# IMPACT ASSESSMENT

# ANNUAL REPORT

# 2001

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Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

# Impact Assessment
# Annual Report
# 2001

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## 2001 HIGHLIGHTS

### Output I: Future Impact of Research Estimated

Legally binding regulatory frameworks controlling the deployment of transgenic crop varieties are now in place internationally through the Biosafety Protocol to the Convention on Biodiversity as well as at the national level in the United States and at the community level in Europe.

Science based risk assessment of transgenic crops is required for their liberation, including both environmental and human health risks but the potential benefits are not a formal factor in decision making.

Research institutions, either NARS, private corporations, or international Centers, must provide scientific information on environmental consequences including risks of gene flow, weediness/invasiveness, impacts on biodiversity including non-target species and changes in crop management systems among other considerations.

Impacts of improved watershed management programs can not be assessed solely through bio-physical indicators such as increases in forest cover or adoption of a management technology, but must also include indicators of human or social capital that measure the capacity of local communities to learn to manage their resources.

The use of participatory methods for watershed resource management is increasingly accepted, but further research is needed on the institutionalization of these approaches.

Disease free cassava planting material would lead to substantial benefits at the farm level, but public sector intervention is likely required because of the difficulties of establishing a fully commercial system for producing and distributing disease free planting material.

Preliminary results suggest that transgenic herbicide tolerant cassava could produce direct economic benefits almost as high as those of conventionally bred high yielding cassava, and in some regions herbicide tolerant cassava would produce greater benefits.

The labor displacing effects of transgenic herbicide tolerant cassava are not significantly greater than conventionally bred high yielding cassava. High yielding cassava reduces the area planted while maintaining the labor use per hectare constant in contrast to herbicide tolerant cassava which would not reduce the area planted but would reduce labor use per hectare.

Many low-income tropical countries would be net payers in a system of ownership rights in genetic resources. While farmers rights in common bean germplasm administered along royalty principles would result in income flow from high-income temperate latitude countries to the benefit of tropical countries, Africa, Brazil and the Caribbean would also be substantial net payers for bean germplasm.

Most low income tropical countries, even those with a wealth of bean genetic resources, have far more to gain from a research capacity that enables them to more effectively utilize genetic resources than they would gain from a system of ownership rights in bean genetic resources.

In a collaborative study with IFPRI, the expected benefits of improved maize varieties in the savannas of Colombia were estimated.

**Output II: Impact of Past Research Monitored**

In all of three case studies, farmer participatory research was found to influence the technology development process, with greater impact when participation is at an earlier stage.

Collaborative participation was shown to increase human capital of participants, but this effect was small when the participation was consultative.

Feedback from participatory research methods had a greater influence on NGOs and international center activities than it did on national agricultural research institutes.

Cost effectiveness increases with the use of participatory research methods even as total costs increase.

Rice research has generated substantial economic benefits in Colombia, but these are distributed unevenly among regions, with some gaining while other actually lost.

**Output III: Data Base and Methods**

Emphasis has been place on web based dissemination of data bases. The Impact Assessment web page was completely redesigned and new data bases were added.

**Output IV: Institutional Capacity for Assessment Enhanced**

A comprehensive system for monitoring and evaluation was designed and implemented to support CIAT research in the savannas of Colombia under the agreement with the Ministry of Agriculture.

## PROJECT BP-1: IMPACT ASSESSMENT

### PROJECT DESCRIPTION

**Objective:** To generate and disseminate information and tools to improve the capacity of CIAT and partner organizations to allocate research resources efficiently.

**Outputs:**
1. Expected impact of future research estimated.
2. Impact of selected past CIAT research monitored.
3. Tools developed to assess the impact of research, *ex ante* and *ex post*.
4. Institutional capacity for estimating, monitoring, and evaluating research impacts improved.

**Gains:** Improved allocation of resources can increase the rate of return on investment in agricultural research. Project target is 2%.

**Milestones:**

2002 Study on research efficiency of molecular markers completed. Fieldwork for monitoring impact at Central American reference sites initiated. Economic impact of herbicide-resistant cassava estimated. Consumer attitude to food risks assessed in one country.

2003 Impact monitoring system developed and implemented for all agroecological sites and CIAT projects. Expected benefits of four CIAT research outputs appraised. Two new field studies on technology adoption and acceptability initiated. Two new field studies on technology adoption and acceptability completed.

2004 Two studies on technology adoption completed. Impact of investments in social capital on NRM estimated. Two new field studies on technology adoption initiated. Impact of CIAT research on poverty reduction estimated.

**Users:** Research planners in NARS and the CGIAR who make decisions on resource allocation. Stakeholders who need to measure expected returns to investment in agricultural and resource management research.

**Collaborators:** *Future impact of research:* Ministry of Agriculture (Colombia); University of Hohenheim; California State Polytechnic University, San Luis Obispo; Center for Development Research, Denmark; University of Valle, Colombia; CIAT projects Genetic resoruces, biotechnology on forages, rice, cassava, beans, Hillsides and CLAYUCA. *Impact of past research monitored*: CIMMYT; IFPRI; Systemwide Participatory Research and Gender Analysis Program; CIAT projects on cassava, rice, forages, IPM, Hillsides, Land Use, and Agroenterprises; all CIAT projects.

