capital, although may be due to nature of resource or technology.	Significant impacts observed.	Additional costs regarding training and data analysis. However, these are one-time costs that occurred because PR methods are new.
	No strong support for importance of gender differentiation.	Not including women as participants in collaborative testing deprived them of human capital benefits.	Collaborative not necessarily better than consultative	Including women in consultative testing did not increase costs.
Diffusion	Impacts observed from farmer input to the methodology.	High impacts observed on a subset of non-representative participants.	High impact regarding recognition of importance of skills and knowledge as key complementary inputs issues, less on farmer-to-farmer dissemination.	Short-run costs increased slightly, but overall cost effectiveness also increased.
	Gender differentiation may be important.			

a. NARS = National Agricultural Research Systems; NRM = natural resource management, and PR = participatory research.

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OUTPUT II: IMPACT OF PAST RESEARCH MONITORED

2.2 Evaluación ex-post: El cambio técnico en las sabanas de Colombia. - by: *L.Rivas*

Meta 2001. Evaluar el impacto del cambio técnico logrado en el período 1967-1997 en el cultivo de arroz en Colombia.

Resultados sobresalientes

? Las estimaciones de los beneficios sociales señalan que si bien a nivel del conjunto del país, el cambio técnico evaluado muestra excedentes económicos positivos tanto para los productores como para los consumidores, al desagregar tales beneficios por región y por sistema de producción, se puede apreciar que no todas las regiones del país, ni todos los sistemas de producción, resultaron ganadores en el proceso de cambio técnico durante el período evaluado.

? En las regiones arroceras donde los procesos de adopción tecnológica fueron más dinámicos e intensos como el área Central del país y los Llanos Orientales, se generaron grandes excedentes tecnológicos.

? En el Bajo Cauca, la Costa Norte, los Santanderes y la región Sur – Occidental, en donde la reducción de los costos de producción fue inferior al 20%, el efecto de la caída de los precios del arroz implicó una pérdida neta para esos productores.

? La totalidad de los beneficios de la modernización del cultivo de arroz en Colombia se concentraron en los sistemas de riego y secano mecanizado. El secano manual al no adoptar nuevas tecnologías resultó ser un perdedor neto.

? Los resultados sugieren que en los procesos de diseño de nuevas tecnologías agropecuarias para un país o región, es importante que las opciones tecnológicas a implementar tengan un de amplio espectro en cuanto a regiones geográficas, sistemas de producción y tipo de productores. Un cambio técnico muy exitoso como el evaluado, no necesariamente generó beneficios para todos los actores.

? Lo anterior implica que para buscar la equidad social a través del desarrollo técnico se requiere tener un amplio abanico de posibilidades para todos los grupos de productores involucrados. En particular para los productores de menores recursos.

Informe de avance

Introducción: Dentro de las actividades de evaluación del impacto del Convenio MADR – CIAT se incluye la evaluación del impacto ya logrado por la adopción tecnológica en el área de actuación del mencionado Convenio, la Amazonia y Orinoquia colombianas (A&O).

El cultivo de arroz en el país y en la región de interés es de gran importancia socioeconómica por la magnitud del área sembrada, el nivel de producción alcanzado y por constituirse en un alimento básico en muchas regiones de Colombia. Este cultivo es líder en lo referente a adopción de nuevas tecnologías de producción, observándose un rápido crecimiento de su productividad en el transcurso de las últimas décadas.

La gran dinámica del cultivo observada a nivel de país como un todo, también se aprecia en la región objetivo, especialmente en la Orinoquia. Hacia 1981 el cultivo de arroz en A&O ocupaba 69.3 mil hectáreas, 36% del área en cultivos en esa región, y generaba 298 mil toneladas de arroz paddy. Hacia fines de la década del 90 el área plantada se había más que duplicado, situándose alrededor de 155 mil hectáreas para una producción total de casi 730 mil toneladas (Rivas, 2000). El avance de los rendimientos en producción de arroz en A&O, es un de los principales indicadores del progreso técnico en esa región de Colombia. En efecto en el período 1967-1997 los rendimientos crecieron desde 1720 a 4273 kg/ha. (Rivas 2000 B).

La adopción tecnológica en arroz ha estado íntimamente relacionada con cambios sustanciales en los sistemas de producción imperantes y en su distribución regional. Hacia la primera mitad del siglo pasado, la producción arrocera del país se concentraba en la Costa Norte (28%) y el Magdalena Medio (35%), en tanto que la producción de los Llanos Orientales solo representaba el 6% del total del país (Scobie & Posada,1977). La información del Ministerio de Agricultura para 1997 muestra una reducción sustancial de la participación de la Costa Norte en la oferta nacional de arroz, 9.3%, y un avance muy significativo de los Llanos Orientales, 31.2% (Cuadro 1).

Los estudios de Scobie & Posada (1977) y de Fedearroz (1997) documentan claramente como el predominio de los sistemas de producción de secano que prevalecieron en el escenario de la producción nacional de arroz hacia la primera mitad del siglo pasado, ha declinado paulatinamente. En 1954 ellos representaban el 42% de la producción total, en 1975 esa proporción había caído a 9% y en 1997 solo llegó a 2%. Entre 1981 y 1997 el área cultivada bajo el sistema de secano manual cayó de 200 a 28 mil hectáreas. (Fedearroz, 1997).

El desarrollo tecnológico que aportó variedades de alto rendimiento que se utilizan intensivamente en los sistemas de producción bajo riego y en condiciones de secano mecanizado, implicó sustanciales avances en la producción, la productividad, y el consumo en Colombia. La adopción tecnológica en el cultivo de arroz ha sido permanente y muy dinámica y los indicadores del progreso técnico son el empleo de insumos modernos como la semilla certificada y uso de equipos cada vez mas sofisticado como tractores y cosechadoras. (Fedearroz, 1997)

Con base en lo anterior y dada la heterogeneidad de los sistemas de producción a través de las regiones arroceras del país, se plantea que el impacto económico del cambio técnico resulta de distinta magnitud e intensidad si se evalúa a nivel de región y de sistema de producción.

Impacto del Cambio Técnico en producción de arroz en Colombia.

Para evaluar el impacto ex - post de las nuevas tecnologías de producción de arroz en Colombia se utilizó el Modelo DREAM (Wood y Baixt, 1998), el cual permite evaluar el impacto tecnológico desagregando por región y sistema de producción.

Para tal evaluación se consideraron 6 regiones productoras y dos sistemas de producción. Las regiones consideradas fueron: Central, Llanos Orientales y Amazonia, Bajo Cauca, Costa Norte, Santanderes y Sur Occidente. Los sistemas de producción evaluados fueron riego y secano mecanizado considerados como un solo sistema y el secano manual.

Cuadro 1. **Distribución geográfica de la producción de arroz en Colombia 1967-1997**

Región	1967		1997	
	Producción ‘000 tm	%	Producción ‘000 tm	%
Central 1/	205.1	31.0	688.0	37.6
Llanos Orientales y Amazonia 2/	119.1	18.0	571.0	31.2
Bajo Cauca 3/	172.0	26.0	253.0	13.8
Costa Norte 4/	92.6	14.0	170.0	9.3
Santanderes 5/	33.1	5.0	104.0	5.7
Sur Occidente 6/	39.7	6.0	44.0	2.4
Total	661.5	100.0	1830.0	100.0

1/ Central: Huila, Tolima, Caldas, Cundinamarca y Boyacá. 2/ Meta, Casanare, Arauca, Caquetá, Amazonas, Putumayo y Vichada. 3/ Antioquia, Bolívar, Córdoba y Sucre. 4/ Cesar, Guajira y Magdalena. 5/ Santander y Norte de Santander. 6/ Cauca, Valle, Nariño y Chocó.
Fuente: Cifras del Ministerio de Agricultura de Colombia, agrupadas según la regionalización de la producción aportada por Fedearroz (1997).

En la región Central, la más importante en cuanto a volumen de producción, ella se concentra en los departamentos del Tolima y Huila, en los cuales se observan altos niveles de desarrollo tecnológico y en donde predomina el sistema de riego. En los Llanos Orientales, la segunda región en importancia, el grueso de la producción se genera en los departamentos del Meta, Casanare y Arauca. En el primero de ellos utilizan predominantemente el riego y el secano mecanizado, en el Casanare es más frecuente el sistema de riego y en Arauca el secano mecanizado (Fedearroz, 1997).

El bajo Cauca, que incluye los departamentos de Antioquia, Bolívar, Córdoba y Sucre, presenta niveles tecnológicos relativamente bajos, debido al predominio del sistema de secano manual. En la Costa Norte del país una alta proporción de su producción se genera en condiciones de riego. Los Santanderes y el Sur Occidente son áreas arroceras relativamente marginales, que en conjunto no superan el 10% de la producción nacional.

Supuestos técnicos y Económicos

En el Cuadro 2 se incluyen los supuestos económicos y técnicos utilizados para evaluar el impacto económico de la adopción tecnológica en el cultivo de arroz en Colombia en el período 1967-1997. Esta información se refiere a las condiciones de equilibrio inicial del mercado de arroz en las diferentes áreas arroceras del país en términos de producción y precios. También las elasticidades y el crecimiento autónomo tanto de la oferta como de la demanda y los factores de desplazamiento de la función de oferta originadas en el uso de las nuevas tecnologías. Estos supuestos son resultantes de la revisión de numerosos estudios sobre la industria arrocera del país, entre otros: Scobie &Posada, 1977; Montes et al, 1980; Gutiérrez y Herford,1974; Sanint L.R., 1992 y los Anuarios Estadísticos del Ministerio de Agricultura de Colombia de varios años.

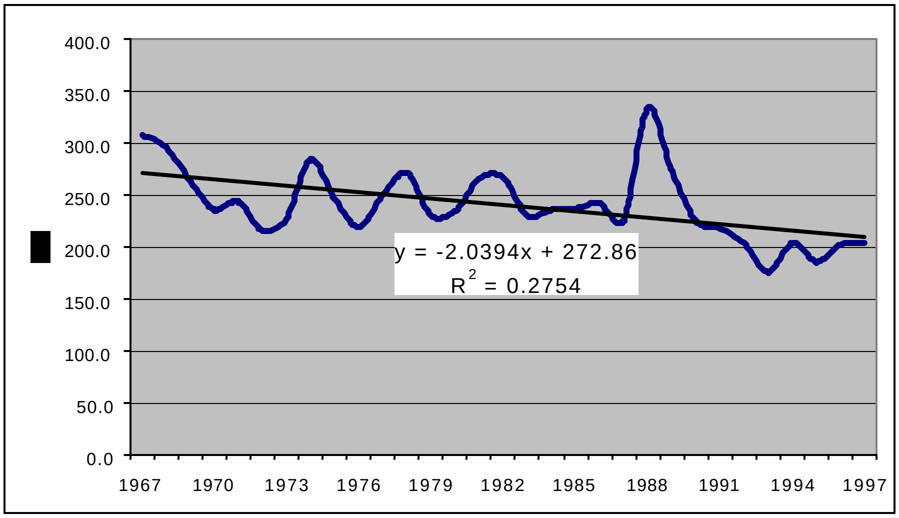
Resultados

Los resultados de la evaluación se expresan en términos de los beneficios sociales recibidos por consumidores y productores y que se originan en el crecimiento de la productividad y en la reducción de los precios reales en los mercados de arroz.

Las estimaciones señalan que si bien a nivel del conjunto del país, el cambio técnico evaluado muestra excedentes económicos positivos tanto para los productores como para los consumidores, al desagregar tales beneficios por región y por sistema de producción, se puede apreciar que no todas las regiones del país, ni todos los sistemas de producción, resultaron ganadores en el proceso de cambio técnico durante el período evaluado.

En las regiones arroceras donde los procesos de adopción tecnológica fueron más dinámicos e intensos como el área Central del país y los Llanos Orientales, se generaron grandes excedentes tecnológicos. En ellas los costos de producción unitarios se redujeron en una proporción superior al 80%. Por el contrario, en las áreas más marginales y en donde la magnitud e intensidad del cambio técnico fue significativamente menor, se observan excedentes negativos para los productores. En el Bajo Cauca, la Costa Norte, los Santanderes y la región Sur – Occidental, en donde la reducción de los costos fue inferior al 20%, el efecto de la reducción de los precios del arroz implicó una pérdida neta para esos productores. Por ejemplo en Bogotá, el principal centro consumidor del país, el precio real al consumidor de arroz se redujo en casi una tercera parte en el período de análisis (Figura 1).

Figura 1. **Precios reales de arroz al consumidor en Bogotá: 1967-1997**
$ de 1990/kg



Precios de arroz de primera, deflactados por el IPC 1990=100
Fuente: cálculos basados en cifras del Banco de la República y el DANE.

Al evaluar el impacto del cambio técnico sobre los diferentes sistemas de producción se consideraron dos tipos: 1) Riego y secano mecanizado, considerados como un solo sistema y 2) Secano manual. Ellos presentan un acentuado contraste a lo largo de un período de casi tres décadas en términos de producción, áreas cultivadas y productividad. El secano manual tiende a desaparecer al contraerse drásticamente tanto sus áreas sembradas como el volumen de producción aportado por este sistema, el cual ha sido relegado cada vez más hacia área más marginales y de menor aptitud para la agricultura. A comienzos de la década de los 60 el 56% del área arrocera de Colombia utilizaba este sistema de producción. Hacia fines de los 90 solo el 2% del área cultivada con éste cereal utilizaba el secano manual (Cuadro 3)

Cuadro 3 **Distribución del área y la producción de arroz en Colombia, según sistema de producción: 1961-1997**

Año	Distribución del área (%)		Distribución de la Producción (%)		Rendimiento (tm/ha)	
	Secano manual	Riego & secano mecanizado	Secano manual	Riego & secano mecanizado	Secano Manual	Riego & secano mecanizado
1961	55.7	44.3	42.3	57.7	1.5	2.6
1997	6.8	93.2	2.2	97.8	1.4	4.5

Fuente: Cálculos basados en cifras de Fedearroz., 1997.

Cuadro 2 **Coeficientes Técnicos e Impacto del cambio tecnológico en la producción de arroz en Colombia, según regiones**

1.1 Valor presente de los beneficios sociales: 1967-1997

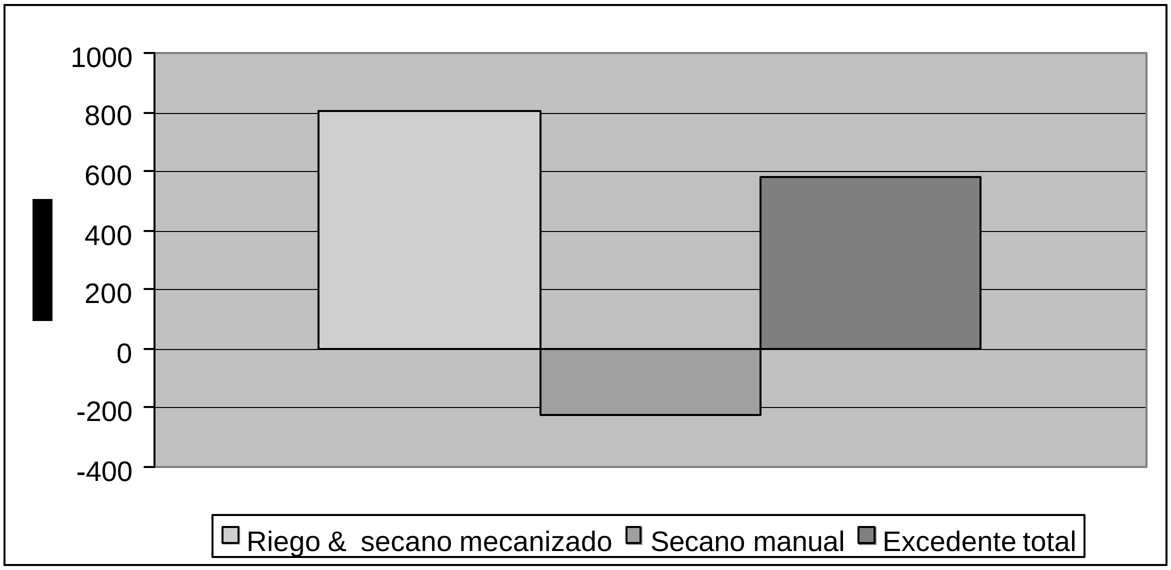
Región 1/	Equilibrio Inicial 2/		Elasticidades precio		Crecimiento autónomo (%)		Desplazamiento de la oferta (%)		Valor presente de los beneficios tecnológicos us$ millones (i=10%)	
	Cantidad '000 tm	Precio '000$/tm	Oferta	Demanda	Oferta	Demanda	Horizontal 3/	Vertical 4/	Productor	Consumidor
Región Central	205.1	584.6	0.80		3.0		73.0	91.3	556.2	
Llanos Orientales	119.1	485.3	0.80		4.0		68.0	85.4	231.9	
Bajo Cauca	172.0	641.2	0.80		1.0		12.2	15.2	-84.3	
Costa Norte	92.6	594.2	0.80		1.5		11.7	14.7	-53.4	
Santanderes	33.1	540.7	0.80		2.9		10.8	13.5	-25.3	
Región Sur - occidental	39.6	583.3	0.80		2.5		0.6	0.8	-44.1	
Total Colombia	661.5	592.7	0.80	-0.50	2.6	2.7	176.3	220.9	580.7	873.5
									Total : 1454.2	

1/ Las regiones consideradas se definen así: **Región Central**: Huila, Tolima, Caldas, Cundinamarca y Boyacá. **Llanos Orientales**: Meta, Casanare, Arauca, Caquetá, Putumayo y Vichada. **Bajo Cauca**: Antioquia, Bolívar, Córdoba y Sucre. **Costa Norte**: Cesar, Guajira y Magdalena. **Santanderes**: Santander y Norte de Santander. **Sur Occidente**: Cauca, Valle, Nariño y Chocó. 2/ Cantidades y precios de equilibrio del mercado de arroz en el año inicial de evaluación. Los precios se expresan en pesos de 1997. 3/ Aumento porcentual de la producción debido al cambio técnico. 4/ Reducción porcentual de los costos unitarios con respecto a la tecnología tradicional..