**CGIAR system linkages:** Improving Policies (100%).

**CIAT project linkages:** All CIAT projects.

# Log Frame Work Plan for BP-1, 2002-2004

**Area:** Strategic Planning
**Manager:** Douglas Pachico

| Narrative Summary | Measurable Indicators | Means of Verification | Important Assumptions |
|---|---|---|---|
| **Goal**<br>To obtain knowledge and expertise for enhancing performance of decision making in the agricultural and development sectors are made available to appropriate users. | Performance of investment in tropical agricultural research improved. | Research project portfolios in tropical agricultural research. | |
| **Purpose**<br>To generate and disseminate information and tools to improve the capacity of CIAT and partner organizations to allocate research resources efficiently, and document the impact of research investments. | • Research resources allocated more efficiently (expected rate of return to CIAT research portfolios increased).<br>• Results of impact analysis used in decision making and priority setting.<br>• Economic and environmental impact of selected past research identified and quantified. | Scientific publications from BP-1 and other projects.<br>Published planning documents of CIAT and partner organizations.<br>Published minutes of planning meetings in CIAT (BoT, MT, Project Managers) and partner organizations.<br>External reviews of CIAT.<br>Data on use of CIAT-developed tools. | Adequate funding to agricultural research and extension.<br>Decision makers willing to use economic analysis in research priority setting. |
| **Output 1**<br>Expected impact of future research estimated. | • Expected rate of return for potential research projects estimated.<br>• Expected economic, distributional, and environmental impact identified and quantified. | CIAT technical publications.<br>CIAT published planning documents. | Willingness of decision makers to use the information.<br>No external shocks that invalidate the results. |
| **Output 2**<br>Impact of selected past CIAT research documented. | • Economic, social, and environmental impact of CIAT research outputs identified and quantified. | CIAT technical publications. | |
| **Output 3**<br>Tools developed to assess the impact of research, *ex ante* and *ex post.* | • Methodologies generated.<br>• Databases compiled and maintained. | Scientific publications and other technical publications such as manuals and guidelines.<br>Databases available on BP-1 sites on Internet, on CIAT's internal network, and in BP-1's data library.<br>Site flow data from web sites.<br>Data on registered users of BP-1 software.<br>Citations of project publications and tools in technical publications. | Analysts willing to use the tools in their impact analyses.<br>Data available for using the tools. |
| **Output 4**<br>Institutional capacity for estimating, monitoring, and evaluating research impacts improved. | • Appropriate and well-designed impact assessment components included in the work plans and budgets of CIAT projects and projects of partner organizations. | CIAT project log frames and budgets.<br>Work plans of CIAT researchers.<br>Research proposals submitted by projects.<br>Similar documentation from partner organizations. | Institutional and financial support for impact assessment. |

# OUTPUT I: FUTURE IMPACT OF RESEARCH ESTIMATED

## 1.1 TRENDS AND POLICY ANALYSIS

### 1.1.1 Farmers Rights in Beans Genetic Resources: An Analysis of Benefit Sharing *- by: D. Pachico*

Crop genetic resources are the foundation of modern agriculture. When the original farmers in Asia, Africa, Europe and the Americas first learned to cultivate wild food plant species, they began a long process of plant improvement. Farmer selection increased the yield of crop species, changed plant architecture and adapted crops to new growing environments (Gepts 1988). Millennia of farmer selection have endowed today's world with a wealth of crop genetic resources commonly called farmer land races.

In the last century, by building upon the inheritance of farmer land races, the science of genetics and plant breeding has vastly accelerated the process of plant improvement, leading to huge increases in crop productivity through breakthroughs like hybrid maize and semi-dwarf rice and wheat. This progress has been heavily dependent on the availability of crop genetic resources. It has been estimated that up to one half of the gains in U.S.A. agricultural yields from 1930-1980 can be attributed to genetic resources (Office of Technology Assessment 1987).

Despite some efforts to control ownership, for example by preventing the export or rubber tree seeds from Brazil, to a very considerable degree plant genetic resources were long treated as a common global heritage, freely accessible by anyone. More recently, however, there has been a trend towards establishing ownership rights in genetic resources. In 1930 the U.S.A. passed the Plant Patent Act establishing intellectual property rights (IPR) in some improved plants that are asexually produced. Subsequently in Europe in the 1960s and then in 1970 in the U.S.A., legislation established breeders' ownership rights in improved sexually reproduced plants. This was followed by U.S.A. court decisions in the 1980s that expanded IPR coverage to include patents over plants and animals (National Research Council 1993).

This process of privatization of what previously had been common resources led to a questioning of the propriety of treating farmer improved genetic resources, mostly from the South, as a freely available public resource while scientist improved genetic resources, mostly from the North, were increasingly protected as private property (Mooney 1979).

As a result, in 1989 the concept of Farmers' Rights was endorsed by the Food and Agriculture Organization International Undertaking on Plant Genetic Resources. This concept recognizes the enormous contribution of farmers to the conservation and development of plant genetic resources, and posits that farming communities should be compensated for the use of their genetic resources (Pistorius 1997; Rural Advancement Foundation International 1997). Farmers' Rights are considered to be vested in the international community as trustees for present and future farmers (Food and Agriculture

Organization 1994). An International Fund on Plant Genetic Resources was envisioned as the mechanism through which Farmers' Rights would be implemented.

It is generally accepted that low-income countries would be net beneficiaries from a system of compensation for Farmers' Rights in germplasm. Analysis at the level of regional groupings has confirmed this tendency (Kloppenburg and Kleinman 1987). Yet it is clear that most countries are dependent on germplasm that originated outside their borders creating a situation of mutual interdependence among countries for their crop germplasm (Flores-Palacio 1999). These previous studies have examined this issue in terms of mega-centers of diversity each of which include a number of countries. However, use of the mega-centers as a unit of analysis conceals what may be considerable differences among countries associated with a mega-center in terms of its contribution to genetic diversity. Moreover, a fuller understanding of the distribution of benefits among countries is needed to assist in the implementation of Farmers' Rights (Food and Agriculture Organization 1994).