La estimación de los beneficios sociales al productor, según sistema de producción, revela que todos los beneficios se concentraron en el sistema de riego & secano mecanizado, en el cual el proceso de adopción de nuevas tecnologías fue intenso y de carácter masivo, lo cual posibilito la expansión de sus áreas cultivadas, en desmedro del secano manual para el cual la oferta de nuevas tecnologías prácticamente fue inexistente.

La figura 2 muestra el valor presente de los beneficios tecnológicos capturados por cada sistema de producción.

Figura 2. **Valor presente de los beneficios del cambio técnico al productor de arroz en Colombia, según sistema de producción:1967-1997** (i=10%)



Los resultados obtenidos sugieren que en los procesos de diseño de nuevas tecnologías agropecuarias para un país o región, es importante que las opciones tecnológicas a implementar tengan un de amplio espectro en cuanto a regiones geográficas. sistemas de producción y tipo de productores. Un cambio técnico muy exitoso, como el de arroz en Colombia, no necesariamente generó beneficios para todos los actores. Esto implica que para buscar la equidad social a través del desarrollo técnico, se requiere tener un amplio abanico de posibilidades para todos los grupos de productores involucrados.

Actualmente los productores de arroz de secano corresponden al grupo pequeños agricultores de áreas marginales que viven en condiciones de subsistencia. La falta de desarrollo técnico para ese sector ha implicado pérdida de competitividad y una reducción dramática de su participación en el mercado del cereal. Si se considera que ese segmento de los productores de arroz es huérfano debido a la falta de nuevas alternativas tecnológicas, se plantean varias posibilidades. a)Se debe efectuar un esfuerzo importante para dotar a ese sector con nuevas tecnologías que mejoren su competitividad b) Se deben encontrar otras opciones de producción diferentes al arroz para estos productores y enfatizar la investigación de arroz en los sistemas bajo riego. La respuesta no es fácil, no existe consenso entre los investigadores y planificadores sobre las posibles líneas de acción. Algunos argumentan que las posibilidades del arroz de secano son muy limitadas y que en consecuencia todo el énfasis debe colocarse en los sistemas de riego y de secano favorecido, en tanto que otros investigadores consideran que el potencial de los sistemas de secano ha sido subestimado.

Independiente de lo anterior, lo más práctico parece ser, que el portafolio de investigación sea lo suficientemente amplio en términos de cultivos y sistemas de producción, para permitir un proceso de modernización de la agricultura en el cual todos los actores y en particular los de menores recursos, en los diferentes sistemas y regiones geográficas, tengan la posibilidad de involucrarse en el proceso y capturar beneficios del mismo.

Donante: Ministerio de Agricultura de Colombia. Convenio de Cooperación Técnica y Científica MADR - CIAT

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2.3 Economic Evaluation of Agricultural R&D for the Savanna Ecosystems of Latin America: The Case of Maize in Meta Department, Colombia – *by L. Mosquera*

Introduction

In recent years, with an ever increasing demand for food from a growing population, there have been pressures to expand the agricultural frontier as a means of enhancing food production. Two geographically large areas for potential expansion are the forest and savanna regions in the humid tropics. However expansion into forest areas has many negative environmental consequences – reduced biodiversity and wildlife habitat reduced carbon storage, and often, significant disruption of the hydrological cycle for downstream water uses. Thus, expansion of agriculture into the savanna areas has long been an agricultural development goal. However, despite the great potential for these very large tracts of land, particularly in Latin America and Africa, it has proved extremely difficult to generate new technologies that can provide environmentally and economically sustainable production because of the poor quality of most tropical savanna soils. Tropical savanna soil has been classified as highly acid with high levels of aluminium toxicity and, generally speaking, infertile (Sanchez and Salinas, 1983).

For several years the Instituto Colombiano Agripecuario (ICA), the International Centre for Tropical Agriculture (CIAT), and the International Centre for Wheat and Maize in Mexico (CIMMYT), have been working on livestock-based production systems for savanna soils. This has included breeding grasses tolerant to high aluminium saturation and the development of crop varieties that are more tolerant to special conditions encountered in the savannas. The latter approach has been tried in four regions since 1980: Eastern Africa, South and Southeast Asia, the Andes and Central America. And CIMMYT has maintained a presence in the Andean region since late 1977 for co-operative research work in Colombia, Ecuador, Peru, and Bolivia in the development of new maize varieties for acid soil.

Genetically, maize is more susceptible than rice to aluminium toxicity, and this complicates the crop improvement – breeding – process. Late in the 1980 a co-operative program started (ICA, CIMMYT and CIAT) to develop the variety SIKUANI V-110, which is tolerant roughly to 55% aluminium saturation, and provides yields of about 3.0 ton/ha under those conditions and about 7.5 ton/ha in normal fertile soils.

Maize has a comparative advantage over other species as a component in savanna cropping systems for the following reasons:

1) It does not need high levels of mechanisation for sowing and harvest
2) It is less demanding in labour
3) It does not need industrial processing for direct human or animal consumption
4) Cultural practices may be performed manually or with reduced mechanisation.

Improved maize technologies could, thus, potentially lead to the improvement of the Eastern Savanna (Llanos Orientales) of Colombia for crop and animal production, reduce expansion pressure into Amazonian forest areas, and help in the long-run recovery of these soils. With new maize varieties the inherent acidity, and infertility of soils in the Llanos Orientales becomes less problematic for rural households.

The variety SIKUANI V-110 was released in 1994 by the Corporación Colombiana de Investigación Agropecuaria, Regional 8 (CORPOICA), based in Villavicencio – but including places such as La Libertad, Carimagua and Meta, where the most of the research was carried out.

The research undertaken in the Llanos Orientales focuses on sustainable production system in maize, to meet increased human food and animal feed demands, to develop some comparative advantage for farmers in that region, and to generate technologies compatible with the fragility of this particular agro-ecosystem.

The origin of the SIKUANI V-110 variety lies in the 192 materials evaluated under aluminium toxicity conditions (with 45 to 75% of saturation). The best material populations were chosen from these trials for subsequent breeding and further improvement and only after thirteen year of tests and trials in such acid soils was the variety considered ready for release.

The evaluation trials were conducted in Colombia, Thailand, Indonesia, Peru, Venezuela and Brazil, and the representative yield was around 3.0 ton/ha. The results presented by researchers show that this variety has potential in other regions in the world with similar soils to those of the Colombian savannas (saturation in aluminium 55%, acid, and low availability of phosphorus).
However, these results were only achieved through the combined efforts of research institutes (ICA, CORPOICA, CIMMYT AND CIAT) over 17 years.

Background and justification

Colombia is the third largest maize producer in South America, after Brazil and Argentina. Maize plays an important role in the diet of the Colombian population. Great efforts are therefore made to maintain and increase production steadily, both by better cultural methods and by the use of more suitable varieties and hybrids. All of these productivity increasing activities require investments in agricultural research – research targeted to improving yields, reducing crops losses, minimising the need for cultivation in fragile soils, improving the processing and nutritional value of the grain, and so on. However, it is important to ensure that limited public research and development (R&D) dollars are targeted to the mix of commodities, geographical areas, production technologies and, often, social groups that can best maximise social welfare.

Greater demands for accountability, shrinking research resources, and the growing complexities of research goals are focusing the attention of R&D managers on the need for improved R&D evaluation and decision making methods. Furthermore, the increasingly competitive nature of R&D funding is accelerating the search for areas of

comparative advantage or complementarily in research – in order to select appropriate R&D partners and strategically important research themes.
Methods for evaluating the direct production effects of technology, such as those involving increased genetic potential or improved efficiency in the use of inputs such as seed, labour, machinery, and fertiliser are fairly well established and increasingly applied. However, when the research must include productivity changes arising from the interaction between new technologies, production systems, and natural resources – such as poor savanna soils, these methods are not effective. There is an urgent need to systematically extend the R&D evaluation framework in order to encompass this natural resource quality issue.

As previously discussed, a major development issue in the extensive humid tropical savannas of Latin America is the difficulty of managing the highly weathered soils in a sustainable way. Even modest attempts at increasing livestock and crop productivity must be undertaken with great care if a rapid decline in (already low) soil fertility is to be avoided. Furthermore, new technologies should not only prevent soil productivity losses in a cost-effective manner but, ideally, should also help to increase the inherent productive capacity of soil over the long run. As has been demonstrated in the Brazilian Cerrados, there are potentially large payoffs from bringing savannas into more intensive agricultural production. In Colombia, however, the savanna (or Llanos) area has been subjected to much land speculation associated primarily with the laundering of drug money, and land prices have been artificially inflated relative to their agricultural opportunity cost. At the same time, continued guerrilla operations and high interest rates have done little to foster positive attitudes to long-term land-enhancing investments. It is important, therefore, that realistic analyses are made of the potential economic attractiveness of new agricultural technologies targeted to such areas.

This study is concerned with the development of improved methods to assist in the ex ante economic evaluation of the likely outcomes of research and extension investments into new maize technologies target to the Llanos conditions.

Objectives of the Research

The principal objective of this thesis is to apply new methods of economic evaluation to agricultural production systems that incorporate technologies designed to simultaneously enhance crop productivity and soil resource conditions. If such an approach can be validated it can serve not only to assess the likely impact of technologies currently under development for the Colombian Llanos, but also as a general means of testing a range of strategic research policy and technology design options. The approach could help to design research that has greater research benefits, and alter the distribution of benefits in ways seen more socially acceptable (for example, by increasing the share of benefits going to poor rural households).

Specific Objectives

1. To describe the existing production systems in the Meta department with regard to the production of maize.

2. To analyse the trends in prices, production costs and technology adoption (specifically in technical and traditional maize production systems) in Meta department.

3. Make an assessment of the size and distribution of economic benefits by *municipios*, by producers and by consumers.

Next to the fact analysis regarding to these specific objectives the following questions were formulated in order to address points 2 and 3:

1. What are the likely socio-economic benefits of maize research for the Llanos (Meta)? What are the impacts on modern and traditional maize growing producers and maize consumers? How the impacts vary across *municipios*?
2. Assuming no technical change and falling world commodity prices can Llanos crop producers remain competitive? How much would the sector shrink in the next 25 years if no new technologies were introduced?

The Statement of the Problem

Accelerated loss of soil productivity under cultivation

The development problem faced is that while the savannas are extremely extensive their agricultural use is limited, primarily because of poor soil productivity. Not only are the savanna soils of relatively low inherent fertility under natural conditions, but even those low levels degrade relatively rapidly under cultivation (typically the soils are unproductive after 3-5 years of cultivation). Furthermore, the soils are relatively poorly drained, and in the rainy season many areas are difficult to access. These biophysical limitations have, in turn, provided little incentive for systematic, sustained investment in infrastructure in the savanna. Most economic exploitation has been associated with low-productivity extensive livestock operations. Investment in agricultural research targeted to the savannas has been made in the expectation that more intensive, sustainable production systems can be developed. There is even a hope that some of these production systems could bring about significant long-term increases in the productive capacity of savanna soils (e.g., by building up organic matter, and improving the soil's physical and biochemical properties).

The Llanos Orientales are located in a humid tropic ecosystem, with an annual precipitation in excess of 2100 mm. and an average temperature of 26^{o}C. Those environmental conditions can induce rapid soil degradation in the kind of agro-ecosystems under development for intensive agriculture in the region. Soil degradation drastically reduces the profitability of production systems with low crop yields, low response to fertiliser application, low seed germination, fungus infections, soil erosion and more labor costs, among other things.

The rotation systems recommended in the region, most incorporating green manure, are maize-soybean, rice-soybean, rice-cotton, maize-cotton and also rotations with sorghum during the second semester. These types of rotations require careful management. It has been reported that using legumes (as a green manure) in association with maize crops increases soil organic matter, the micro-organism and the availability of macro and micronutrients, decreases aluminium (Al), increases pH and helps to aggregate the soil in ways that improve water holding capacity, ventilation and electric conductivity, and the regulation of soil temperature (Lal, 1995, mentioned by Luna and Rodas 1996).

Designing of Scenarios

Simulating the process generation, adoption and economic impact of the technology, it's necessary to know the context in which the technology is developed and adopted. The likely way how R&D impacts to the society is related with a lengthy range of factors – many of them not related with R&D products themselves. Among these factors could be included the macro approaches, such as basic economic and the demography structure of the regions, as well fiscal policies, agricultural and commercial – domestic and international. This includes a number of factors that influence the capacity and availability of the producer to adopt new technologies or practices. These factors are often directly related with expectations about the input markets and agricultural outputs.

The *ex ante* analysis of the research economic impacts, has been implemented in the software DREAM (Wood & Baitx, 1998), which is a temporal simulation of the generation and adoption of new technology as well its subsequent impact on markets and social welfare. Besides this, the DREAM model can explicitly take into account other factors, such as taxes or subsidies to production and consumption, and also production and consumption growth which arise from sources other than technological change. Those factors, as well as the producers and consumers response to price changes (elasticities), are parameters of the model over which the users have control.

To develop scenarios it is necessary to consider the strategic framework in which the R&D investment is carried out. This includes the institutional objectives or goals to be reached by the R&D, i.e. increasing agricultural productivity and rural incomes, food security improvement, or minimisation of negative impacts on the environment.

Other information to formulate scenarios is related to the scale and purpose of the evaluation. There are two dimensions in the scale – the first one is connected with the geographical target and the another one is concern with the split between research components, i.e. national programs, projects and even sub-projects. These factors are critical in determining the level of detail and complexity required for the analytical representation.

As concrete example of the factors that influence in the design of scenarios:

- Agricultural price policies – often expressed as taxes and subsidies related to production and consumption. This factor can change in the time.

- Development factors that promote changes in the agricultural product supply – like possible investments in rural infrastructure, credit systems or better peasant organisation models.

- Factors that stimulate demand – population and real income growth, changes in the consumer’s taste and new uses for agricultural commodities.

- Heterogeneity of production and consumption in relation to research objectives. It is possible to estimate what would be the technological impacts in specific social groups – small producers, hillside producers, rural and urban poor consumers etc. It is necessary to have appropriate groups for the disaggregation of regional data. The framework allows for different definitions for each group, but the analysis treats the groups simultaneously giving the possibility to observe not only the impact on the group, or but also how it would change the equilibrium among groups according to the different patterns of research investment.

In this case a number of regions of market regions on municipalities were defined; and it is possible to evaluate the simultaneous effects of the new technologies impact adopted in one or all regions. For the analysis it is necessary to assume that the total production across all regions is equal to the consumption in all regions, but it is not necessary that production and consumption are in equilibrium in each region. The model computes the annual prices for each region considering the conditions of all market simultaneously (endogenous).

The results of the evaluation have several elements and many ways to display them. The detailed results are important for the scientists who explore alternative strategies of implementation for a given research theme.

Data

The information on which this study is based comes from primary and secondary sources. Primary data come from several sets of “long-term” (3-5 year) experimental field data and on-farm trials involving different crop, crop rotations, and management practices in the Llanos. The experiments monitored changes in crop yields over time as well as recording the simultaneous changes in a range of soil properties. These benchmark data help to establish the economic impacts of new production systems in an experimental setting. The on-farm trials and municipal production data provide additional information on the extent to which producers are actually adopting new technologies given the overall sector trends and the resource and market constraints that producers face. These data have been collected over the last 10 years by CIAT in collaboration with the Colombian national research agency CORPOICA (formerly, until 1993, known as ICA), the International Fertiliser Development Centre (IFDC) and others.

Secondary information for the Meta province was collected in Bogotá and Villevicencio includes; production, area, yield, and prices, as well as census data on population and farm size. As far as possible these data were collected at the municipal level (of which there are 24 in Meta). Additional information included detail on wholesaler prices at Villevicencio and Bogotá the major markets for agricultural trade to and from Meta Department. In the case of maize, the region is a net importer to meet the needs of both human and animal consumption

In terms of the market data, we have used the *municipio* as the basic economic unit of analysis. Maize production data was collected at the *municipio*. Only two demand (consumption) regions were defined, one to represent the current and projected human consumption in the Meta department, and the other to represent the current and projected demand for animal feed. Another region, external to the Meta was defined as a production source for the net import of maize currently required by the department. A preliminary list of the specific production and consumption regions defined for the simulation is shown in table 1.

Maize production data is available for two maize production systems. The new technologies being tested in the Carimagua experiments are "technical" (improved) maize varieties. But many producers use long established, open-pollinated maize varieties, and these are described as "traditional" maize production systems. Both technical and traditional maize production is included in the economic analysis to ensure that the total maize market is taken into account.

Table 1. Production and consumption regions defined for the maize simulation

Regions	
Villavicencio	La Macarena
Vista Hermosa	Uribe
Others – Technical	Puerto Rico
Fuente de Oro	Others – Traditional
Cumaral	Mapiripan
San Juan de Arama	Mesetas
Granada	Lejanías
El Castillo	External production source
Puerto Concordia	Meta – Human consumption
Puerto Rico	Meta – Animal consumption

The R&D evaluation package, DREAM[4], was used to simulate the likely magnitude and distribution of the economic benefits of technical change, after defining the scenarios for estimating the potential economic impact of new production technologies in the Llanos of Meta, department.

After defining the scenarios for estimating the potential economic impact of new production technologies in the Llanos of Meta, the R&D evaluation package, DREAM,

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[4] Dynamic Research Evaluation for Management (DREAM), is a tool to support the economic impact evaluation of agricultural research .

was used to simulate the likely magnitude and distribution of the economic benefits of technical change.

Conceptual Economic Frame: Representing Technical Change

If we first consider that a new technology is fully adopted, its likely impact will depend on two main considerations:

1. The initial market conditions for the specific agricultural commodity that the technology was designed for.
2. The subsequent change in supply and demand conditions for the given commodity over time. Specifically the difference between the market evolution *with* and *without* the new technology.

In reality the decision to adopt (or not adopt) the new technology is taken by different producers at different times so the likely rates and levels of adoption in different regions are important elements in estimating the stream of economic benefits arising from technical change. The full technology investment and use cycle incorporated in the economic model includes:

1. A time lag for the development and testing of new technologies.
2. A measure of the uncertainty associated with the R&D process (probability of R&D success)
3. The potential impact of technology, K (arising from, say, yield increasing or input reducing technologies) that is expressed as a *reduction in the unit cost of production.*
4. A time lag following the release of a new technology until the ceiling level of adoption is likely to be reached.
5. A ceiling level of adoption (in area or quantity terms)
6. A period of dis-adoption if, say, the effects of a single “wave” of new technology are being modelled, and we know the new technology will itself be replaced within a few years.

Basic Economic Model

In its simplest form, the DREAM approach can be represented for a single commodity market as depicted in Figure 1: S_0 represents the supply function before a research-induced technical change, and D_0 represents the demand function for a homogeneous product. The initial price and quantity are P_0 and Q_0; after the supply shift they are P_1 and Q_1. Suppose research generates yield increasing or input saving technologies. These effects can be expressed as a per unit reduction in production costs, K, that are modelled as a parallel shift down in the supply function to S_1. This research-induced supply shift leads to an increase in production and consumption to Q_1 ($\Delta Q = Q_1 - Q_0$), and the market price falls to P_1 (by $\Delta P = P_0 - P_1$). Consumers are better off because R&D enable them to consume more of the commodity at a lower price.

The total (annual) benefit from the research-induced supply shift is equal to the area beneath the demand curve and between the two supply curves ($\Delta TS = area\ I_oabI_1$).

This area can be viewed as the sum of two parts: (a) the cost saving on the original quantity (the area between the two supply curves to the left of (Q_o – $area\ I_oacI_1$) and (b) the economic surplus due to the increment to production and consumption (the triangular area *abc* total value of the increment to consumption – $area\ Q_oabQ_1$ – less the total cost of the increment to production – $area\ (Q_ocbQ_1)$ --. Alternatively, is possible to portion the total benefits into the benefit to consumers in the form of the change in consumer surplus ($DCS= P_oabP_1$) and benefits to producer surplus ($DPS = area\ P_1bI_1$ minus area P_oaI_o).

Although they receive a lower price per unit, producers who adopt the new technology are better off, because their unit costs have fallen by an amount, K per unit, that is more than the fall in price. Total benefits are obtained as the sum of producer and consumer benefits.[5] Thus the size of the market, as indexed by the initial quantity Q_0, as well as the size of the research-induced savings in the per unit cost of production, K, are critical factors in estimating the economic benefits from R&D. Better estimates of K mean better estimates of the benefits from research, and a better basis on which to allocate scarce research resources.

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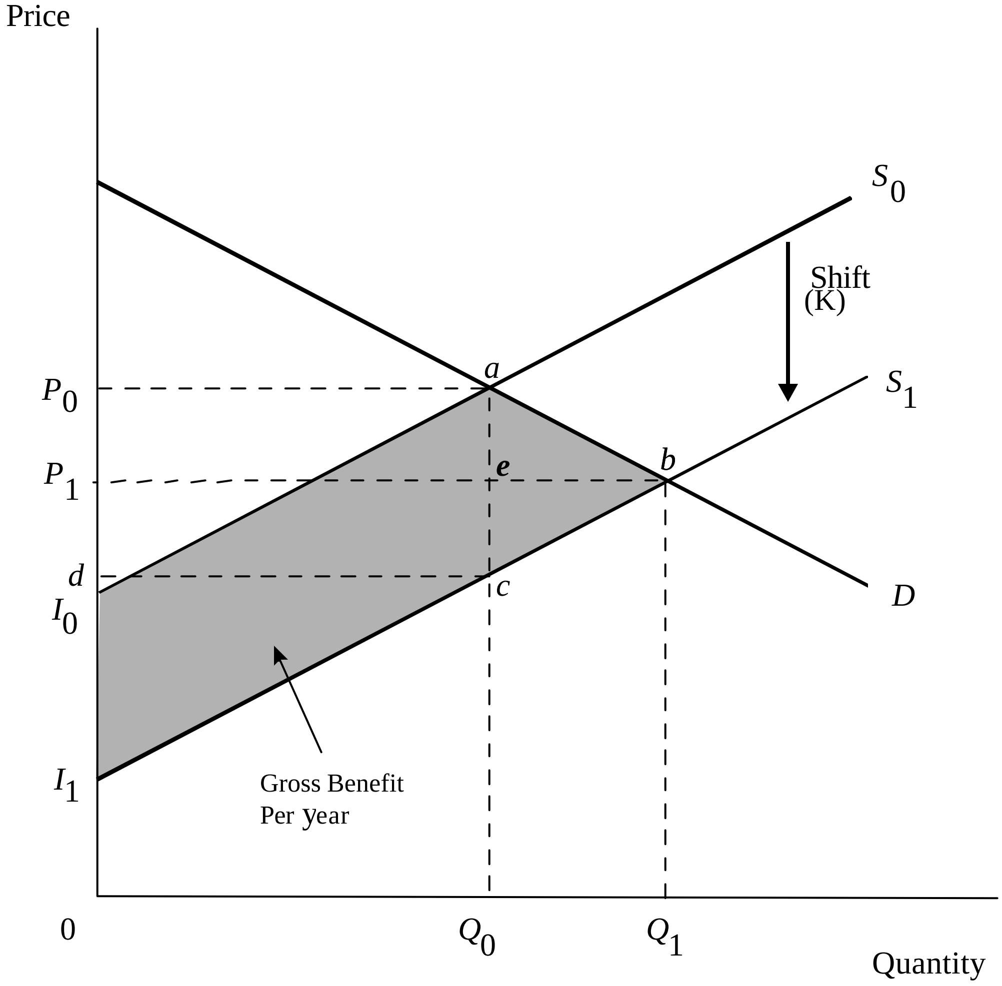
[5] The consumer surplus measure of the consumer benefit is equal to area P_0abP_1, i.e., rectangle P_0aeP_1 (= $Q_0 \times \Delta P$) plus triangle *abe*. The producer surplus measure of the producer gain is equal to area P_1bcd in figure 1, i.e., rectangle P_1ecd (= $Q_0 \times [R - \Delta P]$) plus triangle *bce*.

Figure 1: Surplus distribution on the basic model of research benefits



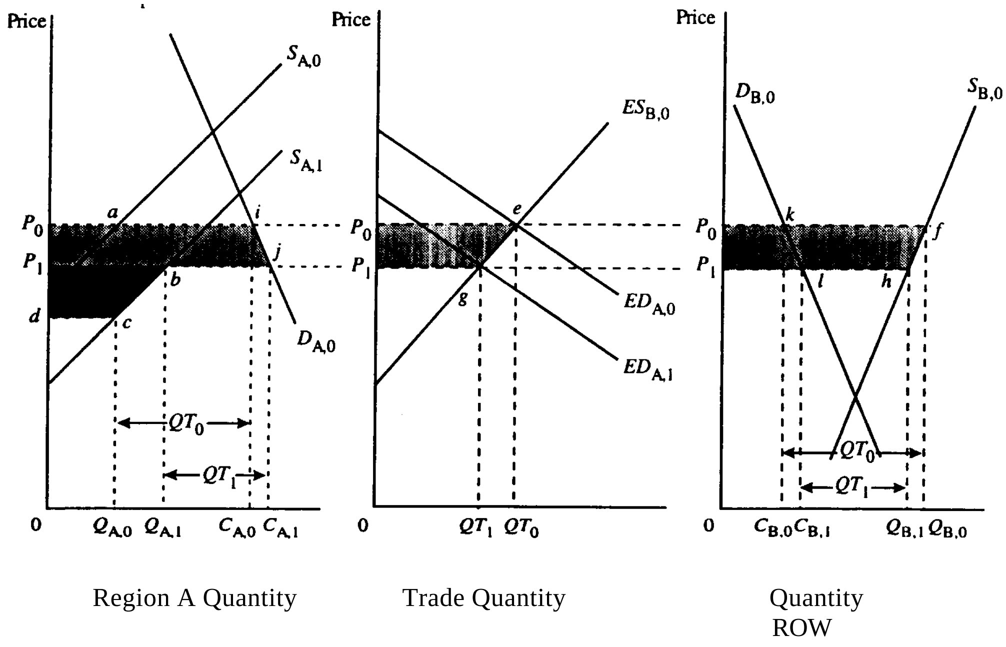
Source: Alston, Norton and Pardey(1995)

Given the site-specific nature of much agricultural R&D, knowledge of the agro-ecological factors that shape the various biophysical responses to a new technology -- be it a new seed variety or a new crop management practice -- can substantially improve the estimate of *K* used to calculate the benefits from research. A weighted sum across the zone *K*'s, using, say, production shares as weights in the aggregation, is likely to yield a more informative and accurate estimate of the overall *K* compared with an approach that leaves this aggregation process implicit or undefined. Used in this way, multimarket models, in a sense of more markets for one product, have the capacity to capture both spatial variation in the effects of R&D that primarily have an agro-ecological dependence and the spatial variation in market factors that span agro-ecological domains.

Agro-ecological and biophysical data are useful for evaluating the *potential* results of R&D in changing productivity and natural resource conservation, but realising this potential also depends on other factors such as rural infrastructure investment, communication systems, roads, education and health services, as well as the national structure of the agricultural sector and distortionary government policies.

This framework also has the capacity to represent multiple regions (markets) and interacting with each other through trade. Figure 2 shows the case of two regions. Under the assumption of free trade it is not necessary to have internal equilibrium conditions in each region.

Figure 2 Import Innovator Region and its National Impact and through Interregional Trade


(a) Region A. Production, Consumption & Trade (Importer region)

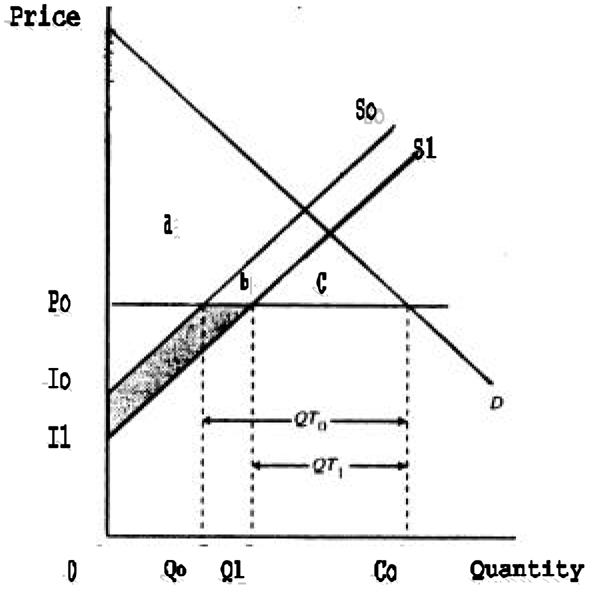
(b) Excess supply demand & Trade

(c) Region B (or ROW) Production, consumption & Trade

If the innovator region, Region A, is an importer, consumers world-wide benefit from the research-induced, price decrease (domestic consumers gain P_oijP_1 in graph (a), and ROW producers loss (area P_ofhP_1 in graph (c). The innovator region gains. In contrast with the export innovator region the ROW looses because the loss to ROW producers (area P_ofhP_1 in graph (c) exceeds the benefit to ROW consumers (area P_oklP_1). The net ROW loss is shown as the area P_oegP_1 in graph (b) (which equals area P_ofhP_1 minus area P_oklp_1=area *kfh*l in graph (c) in Fig. 2.

The impact of research in a small-region importer of a commodity as in the case of Meta department in Colombia is illustrated in Figure 3.

Figure 3 Small Open Economy: Importer Case.