A variety of indicators are currently being assessed for their suitability as guides to mechanisms to share the benefits of germplasm (Food and Agriculture Organization 1999). Among the considerations proposed are the amounts of benefits that have been or might be obtained from plant genetic resources as well as the amount and kind of plant genetic resources that have been provided.

This paper seeks to assess in more detail the international distribution of benefits that might guide the implementation of Farmers' Rights in land race germplasm. It develops a conceptual framework for estimating such benefits, and the framework is applied to common beans (Phaseolus vulgaris L.) as a model crop for this analysis. The paper first attempts to quantitatively estimate the potential magnitude of benefit flows that would accrue to countries of origin of germplasm based on a market derived approach to calculating benefits. Second, it breaks down benefit flows by individual countries rather than regions, thereby revealing significant intra-regional variation. Next, estimates are made of the potential productivity gains that could come to different countries from improved bean germplasm. These potential benefits are contrasted with evidence about gains that have already been made from germplasm improvement. Finally, some implications are drawn and directions for future research are pointed out.

**A Royalty Model to Estimate Payments for Farmers' Rights**

Typically incomes from intellectual property rights are accrued through a market based system of royalty payments. This reflects the willingness of users to pay for the use of the intellectual property while the holder of the IPR obtains a return based as a per cent of the value purchased in the market. To estimate the benefit flows associated with Farmers' Rights in land race germplasm this paper develops a simple model of the incomes that could accrue if payments were based on a royalty system.

(1) $Y_i = A_g * S * P * R * D_i - E_i + O_i$

where

$Y_i$ is the income from land race genetic resources in country i.

$A_g$ is the global area planted with seed using the genetic resources of country i.

S is the amount of seed planted per unit area

P is the price of seed

R is the royalty rate earned for rights in land race germplasm

$D_i$ is the share of land race genetic diversity of country i

$E_i$ is the transaction cost of enforcing ownership rights in land race germplasm

$O_i$ is the spillover benefits from the use of land race germplasm to improve other crops

This model uses a market derived royalty approach to estimating an appropriate level of benefit sharing for farmers' rights in germplasm. In this model payments by users of germplasm are assumed to be made to countries of origin of germplasm as a per cent of the value of the seed price. Thus, income generated by the use of germplasm is the product of the quantity of seed sold that is based on the germplasm, the price of the seed and the proportion of the seed price that is paid as royalties.

Countries will not only "export" their land race germplasm for use elsewhere, but also countries will be "importing" land race germplasm for their own use. Even for countries with a wealth of genetic resources, self-sufficiency would be unattractive. It has been found, for example, that the anthracnose pathogen (one of the most important bean pathogens in Mexico) has co-evolved separately with its host in the two major centers of primary diversity. Mexican strains of anthracnose can attack Mexican bean germplasm, but Andean germplasm is highly resistant to Mexican anthracnose. Hence, Mexico's best strategy for dealing with several of its most important pathogens is to import novel resistance alleles from the Andean center of diversity (Pastor-Corrales et al 1994). Thus as a simplifying premise, it is here assumed that most countries will be "exporting" germplasm in proportion to the amount of genetic diversity they have while they will be "importing" germplasm proportional to the area they cultivate of a particular crop.

Consequently, the net income flows to a country of a royalty system in land race germplasm would be

(2) $B_i = Y_i - C_i$

where

(3) $C_i = A_i * S * P * R*(1-D_i)$

$B_i$ is the net benefits to country i from royalties in land race germplasm

$C_i$ is the payment made by country i for use of land race germplasm of other countries

$A_i$ is the area in country i planted with land race germplasm of other countries

This model will be first used to simulate a situation which provides a reasonable upper limit of the benefits that could accrue to countries for compensation for their role in developing and conserving land race germplasm, consistent with the concept of Farmers' Rights. This initial analysis tries to appraise in the best of circumstances, the maximum of benefits that could be generated by a system of royalty payments that would be roughly consistent with similar market phenomena

Thus, it is assumed that all the global area of beans, $A_g$, is planted with purchased seed that has been improved through the use of land race germplasm and consequently pays royalties for the use of this germplasm. This is necessarily an overestimate of what is likely to in fact occur because many farmers save their bean seed and do not purchase new seed each year, and thus would not pay royalties each year. Calculations are made on the basis of the average area planted to beans for each country in the period 1997-99. The seed rate, S, is taken conventionally at 50 kg./ha. and a standard seed price, P, of US $7.00/kg is assumed.

In actual practice, royalties, R, would accrue both to both owners of the germplasm that is used to generate the genotypes sold as seed, and also to those who performed the research that produced the new genotypes. It is likely that the relative shares of these two classes of royalties would be the subject of negotiation among the involved parties which would be the country owning the land race germplasm and the entity commercializing the final product of improved germplasm that has utilized the land race germplasm.

Typically in such circumstances the relative contributions and the relative risks of the two parties are taken into account. These are reported to vary between 1-5% for genetic resources that are essentially wild and have not been previously characterized. For genetic resources that have had some ethnobotanical characterization, royalties may reach 5%. When there is information on the specific commercial characteristics, for example, specific chemical compounds contained in the resource and their level of efficacy, royalty rates can reach as high as 15% of final product value. Royalties will range between 5% and 15% depending on the degree of specific information about the material (Laird 1993). The case of farmer land race crop genetic resources would appear to exceed that of ethnobotanically characterized wild plants because farmers have actively selected materials for demonstrated performance. Between 7.5% and 10% may be a reasonable range for farmer land race genetic resources, and here the figure of 10% will be used to represent the best of circumstances for payments for farmers' rights.