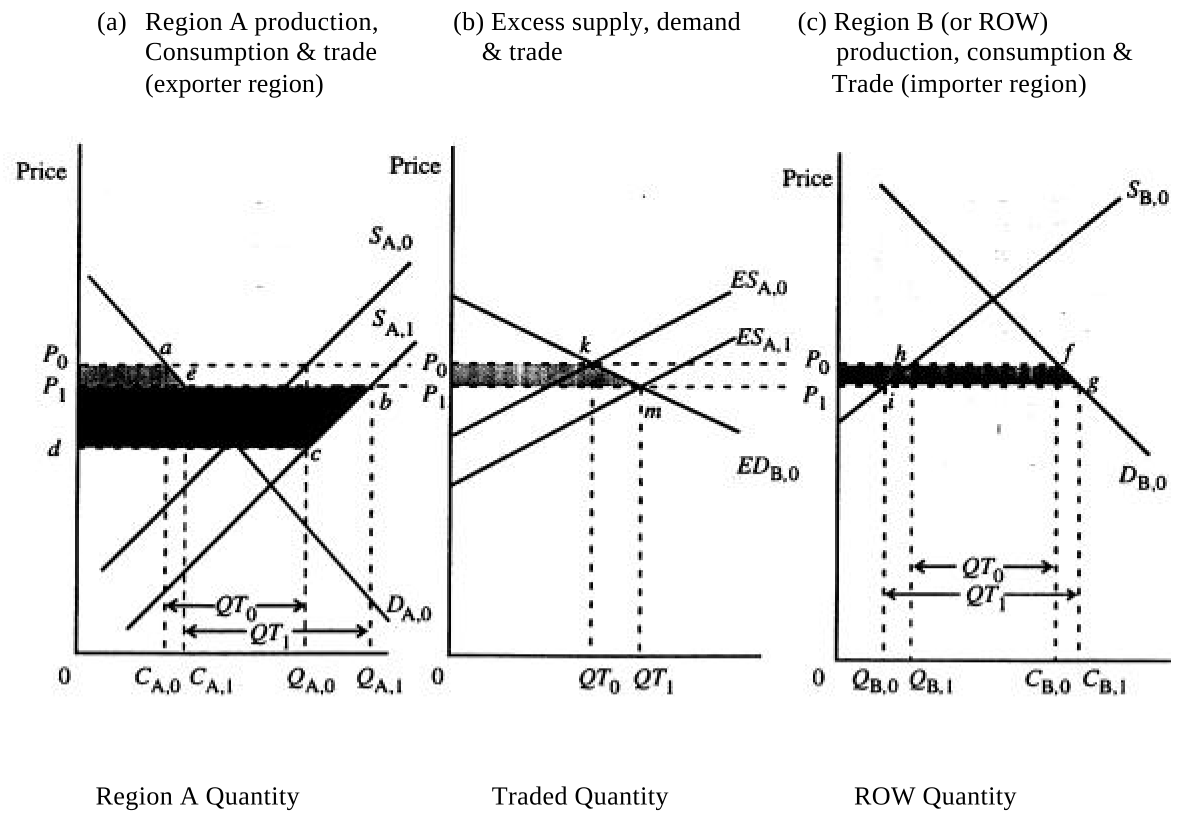


The initial equilibrium is defined by consumption, C_o (which is iqual to $Q_o + QT_0$) and production, Q_o at the world price P_o, with a trade quantity, QT_o (representing imports), equal to the magnitude of the difference between consumption and production. Research causes supply to shift from S_o to S_1 and production to increase to Q_1. As a result, imports decrease to QT_1. (and $Q_1 + QT_1 = C_1$; and $C_1=C_o$). Because the region does not affect the world price, the economic surplus change (iqual to *area* I_oabI_1) is all the producer surplus while consumer surplus does not change (area *abc).*

One advantage of the small-region assumption is that, even when the government could intervene in the commodity market, all the research benefits continue to accrue domestically and there is no need to consider the ROW (unless there is leakage of research results and consequent price spillovers feeding back from the ROW). The price P_o, is a constant in the analysis and defines the opportunity cost of resources used in the production and consumption.

The global equilibrium price in the market, P_o, is determined where the export production surplus in the region A corresponds to the deficit of region B, (Qt_o).
If region A adopts new technology, the supply curves shifts and there will be more production available for internal consumption and trade. The new supply curve is shown as S_{A1} and, if the demand conditions in regions A and B do not change, a new equilibrium will be reached with a lower price, P_1 with a greater quantity of trade, QT_1. This lower price will be reflected in the internal prices of regions A and B, with consequences to production and consumption in the national markets.

Figure 4 Export Innovator Region and its National Impact and through Intern-regional Trade



(a) Region A production, Consumption & trade (exporter region)

(b) Excess supply, demand & trade

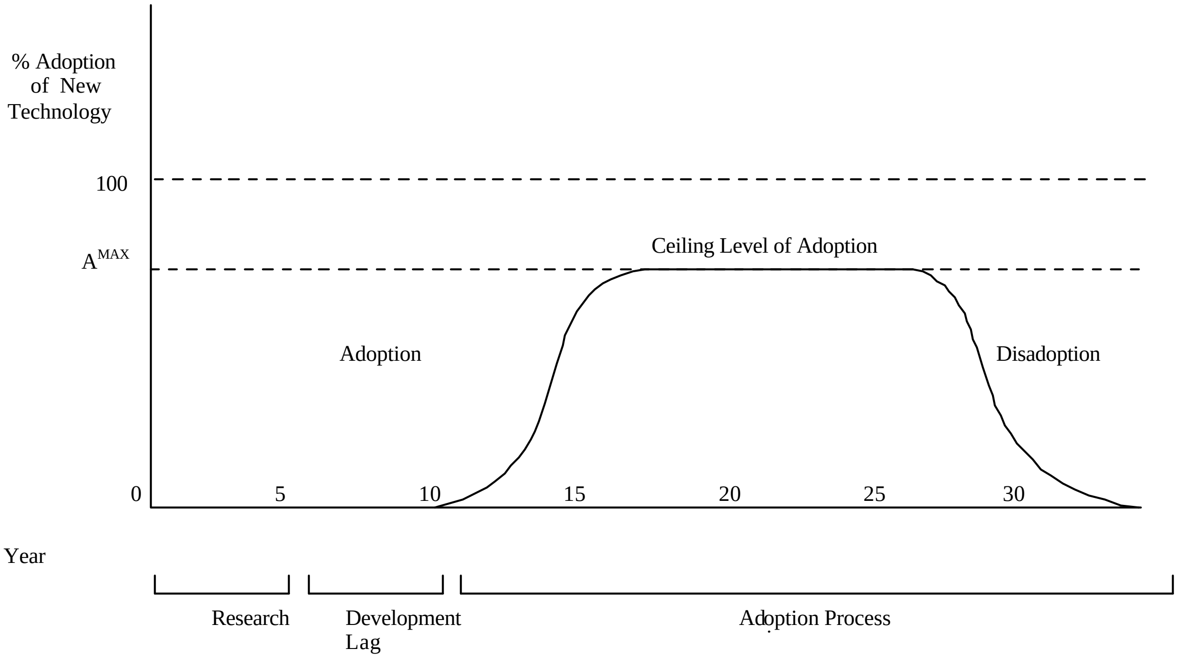
(c) Region B (or ROW) production, consumption & Trade (importer region)

In general, the impacts of the new technology in these cases are:

- **For the innovator region**: Lower price, more production, and more consumption.
- **For trade** : Lower price, more commerce (higher levels of exports and imports).
- **For non innovator regions** : (or lesser innovators): Lower price, less production and more consumption.

Technology adoption

Figure 5. Time lags and the pattern of adoption.



Source: Adapted from Alston, Norton and Pardey. 1995.

The presentation of the conceptual economic framework identified two situations with respect to adoption and use of technologies: *with* and *without* the new technology (the points and lines annotated as 0 and 1 in the figures 1, 2 and 4). It is important to know the time lags associated with the research and adoption process. Figures 5 shows a typical adoption curve of new technologies over time, which requires three parameters to define this simplified representation:

A time lag following the release of a new technology until the ceiling level of adoption is likely to be reached, a ceiling level of adoption (in area or quantity terms), and the shape (or functional form) of the adoption curve.

The methodology requires the specification of these three parameters to approximate an adoption curve for each region. The shape of this curve is sigmoidal up to the ceiling level of adoption. This is supported in the literature. However, there is controversy with respect to the disadoption concept. From one point of view, each technology has a cycle of life until the user abandons it totally and, as from that moment, user benefits stop. From another point of view, the producer will change technology only if the new one gives a better profitability relative to the existing one. Therefore, the benefits (or profits) of the old technology are the benchmark for the new technology and the 'old technology' part of the total profit always continues.

These concepts are implemented in the economic framework by making a simulation from an initial period (the base period), through a specified time (the simulation period). The simulation goes through four stages:

R&D period: It is the investment period in *R&D* until the new technology is released. During that period there are no benefits.
Adoption Period: (From the releasing till achieving the adoption ceiling). In this period the benefits grow each year, in each region, in proportion with the adoption level. It is possible that costs are still being incurred in adoption and diffusion of the technology,
Maximum adoption level of the technology*:* In this period adoption is maintained at the adoption "ceiling" level. During these years the annuals benefits are maximum (and equal) each year. The faster is the technological renovation cycle associated with a research topic, the shorter is this period, and
Disadoption Period (optional)*:* This period can arise from new and better technology becoming available or, sometimes, the loss in effectiveness of the technology. Disadoption does not exclude the possibility of receiving economic benefits (if, for example, the old technology is somehow included in the new technology).

As a result of adoption of a new technology in a region, it is possible to estimate the shift in the supply curve as:

$$K_{i,\,t} = K_{i.}\, A_{i,\,t}$$

Where $K_{i,t}$ is the unit cost reduction of production in region *i* for year t: K_i is the potential unit cost reduction in region *i* if the technology is fully adopted; and $A_{i,t}$ is the adoption level in the region *i* for year *t*.

Estimation of the social benefits of research

The simulation over time estimates changes in prices and in quantities produced and consumed as a consequence of the adoption of new technology. According to the concepts of economic surplus it is possible to transform these changes into approximations of changes in social welfare (Alston, Norton and Pardey, 1995). The annual benefits (changes in the economic surplus) for the *t* year, can be expressed as changes in consumer surplus, ΔPS_t, changes in producer surplus ΔPS_t, and total change in surplus ΔTS_t, and can be calculated as followed:

$$DCS_t = P_o Q_o Z_t (1 + 0.5\, Z_t\, n)$$

$$DPS_t = P_o Q_o (K_t - Z_t) (1 + 0.5\, Z_t\, n)$$

$$DTS_t = DCS_t + DPS_t = P_o Q_o K_t (1 + 0.5\, Z_t\, n)$$

P_o and Q_o are the initial price and quantity, K_t, is the proportionate vertical shift down in the supply curve. In year *t* we can define $Z_t = K_t\, e / (e + n)$, where *n* is the demand elasticity, and *e* is the supply elasticity. *Z* represents the reduction in price, relative to its initial (i.e. pre-research) value, due to supply shift. Or, put another way, it is the proportion of the market price reduction $-(P_0 - P_1)$ relative to the absolute value of the unit cost reduction $K_t \cdot P_0$.

Algebra for the research benefit calculation in a closed economy.

The basic model

The relative reduction in price is defined as $Z_t = K_t e / (e+n) = -(P_1 - P_o)/P_o$ where P_o and Q_o are equilibrium price and quantity before supply shift, e is the supply elasticity, and n the absolute value of the price elasticity of demand. The equation for Z is obtained by solving linear supply-and- demand equations for prices as a function of slope and intercept parameters, treating a research-induced supply shift as an intercept change, and converting to elasticities:

Supply: $Qs = a + b(P + k) = (a + bk) + bP$

Demand: $Q_d = g - dP$

Where k is the absolute shift down of supply due to a cost saving induced by research. In figure 1, $k = (P_o - d)$, and the supply shift relative to initial equilibrium price is $K = k/P_o = (P_o - d)/P_o$.

Equilibrium price change

Setting $Q_s = Q_D = Q$ yields the equilibrium price $P = (\gamma - \alpha - \beta\kappa)/(\beta + \alpha)$. When $k = 0$, $P_o = (g - a)/(b + d)$; When $k = KP_o$, $P_1 = (g - a - bKP_o)/(b + d)$. The research induced change in price is $(P_1 - P_o) = -bK\, P_o/(b + d)$ and the relative change in price is given by $-(P_1 - P_o)/P_o = bK/(b + d)$. Converting the slopes to elasticities (multiplying through the numerator and denominator by P_o/Q_o) yields:
$Z_t = K_t e / (e+n) = -(P_1 - P_o)/P_o$.

Consumer surplus

In figure 1, the consumer surplus change is given by $\Delta CS = P_oabP_1$ = rectangle P_oaeP_1 + triangle $abe = (P_0 - P_1)Qo + 0.5(P_o - P_1)(Q_1 - Q_o)$ or $\Delta CS = (P_o - P_1)Q_o[1+0.5(Q_1 - Q_o)/Q_o]$. Using the definition above that $Z = -(P_1 - P_o)/P_o$ so that $(Q_1 - Q_o)/Q_o = Zh$ yields:
$DCS = P_oQ_oZ(1+0.5\, Zh)$.

Producer surplus

The producer surplus change is $DPS = P_1bI_1 - P_oaI_o = P_1bcd + dcI_1 - P_oaI_o = P_1bcd$ *given that* $dcI_1 = P_oaI_o$ under the assumptions of a parallel supply shift and linear supply and demand. $DPS = P_1bcd$ = rectangle P_1ecd + triangle $bce = (P_1 - d)Q_o + 0.5(P_1 - d)(Q_1$

$– Q_o)$. *Thus,* $DPS = (P_1 – d)Q_o[1 + 0.5(Q_1 – Q_o)/Q_o]$. Then it is possible to define $(P_1 – d) = (P_o – d) – (P_o – P_1) = KP_o – ZP_o$ and $(Q_1 – Q_o) = Z\eta$. Thus,
$DPS = (K – Z)P_oQ_o(1 + 0.5Zh)$.

Total surplus

Note also that $DTS = DPS + DCS = P_oabcP_1 = (P_oacd + abc)$, which in this instance equals $I_oabI_1 =(I_oacI_1 + abc)$ given that $P_oacd = I_oacI_1$.

Using the above equations, a stream of annual benefits can be calculated over the whole simulation period (see figure 2.6). In accordance with the preceding equations it is also possible to distribute the total benefits between the producers and consumers. This kind of information is extremely useful for strategic analysis and the design of research programs or projects, especially since the dynamic nature of benefit and cost streams are clearly visible.

Annual benefit and cost streams can be converted into present values, that is deflated benefits and costs, by choosing a base year and a representative real (commercial minus inflation) discount rate. For instance, the present values of gross benefits for the consumer *VCS*, producer *VPS*, and in total, *VTS*, are calculated as follows:

$$VCS = S_t\, D\, CS_t / (1 + r)^t$$

$$VPS = S_t\, D\, PS_t / (1 + r)^t$$

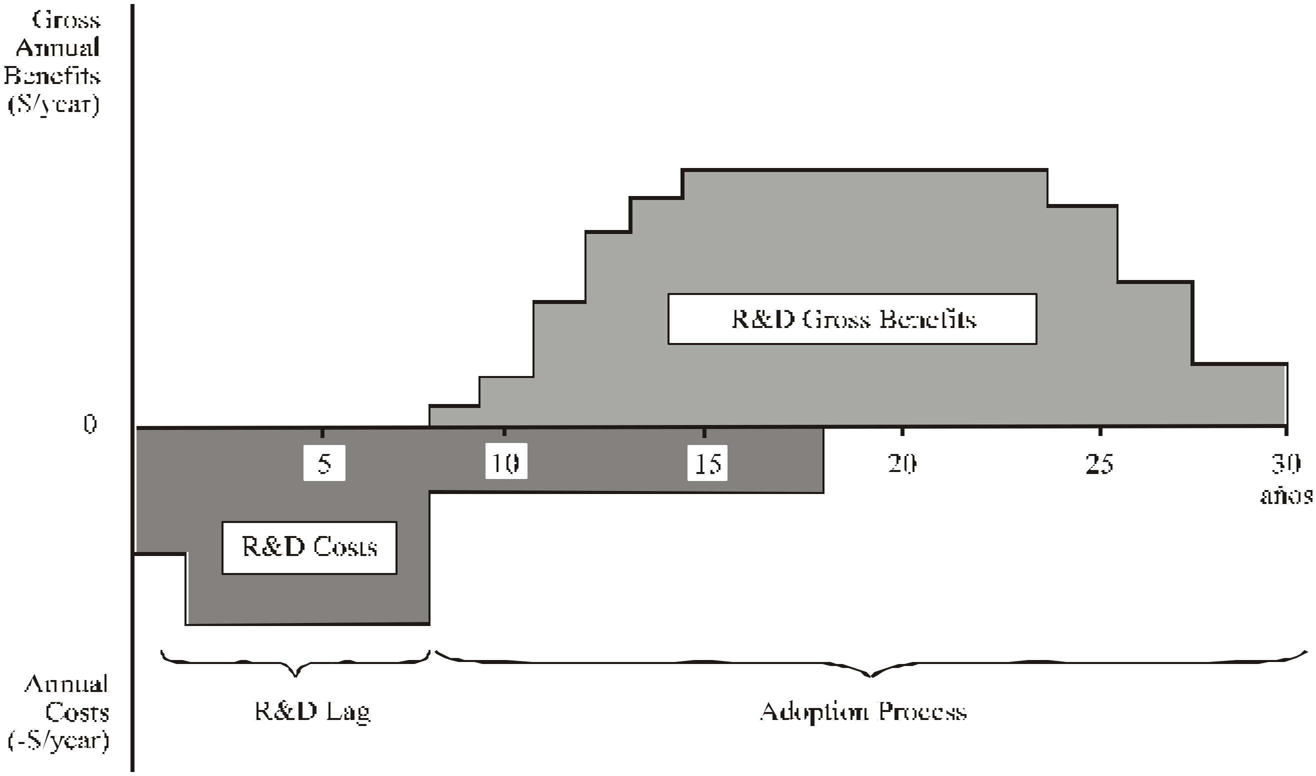
$$VTS = VPS + VCS$$

Where the *r* is the real discount and *t* is the year (between 1 and T, the total period of the economic simulation). With information about the R&D costs in each year, C_t, is possible to calculate the net presents values, *NPV*, that could give better estimates of the true economic attractiveness of the R&D, where:
$NPV = S_t (DTS_t - C_t) / (1 + r)^t$

Another important measure is the internal rate of return, *IRR*, the discount rate at which net present value of benefits is equal to the net present value of costs (e.g., the difference between the net present values is zero:
$0 = S_t (DTS_t - C_t) / (1 + IRR)^t$

With the DREAM model it is possible to calculate the benefit streams (Figure 6), the cost and benefit present values, NPV's and IRR at different levels of aggregation – for example at municipal and at department level) to obtain a clearer picture of what are the incentives to undertake R&D targeted to each level. It is also possible to see the extent to which different producer groups will likely win or lose from the introduction of the new technology.

Figure 6. Cost and benefit streams of R&D over time.



Source: Adapted from Alston, Norton and Parday. 1995

Research and Development

Since it was not possible to obtain all the relevant cost elements of the research undertaken in generating the new maize and soybean rotation system, the emphasis was focused solely on the estimation of the gross benefits of research, and how those benefits might be distributed; by producers versus consumers, by municipio, and over time.[6]

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[6] The cost information proved to difficult to collect for several reasons; there were several research institutions involved; CIAT, CIMMYT, CORPOICA, and ICA, and several projects within each of those institutions that contributed to the research. Furthermore, the accounting systems and record keeping made it extremely difficult to assess how many scientists had been working, and with what level of effort, on generating the specific technologies we are evaluating here. Thus, our benefit estimation will be in terms of GROSS benefits only.

The economic evaluation is of a technology already developed, although the specific maize-soybean rotation proposed had not yet been adopted. Thus, there is already data, used in this study from experimental and on-farm trials about the effectiveness of the rotation. The economic simulations were made to estimate the likely economic returns of that technology within the Meta department according to given adoption and market scenarios (See table 2).

Market data

The most important variables taken into account from a market perspective are:

Production, consumption and prices

The information (data) was gathered of the level of municipality for the traditional and improved maize production systems (See table 2).

- ✓ **Production:** Data on area, production and yield of technical and traditional maize was obtained for the period 1995 to 1998, from the Agricultural, Livestock, and Rural Development Secretary of the Meta Department. Other aggregated production data were obtained for the last 10 years from the Ministry of Agriculture and Rural Development.

- ✓ **Producer prices:** Data on producer prices by crop semester for the periods 1997 (2nd semester) and 1998 (1srt semester), also from Agricultural, Livestock, and Rural Development Secretary from Meta Department. All these prices were converted into constant prices of 1997, using the cereal consumer price index (CPI) of the capital city of Meta, Villavicencio.

- ✓ **Consumption:** To estimate consumption it was necessary to obtain data about population and per-capita consumption of maize in Meta for the year 1997 for each municipality. Animal consumption of maize was also estimated based on annual consumption per head, on the census of slaughtered cattle for the province.

Consumer prices: Detail information was obtained on wholesaler prices at Villevicencio and Bogotá the major markets for agricultural trade to and from Meta Department. These prices were taken in constant values with 1997 as base year using the cereal consumer index prices for each town.

Elasticities

Price elasticity supply and demand were obtained for the commodity selected, these values were calculated by IFPRI based on a demand and supply survey of maize in Colombia. The elasticities values have little impact on the R&D total benefits; however, these elasticities affect significantly the likely distribution of the benefits among producers and consumers.

Item	Demand	Supply
Maize	-0.4	0.5

Source: CIAT *"Trends in CIAT commodities". 1992.*

Demand and supply exogenous (non R&D) rates of growth

Estimations of demand and supply growth rates for Meta Department were based on the population growth projection of the Departamento Administrativo National de Estadísticas of Colombia (DANE), United Nations Program for Development (UNPD) and Agricultural Department of the United States, assuming there is no consumption per-capita changes with respect to the base period (1995 – 1997). The animal consumption estimation was projected taking into account information about livestock slaughtered from DANE data. The supply growth rates (for growth not attributed to R&D) were estimated on base of the harvest area and yield trends during the period 1998 – 1997.

Discount Rate

Taking into account the value of money across time it is necessary to discount from future values using a real interest rate to calculate the R&D cost and benefit present values. The real discount rate was estimated subtracting the inflation rate from the market minimum interest rate.

Data Calibration

The data collected from different sources were integrated and harmonised checking up the consistency and reliability of the different sources of information.

The adoption ceiling for the maize technology was estimated from average production for each region weighted, using the information on production type from the table 3. For the regions defined as traditional producers, the adoption ceiling is zero, because the new technology evaluated in this thesis have been focused on improved maize. We have arbitrarily assumed that 50% of the technological maize producers will adopt the new technology, and have made some sensibility tests regarding changes in prices, quantities and benefits if this assumption is changed.

Basic Research Factors

The table and 3 show some of the key technical factors of the new technology. Before undertaking the analysis it is important to consider the following issues:

- Deciding which market model would be most appropriate for the commodity and technology combination being assessed.

- Deciding on the appropriate levels of aggregation of production and consumption.
- Deciding how to represent the imbalance between production and consumption of maize in the Meta department, that is, how to represent the external trade to maintain the equilibrium among total supply and demand.

Markets and Trade

To support the definition of the technology scenarios to be evaluated it is useful to have a global understanding of the maize market structure.

The maize market is modeled a multiple trading regions. Production is separated into markets for each municipality. The total production in simply the aggregate production from all municipalities. The model requires that total production and total consumption across all regions are equal. It is not necessary the production and consumption are in equilibrium in each individual region. The model estimates the annual market-clearing prices considering the conditions of all markets simultaneously (that is, price is endogenous). In setting up the production regions (the municipios), municipalities with a small participation were grouped together as "others producer". (See Table 3).

In this case of consumption just two regions were defined - one for human consumption and one for animal consumption. Since the combined consumption is greater than the combined production, a separate external (production) region was also defined that serves as a source of the maize imports to the region.

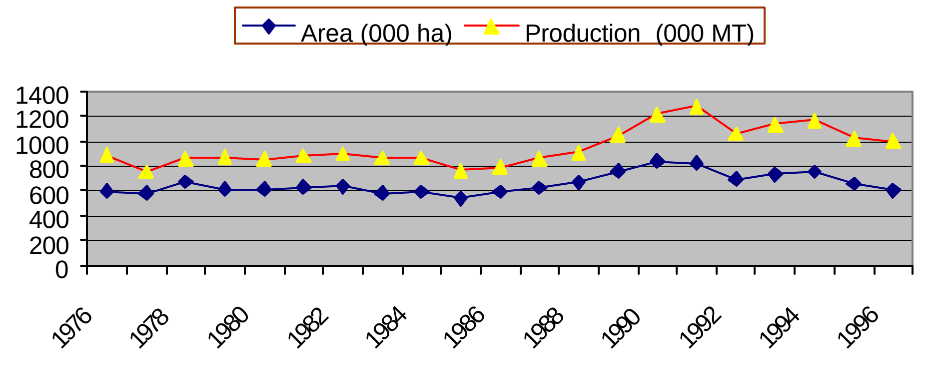
RESULTS

The Maize Economy of Colombia and the Meta Department

Production trends

Maize production systems in Colombia, as in the rest of Latin America, are very variable, reflecting not only the wide rage of production environments in which maize is grown but also differences in farmer knowledge and access to resources. Maize is an important food staple that is produced and consumed by a large part of rural population. Maize is often grown in association with beans, cassava, and other food crops destined for home consumption, and many farmers use. It is also of increasing importance for animal feed, particularly for the fast growing pig and poultry sector. Colombia is the fourth-largest maize-producing country in Latin America after Brazil, Mexico, and Argentina. Annual production of maize in Colombia currently is around one million tons.
Maize in Colombia is grown in a wide range of agro-climatically diverse environments by producers who differ in their resource endowment, technical knowledge, and crop management practices.

Figure 7: Total area, and production of Maize, Colombia. 1976-1996



At one extreme, small scale semi-subsistence producers grow maize primarily as a food crop, some producers plant local varieties with low yield as a food crop; most of these producers plant local varieties with low yield potential, high yield stability, and moderate resistance to local pest and diseases. At the other hand extreme, relative large-scale commercial producers grow maize primarily as a cash crop; most of this producers plant improved maize material, especially hybrids. Between this two extremes lie many intermediate type of producers.

The trend in area sown to maize for the period from 1990 to 1998 demonstrates a loss in cultivated hectares equivalent to 306,037, which is equivalent to the 38,90% of maize area with the greatest reduction being in the year 1998 (See Figure 7).

Maize production in Colombia in the last eight years has decreased by 261,371 tons metric - in 1990 maize stood at 1,155,000 metric tons metric, but in 1998 production was 893,629 metric tons; this reduction is equivalent to 22,6%.

In average in the last thirty years, the yield of technical maize in Colombia has increased from 2.43 ton/ha to 3 ton/ha, that is, an increase of 0.57 ton/ha or 23,46% in roughly thirty years (Figure 8). The lowest value was in 1976 with a yield of 1,89 ton/ha, and the highest in 1997 with 3,01 ton/ha (National Federation of Cereal Producers of Colombia – FENALCE, Hoja del Cerealista. 1999).

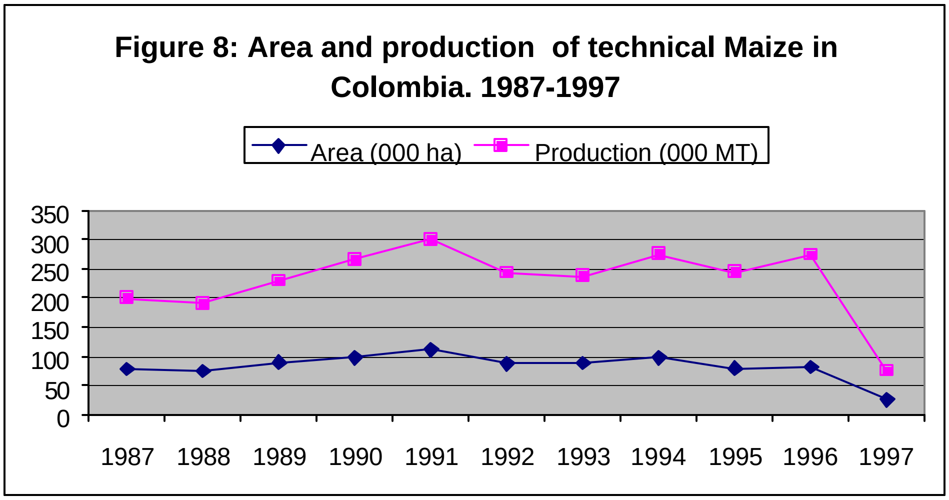


Figure 8: Area and production of technical Maize in Colombia. 1987-1997

Traditional maize production in Colombia, in spite of the reduction in the amount of sowing hectares, falling from 560,300 hectares in 1970 to 489,520 hectares in 1997, increased due to yield improvements (Figure 9 and 10). In 1970 production stood at 631,300 metric tons but by 1997 had reached 723,652 metric tons (FENALCE). Yields increased from 1,13 ton/ha to 1.41

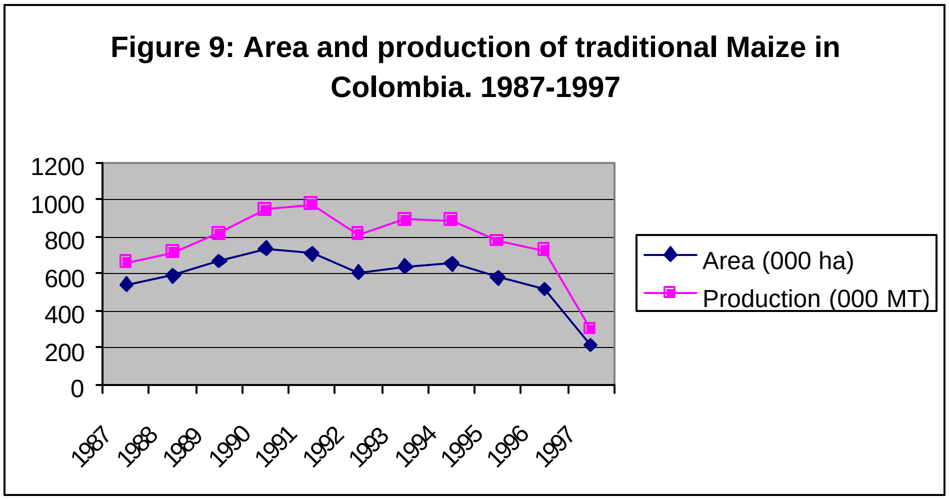
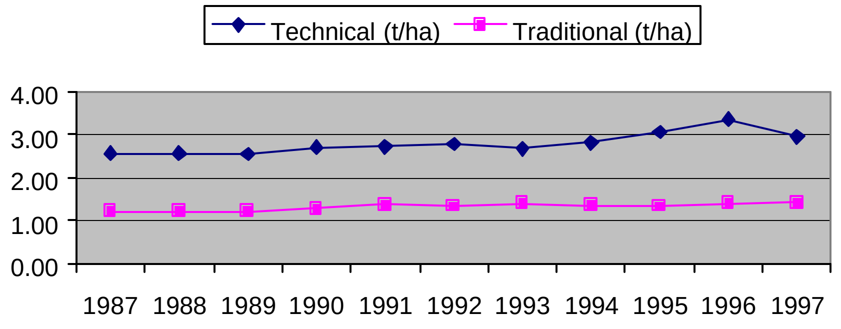


Figure 9: Area and production of traditional Maize in Colombia. 1987-1997

ton/ha over the same period, an increase of 0.35 ton/ha, equivalent to 30,97% (FENALCE: La Hoja del Cerealista, 1999).

Figure 10: Yield of technical and traditional Maize in Colombia. 1987-1997.



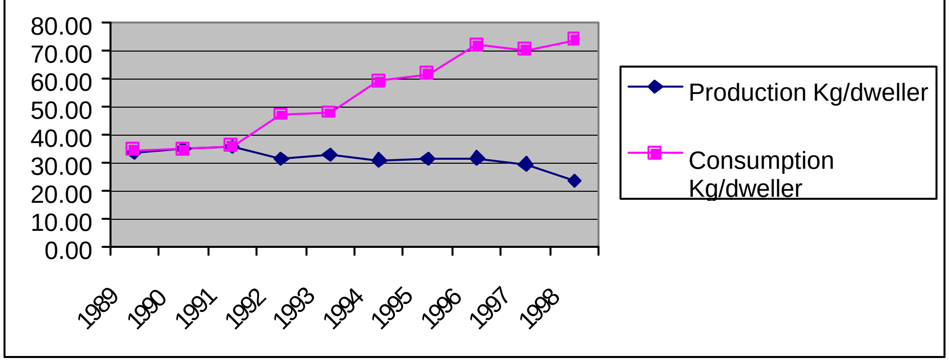
Consumption trends

Maize consumption patterns in Colombia have changed considerably with the migration of a significant part of the population from rural areas to cities.

Traditionally, maize was been a traditional food crop grown mainly by rural households for direct consumption or for feeding animals. As direct human consumption of maize has increased over the year, feed use is currently less than maize for human consumption.

The per capita production (Figure 11) has decreased during the period 1991-1998 by 34% which is equivalent to decreasing in production of 12,09 Kg/per-capita, while the consumption increased tremendously during the same period in 106%, equivalent to increase in consumption 37,95 Kg/per-capita.