If there were asymmetry in the bargaining strength of the negotiating parties, for example, due to cost of enforcement or the superior market access of the seed companies, royalty shares could be biased in favor of the stronger party which might well be the seed company. This paper abstracts from any such bargaining process, and assumes that the countries of origin of germplasm receive royalties equal to ten per cent of the value of seed sold. This may be an overestimate of what might actually be earned by the countries in a market-based system.

Transactions costs, $E_{I,}$ for the enforcement of intellectual property rights can be substantial and in fact have been cited as a barrier that disfavors small scale enterprises, communities or individuals from being able to establish protect their intellectual property rights. In order to portray what the maximum potential flow of royalties from these rights in land race germplasm might be, it is initially assumed that these costs are zero. This again clearly leads to an overestimate of the real net returns that these rights might yield.

For simplicity it is assumed here that there are no transgenic applications made with bean germplasm, that it, that bean genetic resources are used only to improve bean production. Treating, $O_{I,}$ spillovers to other crops as zero is consistent with the call for a moratorium on the deployment of transgenic crops due to lack of certainty about their environmental or health risks (Oxfam Policy Department 1999). It is also an essential simplifying assumption because it is impossible to foresee the extent to which bean genetic resources might be used to improve other crops.

Here it assumed that royalty receipts are garnered by countries for their ownership rights in germplasm, proportional to the degree that their germplasm would be used in genotypes sown by farmers, D. Again in actual practice, negotiations on this point could be complicated because modern varieties have increasingly complex pedigrees, with ancestors typically coming from several countries. Although payments could be calculated relatively straightforwardly based on the per cent of ancestry coming from each country, this might not be fully acceptable. For example, germplasm from a given country might constitute only one of 16 ancestors, but contribute genes of particularly high value. In contrast, genes from another country might overcome only an occasional minor constraint, making it illogical that both countries receive the same royalty.

The procedure used here is to abstract from any negotiating problem and conduct a simulation as if countries received royalties proportional to the amount of genetic diversity they have. This in turn is based on the assumption that useful alleles are randomly distributed. In this conceptual model for common beans, then, a country's royalty receipts are equal to its share of useful diversity which is equal to its share in total diversity of land races.

Historically, most gains in crop improvement have come from land races. However, there are recent examples of introgression of useful traits from wild ancestors into cultivated materials. It is also known that genetic variability in wild materials is often greater than that present in domesticated germplasm (Gepts 1988). Consequently over time, particularly with improved techniques for gene transfer, the contribution of currently undomesticated germplasm to agricultural productivity, could be as great or greater in importance as further use of land races. However, this paper deals only with land race genetic resources that have been selected, cultivated and conserved by farmers.

It must also be noted, that while wild materials are only found in the centers of origin of crop species, land races have a much wider dispersion. In the case of common beans, it is known that they have two centers of origin, Mexico and the Andes (Singh 1989). However, since the encounter of 1492, beans have spread throughout Africa, Asia and Europe, giving rise to the emergence there of unique diversity in the land races in the secondary centers of origin. While previous papers have considered only land race genetic diversity in the center of origin (Kloppenburg and Kleinman 1987), this paper takes a more complete approach by including diversity from the land races of both the primary and secondary centers of diversity.

The share of diversity in different regions and countries is measured by relying on prior work that selected a core collection for common beans (Tohme et al 1994). The core collection was devised to represent the distribution of diversity in common bean germplasm based on knowledge of variability in morphological, agronomic, and molecular characters as well as geographical data on the origin of accession. For this paper, then, the amount of variability in a country or region, is taken to be equal to its per cent participation in the common bean core collections for cultivated land races.

**The Distribution of Benefits Simulated by a Royalty Model**

Based on the proceeding royalty based model for the value of Farmers' Rights, the estimated flow of annual benefits for common beans by major continental groupings was calculated. As noted above, the model is used in this paper to approximate the highest level of royalty flows as a basis for computing possible payments for Farmers Rights. It is assumed that all bean farmers annually purchase seed on which royalties are paid. It is assumed that there are no transaction costs and complete compliance with the system. A royalty rate is assumed that includes some valuation for the information contained in land race germplasm that is recognized as having been historically improved by farmers. Any actual market based system of royalty payments would certainly lead to lower benefit flows than calculated here. The model simulates a pattern of payments for these new genes that is proportional to the share of diversity in land races and wild ancestors by country or region of origin.

On this basis, Tropical America would owe the largest payments for Farmers Rights in bean germplasm since it has the largest area sown in beans, while sub-saharan Africa would owe the second largest amount (Table 1). More importantly, though, as the major source of variability in land races, Tropical America would earn the vast bulk of royalties, $48.2 million, so on balance would receive a positive net income of $11.7 million from common bean genetic resources.

Generally it is anticipated that the high income North would end up paying substantial royalties for agrobiodiversity to the gene rich South. This is indeed the case for the high-income countries of North America, which would have to make net payments under a royalty system for bean seed. Even taking into account receipts accruing from useful genes found in the diversity of their secondary center land race germplasm, the USA/Canada would pay $2.9 million annually. Somewhat surprisingly Europe would emerge as a net gainer from a royalty system in beans. Because beans are not an important crop in Europe, royalty payments would be quite low, only $1.5 million while due to its place as a secondary center of germplasm diversity, Europe would earn $3.0 million for a net income of $1.5 million. These results do not fully confirm the expected view that the wealthy industrialized countries would end up paying in a system of ownership rights for land race germplasm.