Figure 11: Percapita production and consumption of Maize in Colombia. 1989-1998

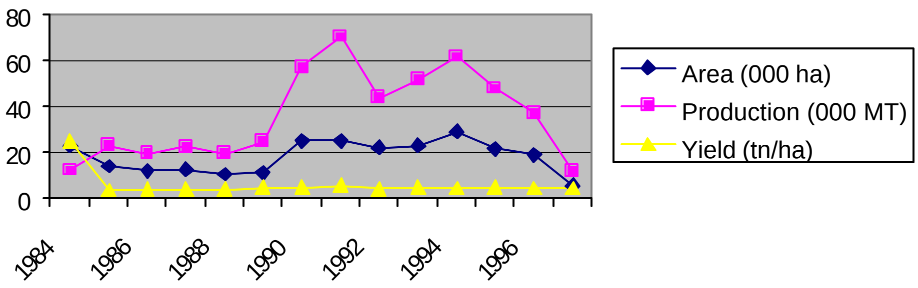


Meta Department

Meta Department and Arauca Intendence have the highest yields and production of maize. This region has 37,867 hectares that represents 11,08% of the Colombian total and corresponds to 9,76% of the traditional system and 1,32% of the improved (technical) system (Figure 12). The average yield for this region in the traditional sector is 1,140 kg/Ha and, 2,500 kg/Ha in the improved maize cultivation. For both traditional and technical systems there are two periods of sowing; from mid February until end of March and during the month of September to harvest in July-August and December-January respectively. The technology used in the different cultivation systems, for the maize production, corresponds to monoculture and multiple cropping with cassava and plantain.

The climate and soil conditions provide unfavourable conditions for the development of maize cultivation. Technical assistance is another highly constraining factor in this region and is linked to limited credit access.

Figure 12 : Total area, production and yield of technical and traditional Maize in Meta, Colombia. 1984-1997



Comparing area planted in the years 1997-1998 for Meta Department, there has been a reduction of 4,110 hectares which, in percentage terms, is equivalent to - 43% with respect to the previous year.

The maize sowing trend for this Department for the period 1990-1998 shows loss in cultivated areas equivalent to 10,240 hectares in technical maize, which is equivalent to – 65%, and while for the traditional commodity there was a slight increment of 1,215 hectares, it means 15% more area were cultivated in 1998.

The maize production in Meta in the last six years has fallen by 26,570 metric tons of technical maize, since in 1993 the production was 42670 metric tons and in 1998 the production was 16100 metric tons – a reduction of some 62%.

Description of the Results

The Tables 2 and 3 show in detail the final data integration. Each table show the values used as inputs for the simulation run. The first table presents the summary of the market data, and the second table summarises the research and adoption data. The number of rows depends upon the level of disaggregation of the different production and consumption regions (markets). If there is no sub-national disaggregation, a single region can be defined that contains both production and consumption characteristics.

Table 2 shows the following row pattern:

Two groups of *municipios* (with and without significant adoption of technical maize production practices). Only production information is defined for each muncipio, consumption data is presented at the department level (for both human and animal consumption). Each municipio has data on quantity of maize produced, farmgate price, price elasticity, and supply growth rates (not caused by research).

Transmission factors are not used in this analysis (they are assumed to be 1.0). But the model does remember the initial structural *differences* in price levels between regions. These are called the price “wedges”. The municipio of Mesetas was arbitrarily chosen as the base region from which to measure price wedges. When new technology is adopted, prices change and the transmission elasticity determines how much of the price change in any region is transmitted to the other regions. This is a crude way of dealing with transport and other transactions costs between regions. Here, however, a perfect free trade with no transactions costs was assumed (transmission elasticity = 1.0). If the transmission elasticity is set to 0.0 the simulation assumes each region acts as a closed economy.

There are two rows of data to define two demand regions, one for human food demand, and the other for feed demand. These regions do not have data about production, technology and adoption.

One row represents production outside of the Meta department, which is not a target of research, and which supplies the maize needed in the Meta, since the total regional production is less than the total demand. This external region has information about production but not about technology and adoption. This external region supplies the production deficit, and this importation represents 59% (29,467.4 metric tons of maize per year) of Meta total consumption.

In Table 3, column 6 is the calculation of the net shift, K_{max}, of the supply curve as a percentage of the initial price, and as a absolute value. It is the product of the potential K, the probability of success (here 100% because the technology has already been developed), the max level of adoption, and the producer price.

In the case of *municipios* with technical adoption the average cost reduction per unit is $13.34/tonne, and the potential impact varies from $8.77/tonne (Mesetas) up to $17/tonne (Other – technical).

It is assumed that the R&D time is zero years, since the technology is already available (but has not been adopted). So an adoption time of 6 years is assumed, and it is assumed that the new technology will ultimately be adopted by all technical producers in each muncipio.

Table 2: Summary of Input Data – Market Data

```
Study:     Technical Change in Colombian Savannas

Scenario:  Maiz/Soybean Rotation – Meta Departments

Commodity: Maize        Regions:  20  Horizontal Multimarket - Spillover: No

Period:    20 years     Base year:  1997

Discount:  10.0%        Benefit units:1000COL$   Quantity units: Tonnes

SUMMARY OF INITIAL MARKET CONDITIONS
                                                           Elasticity  Transmission  Exog. Growth   Tax/Sudsidy
      Region            Production Consumption Price    Sup.     Dem. Wedge  Elast    Sup.  Dem.      Sup.  Dem.
-----------------------------------------------------------------------------------------------------------------
        (1)                    (2)         (3)       (4)     (5)      (6)   (7)    (8)   (9)    (10)   (11)   (12)
                            Tonnes      Tonnes    1000C$                  1000C$          %/yr   %/yr   %/yr   %/yr
-----------------------------------------------------------------------------------------------------------------

Municipios with traditional maize systems

Mapiripan                   1157.2         0.0    250.00  0.500   0.000    9.30  1.00   0.00   0.00   0.00   0.00
Puerto Concordia             524.3         0.0    240.00  0.500   0.000   -0.70  1.00   0.00   0.00   0.00   0.00
Puerto Rico                  261.5         0.0    248.00  0.500   0.000    7.30  1.00   0.00   0.00   0.00   0.00
La Macarena                  305.0         0.0    245.00  0.500   0.000    4.30  1.00   0.00   0.00   0.00   0.00
Uribe                       2000.0         0.0    240.00  0.500   0.000   -0.70  1.00   0.00   0.00   0.00   0.00
Other - traditional         1114.2         0.0    243.96  0.500   0.000    3.26  1.00   0.00   0.00   0.00   0.00

Municipios with significant technical maize systems

Mesetas                     2241.6         0.0    240.70  0.500   0.000    0.00  1.00   0.00   0.00   0.00   0.00
Villavicencio               1588.7         0.0    245.00  0.500   0.000    4.30  1.00   0.00   0.00   0.00   0.00
Vistahermosa                 730.0         0.0    240.00  0.500   0.000   -0.70  1.00   0.00   0.00   0.00   0.00
Fuente de Oro               2485.0         0.0    245.00  0.500   0.000    4.30  1.00   0.00   0.00   0.00   0.00
Cumaral                      378.0         0.0    240.70  0.500   0.000    0.00  1.00   0.00   0.00   0.00   0.00
San Juan de Arama            704.7         0.0    240.00  0.500   0.000   -0.70  1.00   0.00   0.00   0.00   0.00
Granada                     4376.2         0.0    214.00  0.500   0.000  -26.70  1.00   0.00   0.00   0.00   0.00
Lejanias                    1188.0         0.0    245.00  0.500   0.000    4.30  1.00   0.00   0.00   0.00   0.00
El  Castillo                 702.1         0.0    240.00  0.500   0.000   -0.70  1.00   0.00   0.00   0.00   0.00
Other – technical            573.5         0.0    240.70  0.500   0.000    0.00  1.00   0.00   0.00   0.00   0.00

Internal Meta demand

Meta Demand – Animal           0.0      7725.8    240.00  0.000  -0.400   -0.70  1.00   0.00   1.03   0.00   0.00
Meta Demand – Human            0.0     42071.9    245.00  0.000  -0.400    4.30  1.00   0.00   2.01   0.00   0.00

External supply region providing net imports to Meta

Imports – External         29467.4         0.0    240.70  0.500   0.000    0.00  1.00   2.80   0.00   0.00   0.00

-----------------------------------------------------------------------------------------------------------------
          TOTAL            49797       49797
```

Note:

1. Significant growth in both human and animal consumption is projected based on human and livestock population trends.
2. Transmission price wedge is calculated by the program. It is the difference between the price in the “base” municipio (arbitrarily chosen as Mesetas) and all other regions.

Tabla 3: Summary of Input Data – Research and Adoption Data

```
SUMMARY OF R&D & ADOPTION DATA

                     K   Prob.of  Max.           K  Shift   K      ----- Time Lags ------ Adopt
      Region        Pot. Success Adopt   Price   Max  Type  Var      R&D  Adopt AtMax Aband  Form
-----------------------------------------------------------------------------------------------
       (1)          (2)    (3)    (4)     (5)    (6)   (7)  (8)      (9)  (10)  (11)  (12)  (13)
                    -%-    -%-    -%-   1000C$ 1000C$       %/yr   -yrs- -yrs- -yrs- -yrs-

Municipios with traditional maize systems

Mapiripan          0.00    0.0     0.0  250.00   0.00   S   0.00     0.0   0.0  99.0   0.0    X
Puerto Concordia   0.00    0.0     0.0  240.00   0.00   S   0.00     0.0   0.0  99.0   0.0    X
Puerto Rico        0.00    0.0     0.0  248.00   0.00   S   0.00     0.0   0.0  99.0   0.0    X
La Macarena        0.00    0.0     0.0  245.00   0.00   S   0.00     0.0   0.0  99.0   0.0    X
Uribe              0.00    0.0     0.0  240.00   0.00   S   0.00     0.0   0.0  99.0   0.0    X
Other - traditional 0.00   0.0     0.0  243.96   0.00   S   0.00     0.0   0.0  99.0   0.0    X

Municipios with significant technical maize systems

Mesetas            9.00  100.0    40.5  240.70   8.77   S   0.00     0.0   6.0  99.0   0.0    X
Villavicencio      9.00  100.0    64.7  245.00  14.26   S   0.00     0.0   6.0  99.0   0.0    X
Vistahermosa       9.00  100.0    47.5  240.00  10.26   S   0.00     0.0   6.0  99.0   0.0    X
Fuente de Oro      9.00  100.0    77.0  245.00  16.97   S   0.00     0.0   6.0  99.0   0.0    X
Cumaral            9.00  100.0    71.7  240.70  15.53   S   0.00     0.0   6.0  99.0   0.0    X
San Juan de Arama  9.00  100.0    43.1  240.00   9.30   S   0.00     0.0   6.0  99.0   0.0    X
Granada            9.00  100.0    80.0  214.00  15.40   S   0.00     0.0   6.0  99.0   0.0    X
Lejanias           9.00  100.0    51.5  245.00  11.35   S   0.00     0.0   6.0  99.0   0.0    X
El  Castillo       9.00  100.0    65.7  240.00  14.19   S   0.00     0.0   6.0  99.0   0.0    X
Other - Technical  9.00  100.0    80.0  240.70  17.33   S   0.00     0.0   6.0  99.0   0.0    X

Internal Meta demand

Meta Demand - Animal 0.00  0.0     0.0  240.00   0.00   S   0.00     0.0   0.0  99.0   0.0    L
Meta Demand - Human  0.00  0.0     0.0  245.00   0.00   S   0.00     0.0   0.0  99.0   0.0    L

External supply region providing net imports to Meta

Imports – External 0.00    0.0     0.0  240.70   0.00   S   0.00     0.0   0.0  99.0   0.0    L
-----------------------------------------------------------------------------------------------
Kmax is maximum absolute unit cost reduction (in price units). Product of Cols 2-5
Kvar is the variable unit cost reduction (%/year), if specified.
Shift type: S - Supply, D - Demand   Adoption Form: L - Linear, X - Logistic
```

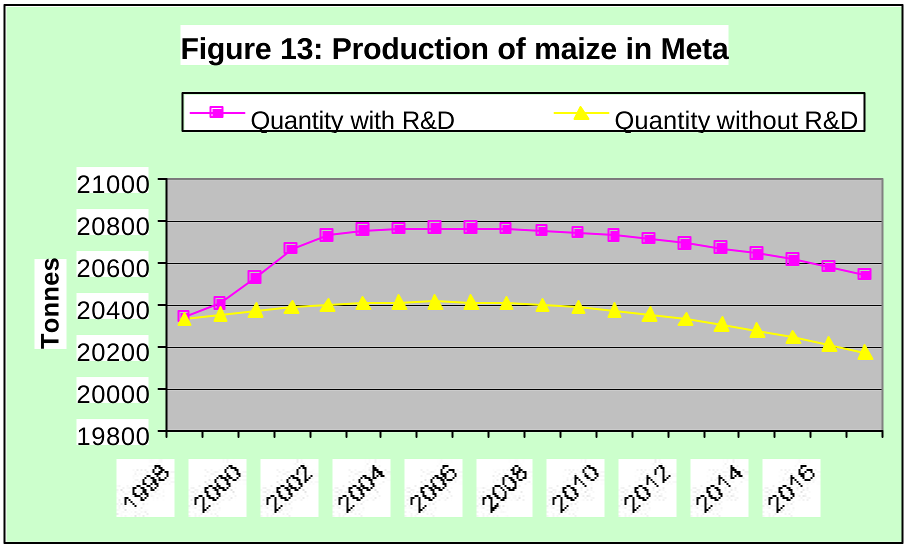
Notes.

1. Since the technology has already been developed, the probability of research success is 100 percent
2. Adoption levels are proportional to the share of technical production in the municipio. The maximum adoption level was taken as 80%
3. Kmax is the maximum unit cost reduction in Col$1000 per tonne that will be achieved in each municipio.
4. No disadoption was assumed. Thus, benefits were received for every year of the simulation period following adoption.
5. No technical change is assumed to be taking place in the external supply region. This assumption can be easily changed by providing R&D and adoption data for that region.

Dynamics of Market

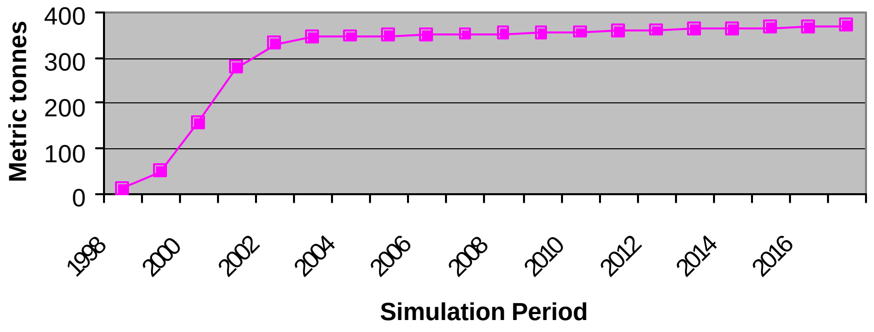
The economic impact of technical change can be visualised in each market, by the changes brought about prices and quantities. Specifically, the time paths of prices and production levels can be compared with and without the introduction of new technologies. This step proceeds the analysis of the estimation of benefits. Thus changes in; prices, quantities produced and consumed, trade, and the values of production and consumption, are calculated in each year as a basis of calculating the benefits of the R&D.

Initially, there is no difference between production and price "with" and "without" technology. However, once the new technology is released and adopted, the “with” and “without” values begin to vary, to an extent that is determined by the cost reducing potential of the new technology and the rate and level of adoption in each region.



The figures 13 and 14 show the tendency over time for the production of maize with and without research in the Department of Meta. The area between the curves is a measure of the potential benefits of R&D. The simulation predicts an expansion in the production of technical maize for this Department (Figure 14).

Figure 14: Increasing in maize production, Meta Department



It is important to notice that the prices and amounts in each region are related, since adoption of new technology in one region impacts the situation of the market in other regions through the effects of trade.

The simulation predicts a cumulative additional production in the quantity of maize produced in Meta, attributable to R&D, to be 6,165 metric tonnes during the simulation period 1998-2017 providing benefits to the producers about Col$1.236.135,0 and benefits to the consumer by Col$846.719,5 because of the decrease in prices (See Tables 4, 5 and Figure 15).