The biggest net payments under this system, through, would come from sub-saharan Africa. As the most important of the secondary centers of land race diversity, it would receive 21.9% of total royalties from land race genes, that being the region's estimated share of land race diversity. These royalty receipts of $5.5 million are, however, considerably overshadowed by projected payments $12.9 million, leaving Africa with a net bill of $7.4 million. The other two groupings of low income countries - East/South Asia and West Asia/North Africa, would also make net payments under a system of royalties for ownership rights in germplasm for common beans.

Thus, this analysis is consistent with the conventional view that in the aggregate, the high-income countries would pay out, while low income countries would earn net positive receipts. However, not all developing regions would gain. Only in the center of highest biodiversity will there be net gains. Further disaggregation by country illustrates that this pattern also repeats itself at the regional level. Table 2 shows estimated annual royalty flows for selected countries and sub-regions of Latin America and the Caribbean. These data portray remarkable disparities in net royalty income even within the region.

At the positive extreme, is Mexico which is the world's greatest source of bean genetic diversity. Although Mexico would earn $16.5 million annually, it would net only $7.4 million because as the world's second greatest bean producer, it would be paying royalties of $9.1 million for germplasm that is brought into Mexico. Peru, as the second most important home of common bean genetic diversity, reaps the second highest level of royalty earnings, $14.1 million. Since it would make very minor royalty payments due to the relatively small area sown to beans in Peru today, it emerges as gaining overall from royalties even more than Mexico. Ecuador, Colombia, Central America, and the Caribbean would also be net winners from royalty payments.

Brazil, and to a lesser extent Temperate South America, represent the opposite extreme. Brazil is the world's largest producer of beans, but it has quite a narrow genetic base in its land races. As a major grower of beans, and thereby a major user of bean seed and bean genetic resources, projected royalty payments from Brazil reach $20.6 million, with a net outflow of $19.2 million.

Clearly there are very substantial potential gains to access to genetic resources. Historically, there has been essentially open access to these resources and their potential benefits. In the context of increasing assertion of property rights over germplasm, the following analysis shows that, for the case of beans, payment of an access free would be worthwhile to producing countries if this was needed to secure continued access

## Productivity Benefits from Germplasm

At first glance, then, developing countries of Asia and Africa as well as Brazil and the Caribbean islands, would emerge as losers from a system of payments to compensate farmers for conserving bean genetic resources. Such a view overlooks the gains from increased productivity that would accrue to these countries due to improved germplasm. Several studies have shown that improved bean varieties can increase yields 30-40% (Janssen et al; Pachico and Borbon). Here, the conservative assumption is made that improved germplasm results in a 10% increase in production.

The benefits of increased productivity due to new germplasm are far greater than royalty payments. For example, although Brazil would pay $19.2 million in royalties, improved germplasm would lead to production gains conservatively worth $134.7 million, 7 times the amount of the royalty payments (Table 3). Total net benefits to Brazil would be $115.5 million annually. Similarly, Africa would gain over ten times as much from improved productivity as it would have to pay in royalties.

For countries that are net recipients of royalties as well as bean growers, the two classes of benefits are additive. Even for most of these countries, the benefits from improved productivity in beans considerably outweigh those from royalties. Only in Peru and Ecuador would royalty receipts exceed projected productivity gains. These countries have the unusual features of a wealth of bean genetic diversity combined with fairly small bean production. Since bean production is modest in these countries, productivity gains are slight. At the same time potential returns from germplasm are high due to substantial genetic diversity.

## Conclusions and Implications

Firm policy guidance can not be judiciously drawn solely from the case of beans which is a crop of secondary importance. Consequently, this conclusion will first summarize the implications of this study of beans as a model crop, then it will touch upon the wider context.

A system that recognized farmers' contributions in developing and conserving common bean land race germplasm would generate income flows for those countries that are major sources of bean agro-biodiversity. Among the high income, gene-poor regions of the north, North America would indeed have to make payments to low income, gene-rich countries in the south, but Europe would actually be a net recipient of royalty payments. This occurs largely because many countries in the south are poorly endowed in bean genetic diversity. In particular, Africa and Asia would be net payers for germplasm, as also would be Brazil and the Caribbean.

Notwithstanding payments for the use of germplasm, the north would very much emerge as gaining from access to germplasm. Even on conservative assumptions for productivity gains, and liberal assumptions for payments as estimated from a simulation of a royalty system, the projected gains in productivity in the north would far exceed payments. This implies that economically it would be worthwhile for the north to pay for germplasm to the degree that breeding gains are dependent on access to wide genetic variability. If agreements about enforcement of farmers rights' in germplasm could be made workable, perhaps through multi-national agreement for an International Fund for Plant Genetic Resources, the system would be viable economically. It must be noted that it appears that many private sector breeders today rely almost exclusively on privately held germplasm and rarely access new germplasm. Since these firms would not face clear market incentives to participate in a germplasm royalty system, they would need to be forced to do so. Lack of political will to run counter to these interests has not facilitated the implementation of an International Fund for Plant Genetic Resources.

While such a system would clearly address fairness concerns of compensation for the domestication, improvement and conservation of agro-biodiversity, it would not automatically provide improved incentives for continued conservation. Moreover, just as patents provide ownership rights for a specified time period, it would have to be clarified whether farmers' rights would similarly be time bound or would exist in perpetuity.

A system based on what the market flow of royalties would be in bean land race germplasm would impose costs on low income countries that are poor in bean diversity and are major bean growers. This might seem disadvantageous to Africa, Asia, Brazil and the Caribbean. Nonetheless these countries would gain substantially from improved productivity, and these gains would be 7 to 25 times greater than projected royalty payments. It would, in principle, be worthwide for gene poor low income countries to pay for access to genes.