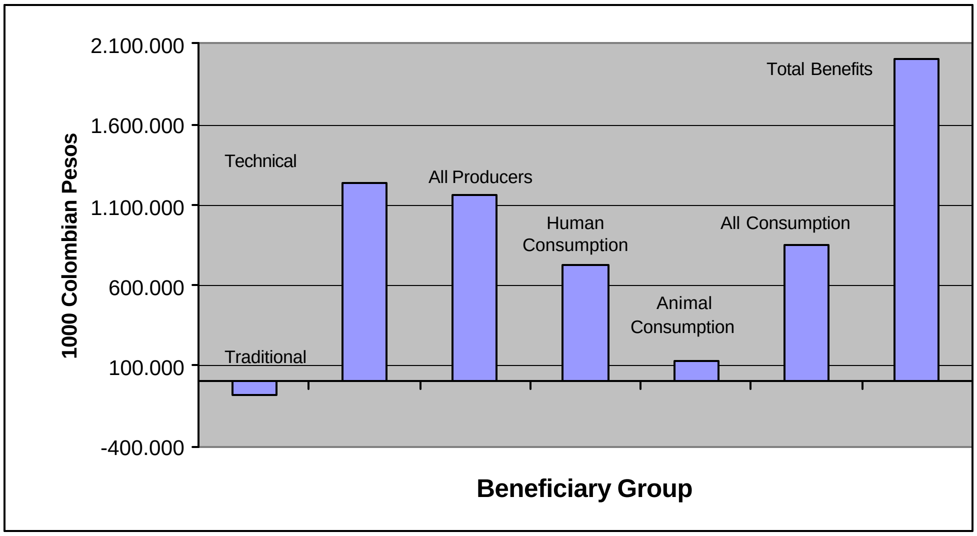
Benefits by Region

As was described in the section on the conceptual economic frame, we can use the concepts of the economic surplus and time preference (discounting values) to turn the changes into prices and amounts over time to a single value of the economic benefit (and costs) of R&D. Thus, for each region we can turn the annual flow of impacts into measures such as the present value of gross benefits (B) and, if the data is available, of costs (C), and other related criteria of investment.

The present value of gross benefits of the producer, consumer and totals considered for each the commodity maize R&D are shown in Figure 15, including details of regions defined. The inspection of these results suggests, that (according to the assumptions described in the Section: Basic Research Factors, the market and the trade performance), consumers always benefit from the R&D. In most of the cases, the producers in regions with significant levels of adoption also benefit from the impact of new technologies.

For the commodity maize the consuming regions receive high net benefits during the period of analysis Col$846719,5 equivalent to 64% of total benefits, due to the increase of the productivity in the defined regions, and to the reduction of the prices. The benefits for all producers are roughly 58% of the total benefits (Table 4 and 5).

Figure 6.9. Meta Department Present Values of Gross Benefits by Producer and Consumer Groups



The benefits to the consumers were constrained because the quantity of maize imported represents a big proportion of the total consumption, and it was assumed that in the external region was no technological change during the simulation. With the introduction of any technical change different to zero in the external region, the benefits to producers in the Meta would drop simultaneously, while the benefits to consumers would increase.

It is important to understand the meaning of the negative benefits to the producer (that is losses for the producer). Such results mean that the gains from the production would have been greater without the new technology (Table 5). This often means that since they could no longer produce competitively, some producers have reduced or stopped production of the affected commodity. We can easily see this effect in the production regions where it is assumed that the new technology will not be available for the adoption (or will not be adoptable, in this case by the traditional maize producers).

The calculated benefits to non-adopting producers are always negative. This is because the price diminishes as a result of the adoption of new technologies in other regions, but the costs of production has not changed for those who do not adopt. This general reduction of the price reduces the net gains - until unacceptable levels. In such cases, rational producers will change to their next best option of production (or, in extreme cases, they stop the production if they are left with no other economic options).

Table 4: Present Value of Gross Benefits for Each Region and Region Group

Technical Production

```
                       ---------- Present Value of R&D Benefits ---------><---Costs---><------ Returns ------------>
   Region                   Producer     Consumer   Government        Total                  (B-C)      B/C     IRR
   ---------------------------------------------------------------------------------------------------------------------
 1 Mesetas                  105756.4          0.0          0.0     105756.4          0.0    105756.4     --.--    --.-
 6 Villavicencio            137317.7          0.0          0.0     137317.7          0.0    137317.7     --.--    --.-
 7 Vistahermosa              42170.6          0.0          0.0      42170.6          0.0     42170.6     --.--    --.-
13 Fuente de Oro            263320.4          0.0          0.0     263320.4          0.0    263320.4     --.--    --.-
14 Cumaral                   36125.1          0.0          0.0      36125.1          0.0     36125.1     --.--    --.-
15 San Juan de Arama         35938.5          0.0          0.0      35938.5          0.0     35938.5     --.--    --.-
16 Granada                  415033.5          0.0          0.0     415033.5          0.0    415033.5     --.--    --.-
17 Lejanias                  77906.7          0.0          0.0      77906.7          0.0     77906.7     --.--    --.-
19 El  Castillo              60320.9          0.0          0.0      60320.9          0.0     60320.9     --.--    --.-
 8 Otros Tecnificado         62245.7          0.0          0.0      62245.7          0.0     62245.7     --.--    --.-

   ---------------------------------------------------------------------------------------------------------------------
 Total NPV Benefits        1236136.0          0.0          0.0    1236136.0          0.0   1236136.0     --.--    --.-
```

Traditional Production

```
                       ---------- Present Value of R&D Benefits ---------><---Costs---><------ Returns ------------>
   Region                   Producer     Consumer   Government        Total                  (B-C)      B/C     IRR
   ---------------------------------------------------------------------------------------------------------------------
 2 Puerto Concordia          -7711.6          0.0          0.0      -7711.6          0.0     -7711.6    --.--    --.-
 3 Puerto Rico               -3845.6          0.0          0.0      -3845.6          0.0     -3845.6    --.--    --.-
 4 La Macarena               -4485.3          0.0          0.0      -4485.3          0.0     -4485.3    --.--    --.-
 5 Uribe                    -29412.4          0.0          0.0     -29412.4          0.0    -29412.4    --.--    --.-
18 Mapiripan                -17018.6          0.0          0.0     -17018.6          0.0    -17018.6    --.--    --.-
 9 Otros Tradicional        -16385.7          0.0          0.0     -16385.7          0.0    -16385.7    --.--    --.-
   ---------------------------------------------------------------------------------------------------------------------
 Total NPV Benefits         -78859.6          0.0          0.0     -78859.6          0.0    -78859.6     --.--   --.-
```

Demand

```
                       ---------- Present Value of R&D Benefits ---------><---Costs---><------ Returns ------------>
   Region                   Producer     Consumer   Government        Total                  (B-C)      B/C     IRR
   --------------------------------------------------------------------------------------------------------------------
10 Meta Consumo Anima            0.0     123641.2          0.0     123641.2          0.0    123641.2     --.--  --.-
11 Meta Consumo Human            0.0     723078.2          0.0     723078.2          0.0    723078.2     --.--  --.-
   ---------------------------------------------------------------------------------------------------------------------
 Total NPV Benefits              0.0     846719.5          0.0     846719.5          0.0    846719.5     --.--  --.-
```

External Supply

```
                       ---------- Present Value of R&D Benefits ---------><---Costs---><------ Returns ------------>
   Region                   Producer     Consumer   Government        Total                  (B-C)      B/C     IRR
   ---------------------------------------------------------------------------------------------------------------------
20 Meta Oferta Extern      -544752.5          0.0          0.0    -544752.5          0.0   -544752.5     --.--   --.-
   ---------------------------------------------------------------------------------------------------------------------
  Total NPV Benefits       -544752.5          0.0          0.0    -544752.5          0.0   -544752.5     --.--   --.-
```

Note: The interpretation of negative benefits. This indicates how much the sector has shrunk (reduced revenue, lost market share) relative to the situation without research. Thus, because the cost of production of traditional producers has not changed, they will lose revenue and profits as prices fall (because of the expansion of technical production). In reality, the traditional prodcucers will move into their next best farming activity – more cattle, cotton etc. The loss is the loss to the maize production sector.

Table 5: Present Value of Gross Benefits for the Meta Department (excluding external supply region)

```
Total Scenario
                      ---------- Present Value of R&D Benefits ----------><---Costs---><------ Returns ------------>
   Region                  Producer     Consumer   Government        Total                  (B-C)       B/C     IRR
   ----------------------------------------------------------------------------------------------------------------
 1 Mesetas                 105756.4          0.0          0.0     105756.4          0.0    105756.4    --.--    --.-
 2 Puerto Concordia         -7711.6          0.0          0.0      -7711.6          0.0     -7711.6    --.--    --.-
 3 Puerto Rico              -3845.6          0.0          0.0      -3845.6          0.0     -3845.6    --.--    --.-
 4 La Macarena              -4485.3          0.0          0.0      -4485.3          0.0     -4485.3    --.--    --.-
 5 Uribe                   -29412.4          0.0          0.0     -29412.4          0.0    -29412.4    --.--    --.-
 6 Villavicencio           137317.7          0.0          0.0     137317.7          0.0    137317.7    --.--    --.-
 7 Vistahermosa             42170.6          0.0          0.0      42170.6          0.0     42170.6    --.--    --.-
13 Fuente de Oro           263320.4          0.0          0.0     263320.4          0.0    263320.4    --.--    --.-
14 Cumaral                  36125.1          0.0          0.0      36125.1          0.0     36125.1    --.--    --.-
15 San Juan de Arama        35938.5          0.0          0.0      35938.5          0.0     35938.5    --.--    --.-
16 Granada                 415033.5          0.0          0.0     415033.5          0.0    415033.5    --.--    --.-
17 Lejanias                 77906.7          0.0          0.0      77906.7          0.0     77906.7    --.--    --.-
18 Mapiripan               -17018.6          0.0          0.0     -17018.6          0.0    -17018.6    --.--    --.-
19 El  Castillo             60320.9          0.0          0.0      60320.9          0.0     60320.9    --.--    --.-
 8 Otros Tecnificado        62245.7          0.0          0.0      62245.7          0.0     62245.7    --.--    --.-
 9 Otros Tradicional       -16385.7          0.0          0.0     -16385.7          0.0    -16385.7    --.--    --.-
10 Meta Consumo Anima           0.0     123641.2          0.0     123641.2          0.0    123641.2    --.--    --.-
11 Meta Consumo Human           0.0     723078.2          0.0     723078.2          0.0    723078.2    --.--    --.-

--------------------------------------------------------------------------------------------------------------
 Total NPV Benefits       1157276.4     846719.5          0.0    2003995.9                2003995.9    --.--    --.--

Annual Benefit Summary Across All Regions in the Scenario

      <--------------- Benefits ----------------->
 Year    Producer   Consumer   Government      Total
----------------------------------------------------
 1998       2933.6     3980.7          0.0     6914.4
 1999      12524.5    17618.8          0.0    30143.4
 2000      39651.6    55346.0          0.0    94997.7
 2001      70854.2    98028.3          0.0   168882.6
 2002      84365.0   116308.3          0.0   200673.3
 2003      87781.6   120946.8          0.0   208728.5
 2004      87784.3   121000.2          0.0   208784.6
 2005      87774.3   121038.2          0.0   208812.5
 2006      87746.6   121053.7          0.0   208800.3
 2007      87705.4   121052.8          0.0   208758.3
 2008      87647.3   121030.7          0.0   208678.0
 2009      87576.0   120992.1          0.0   208568.2
 2010      87487.2   120931.5          0.0   208418.7
 2011      87386.0   120855.6          0.0   208241.7
 2012      87267.5   120757.8          0.0   208025.3
 2013      87136.8   120645.0          0.0   207781.9
 2014      86989.1   120510.4          0.0   207499.6
 2015      86828.8   120360.2          0.0   207189.0
 2016      86652.3   120189.5          0.0   206841.8
 2017      86463.5   120003.4          0.0   206466.9
```

Table 6: Example simulation results for a single technical maize municipio – Mesetas

```
Region: 1  Mesetas               Price wedge information: Relative to Mesetas: Price difference = 0 $1000  Transmission = 1.00

       ---------------- Producers --------------  ------------- Consumers ------------------  ----- Government ---- ----------
       <---no R&D--->  <------- with R&D ------>  <-- no R&D ---> <------- with R&D ------>   < Tax Rev.>             Research
 Year  Price Quantity  Price  Quantity  Benefits  Price  Quantity Price   Quantity Benefits  "Prod" "Cons" Benefits      Costs
 -------------------------------------------------------------------------------------------------------------------------------
 1998   240.7   2241.6  240.6   2242.6      483.1  240.7      0.0  240.6      0.0       0.0    0.0    0.0       0.0        0.0
 1999   241.2   2244.0  240.8   2248.3     2104.5  241.2      0.0  240.8      0.0       0.0    0.0    0.0       0.0        0.0
 2000   241.6   2246.0  240.5   2259.7     6659.4  241.6      0.0  240.5      0.0       0.0    0.0    0.0       0.0        0.0
 2001   242.0   2247.7  240.1   2272.1    11883.3  242.0      0.0  240.1      0.0       0.0    0.0    0.0       0.0        0.0
 2002   242.2   2248.9  240.1   2278.0    14190.1  242.2      0.0  240.1      0.0       0.0    0.0    0.0       0.0        0.0
 2003   242.4   2249.9  240.2   2280.3    14842.0  242.4      0.0  240.2      0.0       0.0    0.0    0.0       0.0        0.0
 2004   242.5   2250.4  240.4   2280.9    14931.2  242.5      0.0  240.4      0.0       0.0    0.0    0.0       0.0        0.0
 2005   242.6   2250.6  240.4   2281.3    15017.9  242.6      0.0  240.4      0.0       0.0    0.0    0.0       0.0        0.0
 2006   242.5   2250.4  240.4   2281.3    15101.1  242.5      0.0  240.4      0.0       0.0    0.0    0.0       0.0        0.0
 2007   242.4   2249.8  240.4   2280.9    15181.5  242.4      0.0  240.4      0.0       0.0    0.0    0.0       0.0        0.0
 2008   242.2   2248.9  240.2   2280.2    15258.5  242.2      0.0  240.2      0.0       0.0    0.0    0.0       0.0        0.0
 2009   242.0   2247.6  240.0   2279.1    15332.6  242.0      0.0  240.0      0.0       0.0    0.0    0.0       0.0        0.0
 2010   241.6   2246.0  239.6   2277.6    15403.1  241.6      0.0  239.6      0.0       0.0    0.0    0.0       0.0        0.0
 2011   241.2   2244.0  239.2   2275.8    15470.7  241.2      0.0  239.2      0.0       0.0    0.0    0.0       0.0        0.0
 2012   240.7   2241.6  238.8   2273.6    15534.5  240.7      0.0  238.8      0.0       0.0    0.0    0.0       0.0        0.0
 2013   240.1   2238.9  238.2   2271.1    15595.5  240.1      0.0  238.2      0.0       0.0    0.0    0.0       0.0        0.0
 2014   239.4   2235.8  237.6   2268.2    15652.6  239.4      0.0  237.6      0.0       0.0    0.0    0.0       0.0        0.0
 2015   238.7   2232.4  236.9   2265.0    15706.5  238.7      0.0  236.9      0.0       0.0    0.0    0.0       0.0        0.0
 2016   237.9   2228.6  236.1   2261.4    15756.7  237.9      0.0  236.1      0.0       0.0    0.0    0.0       0.0        0.0
 2017   237.0   2224.5  235.3   2257.6    15803.8  237.0      0.0  235.3      0.0       0.0    0.0    0.0       0.0        0.0
---------------------------------------------------------------------------------------------------------------------------------
 Present value of benefits              105756.4                                       0.0                      0.0        0.0

-- Price --- ------------- Production -----------  ----------- Consumption ------------
 Year    K      K     K     K                  --R&D change in-  Value of  Benefits  -R&D change in-   Value of Benefits
       Total  Base  Spill  Var  NoR&D   R&D   Price  Quantity  Productn  /VoP (%)  Price  Quantity  Consumptn  /VoC (%)
 --------------------------------------------------------------------------------------------------------------------------
 1998    0.29  0.29   0.0  0.00  240.7  240.6  -0.07       1.0    539622     0.0     -0.07       0.0         0    0.0
 1999    1.28  1.28   0.0  0.00  241.2  240.8  -0.34       4.3    541568     0.3     -0.34       0.0         0    0.0
 2000    4.02  4.02   0.0  0.00  241.6  240.5  -1.07      13.7    543643     1.2     -1.07       0.0         0    0.0
 2001    7.12  7.12   0.0  0.00  242.0  240.1  -1.86      24.4    545635     2.1     -1.86       0.0         0    0.0
 2002    8.44  8.44   0.0  0.00  242.2  240.1  -2.17      29.1    546967     2.5     -2.17       0.0         0    0.0
 2003    8.77  8.77   0.0  0.00  242.4  240.2  -2.22      30.4    547863     2.7     -2.22       0.0         0    0.0
 2004    8.77  8.77   0.0  0.00  242.5  240.4  -2.18      30.5    548366     2.7     -2.18       0.0         0    0.0
 2005    8.77  8.77   0.0  0.00  242.6  240.4  -2.14      30.7    548649     2.7     -2.14       0.0         0    0.0
 2006    8.77  8.77   0.0  0.00  242.5  240.4  -2.10      30.9    548619     2.7     -2.10       0.0         0    0.0
 2007    8.77  8.77   0.0  0.00  242.4  240.4  -2.07      31.0    548355     2.7     -2.07       0.0         0    0.0
 2008    8.77  8.77   0.0  0.00  242.2  240.2  -2.03      31.2    547794     2.7     -2.03       0.0         0    0.0
 2009    8.77  8.77   0.0  0.00  242.0  240.0  -1.99      31.4    547001     2.8     -1.99       0.0         0    0.0
 2010    8.77  8.77   0.0  0.00  241.6  239.6  -1.96      31.6    545901     2.8     -1.96       0.0         0    0.0
 2011    8.77  8.77   0.0  0.00  241.2  239.2  -1.92      31.8    544588     2.8     -1.92       0.0         0    0.0
 2012    8.77  8.77   0.0  0.00  240.7  238.8  -1.89      32.0    542972     2.8     -1.89       0.0         0    0.0
 2013    8.77  8.77   0.0  0.00  240.1  238.2  -1.85      32.2    541149     2.8     -1.85       0.0         0    0.0
 2014    8.77  8.77   0.0  0.00  239.4  237.6  -1.82      32.4    539030     2.9     -1.82       0.0         0    0.0
 2015    8.77  8.77   0.0  0.00  238.7  236.9  -1.78      32.6    536699     2.9     -1.78       0.0         0    0.0
 2016    8.77  8.77   0.0  0.00  237.9  236.1  -1.75      32.8    534094     2.9     -1.75       0.0         0    0.0
 2017    8.77  8.77   0.0  0.00  237.0  235.3  -1.72      33.0    531284     2.9     -1.72       0.0         0    0.0
```

Table 7: Example simulation results for a single traditional maize municipio – Puerto Concordia

```
 Region: 2  Puerto Concordia     Price wedge information: Relative to Mesetas: Price difference -0.7 $1000  Transmission = 1.00

       ---------------- Producers --------------  ------------ Consumers ------------------  ----- Government ---- ----------
       <---no R&D---> <------- with R&D ------>  <-- no R&D ---> <------- with R&D ------>   < Tax Rev.>             Research
 Year  Price Quantity  Price  Quantity  Benefits  Price  Quantity Price   Quantity Benefits  "Prod" "Cons" Benefits      Costs
 -------------------------------------------------------------------------------------------------------------------------------
 1998   240.0    524.3  239.9    524.2     -41.9  240.0      0.0  239.9      0.0       0.0    0.0    0.0       0.0        0.0
 1999   240.5    524.9  240.1    524.5    -182.3  240.5      0.0  240.1      0.0       0.0    0.0    0.0       0.0        0.0
 2000   240.9    525.4  239.8    524.2    -562.7  240.9      0.0  239.8      0.0       0.0    0.0    0.0       0.0        0.0
 2001   241.3    525.8  239.4    523.7    -978.7  241.3      0.0  239.4      0.0       0.0    0.0    0.0       0.0        0.0
 2002   241.5    526.0  239.4    523.7   -1141.0  241.5      0.0  239.4      0.0       0.0    0.0    0.0       0.0        0.0
 2003   241.7    526.3  239.5    523.9   -1166.2  241.7      0.0  239.5      0.0       0.0    0.0    0.0       0.0        0.0
 2004   241.8    526.4  239.7    524.0   -1146.8  241.8      0.0  239.7      0.0       0.0    0.0    0.0       0.0        0.0
 2005   241.9    526.4  239.7    524.1   -1127.3  241.9      0.0  239.7      0.0       0.0    0.0    0.0       0.0        0.0
 2006   241.8    526.4  239.7    524.1   -1107.8  241.8      0.0  239.7      0.0       0.0    0.0    0.0       0.0        0.0
 2007   241.7    526.3  239.7    524.0   -1088.2  241.7      0.0  239.7      0.0       0.0    0.0    0.0       0.0        0.0
 2008   241.5    526.0  239.5    523.8   -1068.6  241.5      0.0  239.5      0.0       0.0    0.0    0.0       0.0        0.0
 2009   241.3    525.8  239.3    523.6   -1049.1  241.3      0.0  239.3      0.0       0.0    0.0    0.0       0.0        0.0
 2010   240.9    525.4  238.9    523.2   -1029.5  240.9      0.0  238.9      0.0       0.0    0.0    0.0       0.0        0.0
 2011   240.5    524.9  238.5    522.8   -1010.0  240.5      0.0  238.5      0.0       0.0    0.0    0.0       0.0        0.0
 2012   240.0    524.3  238.1    522.3    -990.5  240.0      0.0  238.1      0.0       0.0    0.0    0.0       0.0        0.0
 2013   239.4    523.7  237.5    521.7    -971.1  239.4      0.0  237.5      0.0       0.0    0.0    0.0       0.0        0.0
 2014   238.7    523.0  236.9    521.0    -951.7  238.7      0.0  236.9      0.0       0.0    0.0    0.0       0.0        0.0
 2015   238.0    522.2  236.2    520.2    -932.5  238.0      0.0  236.2      0.0       0.0    0.0    0.0       0.0        0.0
 2016   237.2    521.3  235.4    519.4    -913.3  237.2      0.0  235.4      0.0       0.0    0.0    0.0       0.0        0.0
 2017   236.3    520.3  234.6    518.4    -894.3  236.3      0.0  234.6      0.0       0.0    0.0    0.0       0.0        0.0
--------------------------------------------------------------------------------------------------------------------------------
 Present value of benefits               -7711.6                                           0.0                   0.0        0.0

                                  -- Price --- ------------- Production -----------  ----------- Consumption ------------
 Year    K      K     K     K                --R&D change in - Value of  Benefits  --R&D change in - Value of  Benefits
       Total  Base  Spill  Var  NoR&D   R&D   Price  Quantity  Productn  /VoP (%)  Price  Quantity  Consumptn  /VoC (%)
 ------------------------------------------------------------------------------------------------------------------------
 1998    0.00  0.00   0.0  0.00  240.0  239.9  -0.07      -0.0    125788    -0.0     -0.07       0.0         0    0.0
 1999    0.00  0.00   0.0  0.00  240.5  240.1  -0.34      -0.3    125983    -0.1     -0.34       0.0         0    0.0
 2000    0.00  0.00   0.0  0.00  240.9  239.8  -1.07      -1.1    125751    -0.4     -1.07       0.0         0    0.0
 2001    0.00  0.00   0.0  0.00  241.3  239.4  -1.86      -2.0    125412    -0.7     -1.86       0.0         0    0.0
 2002    0.00  0.00   0.0  0.00  241.5  239.4  -2.17      -2.3    125381    -0.9     -2.17       0.0         0    0.0
 2003    0.00  0.00   0.0  0.00  241.7  239.5  -2.22      -2.4    125504    -0.9     -2.22       0.0         0    0.0
 2004    0.00  0.00   0.0  0.00  241.8  239.7  -2.18      -2.3    125622    -0.9     -2.18       0.0         0    0.0
 2005    0.00  0.00   0.0  0.00  241.9  239.7  -2.14      -2.3    125688    -0.8     -2.14       0.0         0    0.0
 2006    0.00  0.00   0.0  0.00  241.8  239.7  -2.10      -2.2    125681    -0.8     -2.10       0.0         0    0.0
 2007    0.00  0.00   0.0  0.00  241.7  239.7  -2.07      -2.2    125620    -0.8     -2.07       0.0         0    0.0
 2008    0.00  0.00   0.0  0.00  241.5  239.5  -2.03      -2.2    125489    -0.8     -2.03       0.0         0    0.0
 2009    0.00  0.00   0.0  0.00  241.3  239.3  -1.99      -2.1    125305    -0.8     -1.99       0.0         0    0.0
 2010    0.00  0.00   0.0  0.00  240.9  238.9  -1.96      -2.1    125050    -0.8     -1.96       0.0         0    0.0
 2011    0.00  0.00   0.0  0.00  240.5  238.5  -1.92      -2.1    124745    -0.8     -1.92       0.0         0    0.0
 2012    0.00  0.00   0.0  0.00  240.0  238.1  -1.89      -2.0    124369    -0.7     -1.89       0.0         0    0.0
 2013    0.00  0.00   0.0  0.00  239.4  237.5  -1.85      -2.0    123945    -0.7     -1.85       0.0         0    0.0
 2014    0.00  0.00   0.0  0.00  238.7  236.9  -1.82      -1.9    123453    -0.7     -1.82       0.0         0    0.0
 2015    0.00  0.00   0.0  0.00  238.0  236.2  -1.78      -1.9    122911    -0.7     -1.78       0.0         0    0.0
 2016    0.00  0.00   0.0  0.00  237.2  235.4  -1.75      -1.9    122306    -0.7     -1.75       0.0         0    0.0
 2017    0.00  0.00   0.0  0.00  236.3  234.6  -1.72      -1.8    121653    -0.7     -1.72       0.0         0    0.0
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Conclusions and Recomendation

The primary determinant of the quality of the economic evaluation is the consistency of the technical R&D data and of the adoption data. It is important to elicit appropriate information from scientists, extension workers, and other informed stakeholders. The data preparation phase includes, as a minimum, an analysis of the trends in production, area and yield, and the structure of prices, adoption and cost of the production where it is possible. This informs the scientific debate, that is an essential part of the evaluation process on the probable impact of new technologies - particularly in order to establish the appropriate with and without R&D cases.

For the calculation of the benefits for geographic and socio-economic targets, nowadays it is important to also consider the socio-economic distribution of the benefits as well as its geographic and agro-ecological distribution. By default the benefits are calculated for producers, consumers, and government sectors, but these groups can broken down further to help to a better understanding. The examples used in other studies include the split of consumers into urban and rural groups, and of producers into different scale of operation and production systems - such as commercial irrigation or small producers in dryland (i.e. Sanint and Wood 1998).

The method employed in the research study appropriate for this task for several reasons. As was demonstrated in this study, each municipality can be represented separately in terms of its own consumption, production systems, trade, generation and adoption of technology. The results of the analysis include the changes in prices, production, consumption and commerce for each region, as well as the benefits (B) at level of the region in this case. This is extremely valuable to establish incentives to participate in initiatives of investigation at a regional and sub-regional level

In order to obtain results that reflect reality in the regions, it is important to have appropriate base information for the model. For maize it was possible to get information detailed at the municipal level, on which the pertinent analyses for the definition of the regions were made.

This information was useful to make necessary analyses of the trends in production, consumption and prices, in the scenarios proposed without and with adoption of technology.

From the point of view of the region, for those municipalities in which the technology is adopted, the benefits are derived broadly in proportion to technology adoption. In the case of maize in the Meta Department, benefits are also obtained because the increase in production allows a reduction in the volume of imports (at the present time imports are roughly 40 kg/per-capita.)

The benefits gained by the improved maize (technical) producers reflect advantages of adopting new technology. On the other hand, traditional producers lose out because of new technology. Traditional producers lose benefits, relative to the situation without research, because the research does not increase their yields or decrease their costs, but the use of new technologies elsewhere is expanding production and reducing prices (relative to what they would be without research). Thus traditional producers lose profits and share of production.

One of the limitations of the methodology used is that the effects of R&D on other commodities cannot be valued because the model does not allow the simultaneous analysis of more than one product.

There are some methodological areas that could deserve attention:

- The capacity to make evaluations that consider interaction between impacts of R&D in multiple commodities (general equilibrium effects, for instance, would integrate the market simulation, important secondary mechanisms and reaction, which would serve to dissipate or to intensify the realistic impacts of R&D).

- The spatial presentation of prices, for example, to take into account the costs of transport and other transactions. Given the confidence already put in GIS technology, its use can be extended (together with other information) to estimate the effects in price formation related to distance, this would bring more realism to the market responses. The present supposition of transference without cost between markets can exaggerate, some times significantly, the potential for trade.

From the ecological point of view, there are high benefits from the adoption of new technology, since this allows greater productivity, reflected in the crop yields. The new production system will allow soil conservation through the fixing of nitrogen (in the new maize/soybean rotation) and the improvement of organic material in the soil, increasing the life of the soil and promoting sustainable agriculture.

By the end of the simulation period the Meta department was producing 20.541 tonnes per year (15.238 tonnes of which came from technical maize producers) which is equivalent to the 31% of the department's total consumption.

The adoption of new technology lead to an increase in the annual production of maize in the Meta department of 6165 tonnes over the simulation period (that is, the difference between the total production for the department with and without the new technology). By 2017 an extra 369 tonnes per year would be produced, made up of an increase of 388 tonnes per year from technical producers, and a decrease of 19 tonnes per year from traditional producers.

By the end of the simulation period the total annual benefits to technical producers were Col$M 180.563.9 per year, to consumers were Col$M 120.003.4 per year, and the losses suffered by traditional producers were Col$M 9.146.6 per year.

If we calculate the present value of the stream of benefits (and losses) over the whole simulation period, using a discount rate of 10 percent, we find that present value of benefits to producers are Col$M 1.236,1 (US$ 630.167), to consumers are Col$M 846,7 (US$ 431.669), and the present value of losses to traditional producers is Col$M 78.9 (US$ 40.203). Thus, the total present value across all groups is some US$ 1.021.633.[7] We acknowledge, however, that the benefits of this research may well be larger because of adoption beyond the Meta department, but we have no means of estimating what that additional adoption might be.

A benefit-cost analysis of this research investment would suggest that the investment would be worthwhile if the total cost of development and diffusion of the new technology was less than US$M 1.02. Since we were unable to get detailed cost and personnel figures attributable only to carrying out the research that underlies this new technology, we can only estimate a general level of effort below which the R&D investment would still be worthwhile.

Based on information from CIMMYT and CIAT, the following assumptions can be made about direct research personnel costs per year: Ph.D. US$50.000, Research Assistant US$18.000, Field Worker: US$10.000 (* 2 workers = US$20.000). This gives a basic research team cost of $88.000 per year. If we add an arbitrary 50 percent for other indirect costs, the total marginal cost of a full-time field based research team would be some US$132.000 per year. On this rough basis, we can say that if the research required less than (1.021.633 / 132.000) about 7.7 full time equivalent research team years, it was profitable. If the research took more than the equivalent of 7.7 full time years of research team time, it was likely not profitable (although, as we suggest we have ignored potential benefits of the new technology beyond the Meta department).

The analysis described here is an ex-ante evaluation, trying to estimate the future effects of a new technology. To make this analysis we had to make many assumptions about, for example the likely rates and levels of adoption, and the growth rate of demand. Obviously our results are sensitive to those assumptions, but other assumptions can be easily tested in the modelling approach used. We can see in Tables 2 and 3 some of the factors we can take into account; such as level of adoption of the new technology, adoption speed, the market scenario and the macroeconomic and sectoral policies applied in the country or region.

The utility of the analysis is based on its capacity to evaluate the economic potential that a new technology offers, and this allows research managers to balance this potential benefit against the likely research costs. As the actual diffusion and adoption process, it is necessary to make ex-post studies to quantify the real levels of adoption and impact, to evaluate that process and to extract lessons. On this basis, R&D managers and policy makers can aim to improve the payoff to farmers and food consumers, as well as improve the efficiency of technology generation and diffusion processes.

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[7] All conversions based on an exchange rate of US$1 =$Col 1.962.

Institutions Involved:

- IFPRI (Environment and Production Technology Division) and CIAT (Impact Assessment Unit)

Donor: Interamerican Development Bank

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- CIAT (Impact Assessment Unit)

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