Alternatively, rather than a uniform system of ownership rights, the system could be discriminatory and offer preferential access to germplasm among low income countries while charging full prices for germplasm to those who can afford it. In practice, germplasm exchange may be negotiated bilaterally and such a system could evolve. It might, though, raise complicated issues of enforcement of rights with respect to subsequent transfer of germplasm to third countries. Due to these considerations, probably the lowest cost system would be to assess payments to the International Fund for Plant Genetic Resources based on crop area while receipts from the Fund would be based on the share of genetic diversity.

Moreover, preferential germplasm access for low-income countries would do away with the bulk of the potential benefit flows in the case of beans. If bean germplasm were exchanged freely in the south without any charges, total payments from Europe and North America would amount to less than $6 million. This is such a small amount as to make the system hardly worthwhile.

In any case, most countries in the south have far more to gain from increasing the productivity of their bean crop than from a royalty system in bean germplasm. This suggests that they have most to gain from investing in agricultural research to develop improved germplasm. Not only is this generally true for almost all countries, but it is likely to be a good strategy even for the most gene rich countries. As noted above, royalties on property rights in improved germplasm include both compensation for genetic resources as raw materials, and compensation for the knowledge needed to identify and use these genetic resources.

Typically raw material prices are a fraction of final product prices, with most income going to value added in processing. Therefore, it would be highly advantageous for countries, which are origins of genes, to also develop them. This would not only contribute to their earning a larger share of royalties, but also could enable them to insure the development of their genes. Some valuable alleles may not be unique to a single country, and sometimes different alleles may produce a similar expression of a desired trait. In addition, this would also contribute to their production agriculture, and in many if not most cases, this may yield benefits much larger than those from ownership rights in germplasm.

Since this paper deals specifically with the case of beans, it is useful to assess the degree to which this case is likely to be representative of other major crops. Royalty incomes from beans are modest in comparison to potential increases in productivity in low-income countries due to improved bean germplasm. To a significant degree, this is due to the fact that 79.6% of beans are produced in low-income countries. Obviously, the higher the share of production of a crop that occurs in low-income countries the relatively less important royalty revenues become compared to productivity increases. Many other major crops, like beans, are grown principally in low-income countries. Such crops include rice, sugar cane, cassava, banana, sweet potatoes, yam, millet, coconut and sesame. Significant revenues from ownership rights to this germplasm could only come about through horizontal transfers among low income countries, but not to any important degree as revenues from the north to the south.

In contrast, some major crops are grown mainly in developed countries: wheat (64%), maize (64%), potato (78%), barley (86%) and soybean (66%). Revenues from germplasm rights to these commodities would be relatively more important, compared to productivity gains than in the case of beans. It is likely, though, that as in the case of beans, royalties would accrue principally to a few countries in the south that are particularly rich in genetic variability. Thus, ownership rights in germplasm may be a significant benefit to some selected countries, for example, Mexico and Peru in the Americas, and Ethiopia in Africa. The rest of Africa and Latin America could expect little income from ownership rights royalties in agricultural crops.

Nonetheless, a system of ownership rights in germplasm could be in the common interest if it serves to provide improved incentives for the conservation of genetic diversity. Moreover, ownership rights do reflect a concern for fairness in the distribution of benefits as property rights are increasingly asserted in germplasm. Such a system could produce important income flows for some poor countries. Finally, though, most low-income countries, even the few with a wealth of genes, have far more to gain from a research capacity that enables them to more effectively utilize genetic diversity.

**Table 1. Estimated Flows of Annual Royalties under a System of Ownership Rights in Land race and Wild Common Beans ($US million).**

| | Royalty Payments | Royalty Receipts from Land Races | Net Income from Royalties |
|---|---|---|---|
| Latin America | 36.5 | 48.2 | 11.7 |
| Sub-Saharan Africa | 12.9 | 5.5 | -7.4 |
| USA/Canada | 4.3 | 1.4 | -2.9 |
| East and S. Asia | 2.1 | 0.3 | -1.8 |
| W. Asia/N. Africa | 1.6 | 0.7 | -0.9 |
| Europe | 1.5 | 3.0 | 1.5 |

**Table 2. Estimated Flows of Annual Royalties under a System of Ownership Rights in Land race and Wild Common Beans in Selected Countries and Sub-regions of Tropical America ($US million).**

| | Royalty Payments | Royalty Receipts from Land Races | Net Income from Royalties |
|---|---|---|---|
| Brazil | 20.6 | 1.4 | -19.2 |
| Mexico | 9.1 | 16.5 | 7.4 |
| Central America | 2.5 | 6.1 | 3.6 |
| Chile/Argentina/Uruguay/Paraguay | 1.9 | 1.6 | -0.3 |
| Caribbean | 0.7 | 1.2 | 0.5 |
| Colombia | 0.7 | 3.7 | 3.0 |
| Peru | 0.5 | 14.1 | 13.6 |
| Ecuador | 0.3 | 2.7 | 2.4 |

**Table 3. Comparison of Net Gains from Royalty Flows with Gains From Increased Productivity Due to Improved Germplasm.**

| | Net Payments or Income from Royalties ($ US million) | Benefits from Improved Germplasm (US$ million) | Total Benefits (US$ million) | Ratio of Productivity Benefits to Royalties |
|---|---|---|---|---|
| **Countries or Regions with Net Royalty Payments** | | | | |
| Brazil | -19.2 | 134.7 | 115.5 | 7.0 |
| Sub-Saharan Africa | -7.4 | 80.8 | 73.4 | 10.9 |
| USA/Canada | -2.9 | 80.8 | 78.0 | 28.3 |
| East and S. Asia | -1.9 | 28.3 | 26.5 | 15.3 |
| W. Asia/N. Africa | -0.9 | 23.1 | 22.2 | 24.8 |
| Southern Cone | -0.3 | 19.9 | 19.7 | 69.6 |
| **Countries or Regions with Net Royalty Income** | | | | |
| Caribbean | 0.4 | 4.3 | 4.7 | 10.2 |
| Europe | 1.5 | 19.3 | 20.8 | 12.6 |
| Ecuador | 2.4 | 1.7 | 4.1 | 0.7 |
| Colombia | 3.0 | 6.5 | 9.6 | 2.1 |
| Central America | 3.7 | 15.7 | 19.4 | 4.3 |
| Peru | 13.7 | 1.7 | 4.1 | 0.7 |

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### 1.1.2 Environmental Risk Assessment of Transgenic Crops: An International Comparison - *by: D. Pachico*

Transgenic or genetically modified crops have aroused considerable interest for their potential to make a contribution to world food production and for the possible risks they might present to the environment or to human health (Evans 1998; Oxfam 1999). While some see prospect of great potential benefits from transgenic crops, others see looming environmental catastrophe.

Clarifying the risks of genetically modified crops is an important concern because these crops are already grown in significant areas. As shown in Table 1, by 2000 genetically modified crops covered over 40 million hectares, and accounted for 36% of the global soybean area, 16% of global cotton area, and 11% of global canola area. There is no doubt that transgenic crops are now commercially important and are in the environment in very substantial areas. These crops are concentrated in the United States with 30 million hectares, Argentina with 10 million hectares, and Canada with nearly 3 million hectares (James 2000). In addition, significant planting of transgenic crops are occurring in China, Australia, and South Africa. All continents except Europe now have significant sowings of genetically modified crops.

**Table 1. Transgenic (GMO) Crop Areas 2000 (million hectares)**

| | Transgenic Area | Transgenic as % of Global Area |
|---|---|---|
| Soybean | 25.8 | 36 |
| Cotton | 5.3 | 16 |
| Canola | 2.8 | 11 |
| Maize | 10.3 | 7 |

Source: James 2000

As transgenic crops are being utilized over ever-greater areas, concerns are intensifying to assess the risks and benefits of such crops. A recent appraisal by seven national and international academies of science noted significant potential benefits from genetically modified crops. "GM technology, coupled with important developments in other areas, should be used to increase the production of main food staples, improve the efficiency of production, reduce the environmental impact of agriculture, and provide access to food for small-scale farmers." (Royal Academy et al 2000).

Nevertheless, the scientific community is also keenly aware of the potential for environmental damage from genetically modified crops and considerable research is being conducted to assess these issues, though little is as yet clear (Wolfenbarger and Phifer 2000). Among the possible risks under consideration are that genetically modified crops might become new weeds that could significantly change the balance among plant species with consequent effects on other life forms. Likewise, genetically modified crops or animals might cross with wild relatives of cultivated species thereby affecting their survivability. Genetically modified organisms might directly affect the survival of other species, for example, as feared in the case of the effects on the monarch butterfly of transgenic corn in the USA.

Thus, the same scientific bodies that are aware of the potential benefits of transgenic crops, also make clear the need for thorough risk assessment of such crops, "There is no consensus as to the seriousness, or even the existence, of any potential environmental harm from GM technology. There is therefore, a need for thorough risk assessment of likely consequences at an early stage in the development of all transgenic plant varieties," (Royal Academy et al 2000).

Consistent with this scientific view on the need to assess the risks of transgenic crops, procedures for the assessment of risks from the use of these crops are emerging as part of a regulatory framework in national, supranational (e.g. EU), and international contexts. Many countries are now establishing a clear legal requirement for systematic assessment of potential environmental and human health risks of GMO crops.

This paper examines the current frameworks for risk assessment of genetically modified crops in the United States, the European Union, and under the international convention on biodiversity. This paper will focus on the principles guiding risk assessment, the risks to be assessed, and the criteria to make decisions. The paper will restrict its attention to risk assessment to support the decision to release GMOs into the environment for general use. Issues of regulating or managing risks of GMOs under containment during the process of their development are not considered, nor are other important issues such as intellectual property rights or the sharing of benefits.

**International Regulation: Biosafety Protocol**

Out of concern with potential threats to biodiversity from GMOs, in 1995 the members of the Convention on Biodiversity decided to develop an international protocol on biosafety. The purpose of this Biosafety Protocol is to ensure an adequate level of protection from adverse effects on biological diversity caused when genetically modified organisms that result from modern biotechnology are introduced into the environment (Convention on Biodiversity 2000).

The Protocol focuses on the international movement of genetically modified organisms, (more precisely termed "living modified organisms") that may have adverse effects on the environment. These are defined as any biological organism possessing a novel combination of genetic material obtained through the use of modern biotechnological methods which overcome natural physiological reproductive or recombination barriers. These methods include in vitro nucleic acid techniques, direct injection of DNA into cells, or fusion of cells beyond the taxonomic family, but do not include the techniques of traditional breeding. Thus, the biological organisms of concern to the Protocol depends on the methods used to create them, not on the specific traits or genes they may possess.

There are some instances in which genetically modified organisms are not covered by the full provisions of the protocol. First, the Protocol focuses on international movement of GMOs, but does not directly regulate the internal or national use of indigenously developed GMOs, though it does call for countries to have a domestic risk assessment procedure for locally developed GMOs. Second, the Protocol does not apply to GMOs used as pharmaceuticals for humans on the grounds that these are addressed by other international agreements. Third, since the Protocol focuses on GMOs that are intentionally introduced into the environment, its full provisions do not apply to GMOs destined for contained use, for example, that are used only in scientific laboratories or in controlled field conditions but are not intentionally released into the environment.

The regulatory framework of the Biosafety Protocol focuses on the international movement of GMOs covered by the Protocol. It regulates the mutual responsibilities and rights of importers and exporters. The Protocol's framework is largely centered on the principle of advanced informed consent which obliges the exporter to provide information to the importer, in particular, a science based risk assessment, about the GMO. In accordance with the Protocol, the importer has the right to consent or deny the request for the international movement of the GMO. This decision based on the information that is provided and is guided by the principle of the precautionary approach and advanced informed agreement.

The precautionary approach to decisions is contained in the Rio Declaration on Environment and Development. The Biosafety Protocol applies the precautionary approach so that when there is "lack of scientific certainty due to insufficient relevant scientific information and knowledge regarding the extent of the potential adverse effects" on the conservation and use of biodiversity in the importing country, a decision to deny import of a GMO is justified to avoid or minimize potential adverse effects. Proof of a significant adverse effect from a GMO is thus not required to ban its import.

When there is a lack of scientific knowledge whether there is an unacceptable or unmanageable adverse effect, the precautionary approach to decisions opts for not permitting the action. Rather than regulating when there is evidence of an adverse effect, the precautionary approach would regulate when there is no proof that there is no adverse effect. Lack of scientific knowledge or consensus should not, according to the Protocol, be interpreted as indicating an absence of risk or an acceptable risk but essentially can be viewed as if there were an unacceptable risk. Regulatory permission depends, therefore, on first proving that there is no unacceptable or unmanageable adverse effect.

While the Biosafety Protocol puts forward the precautionary principle as the preferred decision criteria to cover the international movement of GMOs, it also lays out a procedure of advanced informed consent as the process through which decisions will be reached. Prior to the first export of a GMO, the exporter must notify the competent national authority that regulates GMOs. The Protocol clearly envisions that each country will have a regulatory agency with a formal legal status and established procedures to grant or deny consent to import GMOs. It is explicitly recognized that because this issue is so new, many developing countries may not yet have the needed institutional and human capacity. The Protocol commits members to cooperation in capacity building to overcome this limitation.

The notification to the national authority by the exporter must include a minimum set of information about the GMO, its intended use, and its potential adverse effects. A science based risk assessment is central to the required information. The objective of the risk assessment is to identify and evaluate the potential adverse effects of GMOs to biological diversity, taking also into account human health risks.

Risk assessment needs to be scientifically sound and can be guided by expert advice of international organizations. The assessment should be carried out in a transparent manner. Risk assessment needs to be conducted on a case by case basis depending on the specific GMO, its intended use and the likely receiving environment.

A recommendation as to whether or not the risks of adverse effects are acceptable or manageable is critical to the risk assessment. This is derived from the identification of possible adverse effects on biodiversity or human health, the likelihood of these adverse effects occurring, and an appraisal of the potential consequences of the adverse effects. An evaluation of the overall risk based on the estimates of consequences and their likelihood provides the basis for the recommendation.

It is noteworthy that the recommendation of the risk assessment to authorize the international movement of a GMO is not expected to require the demonstration of no possible risks. Rather, authorization can follow if such risks as may be, are acceptable or manageable due to the nature of the anticipated adverse consequences, their level of likelihood, or the possibility of remedial action. The Protocol provides no standards or criteria for what might be an acceptable or unacceptable risk, or a manageable or unmanageable risk. Presumably, this is left to the judgement of the importing country. There could be scope for dispute, however, were the judgements on what is acceptable or manageable to differ substantially between an importer and an exporter.

The Protocol does not include a suggested list of specific types of risks to biodiversity that might have to be considered in the assessment though there is explicit mention of the issues of centers of origin. The Protocol does note the need for a complete description of the parent and donor organisms of the GMO, the characteristics of the introduced modification, detection methods for the GMO, and information about intended use the receiving environment, including location and ecological characteristics.

The great potential of biotechnology for human well being is recognized in the Protocol. Consequently, analysis of the socio-economic impacts of GMOs is encouraged, but not required as part of the recommendation or the risk assessment. Nevertheless, it is recognized that socio-economic benefits that may arise from the use of GMOs may be taken into consideration in the decision to import. While falling short of adopting a full cost benefits methodology, the combination of a risk assessment of the adverse effects and openness to an analysis of the socio-economic impacts of GMOs could essentially legitimize the use of a cost benefit analysis based on the risk assessment.

**European Union Regulation**

The regulatory framework of the European Union for placing a GMO on the market or deliberately releasing it into the environment is important in its own right because it sets the procedures for a large number of countries. Moreover, it also provides a benchmark that reflects the standards a community with a high level of concern about the risks of GMOs.

The precautionary approach is the underlying principle for decision making in the EU framework, and this is highly consistent with the Biosafety Protocol (European Parliament and Council 2001). EU regulations rely on the precautionary principle as a decision criterion and scientific risk assessment as the major element in the decision process. The EU Directive on the deliberate release into the environment of GMOs is also an important model in that, unlike the Biosafety Protocol, it sets out in detail the specific issues that need to be appraised in a risk assessment.

The EU regulatory framework also differs from the Protocol in that it covers issues such as labeling and packaging of GMOs, public consultation, and entails a plan for ongoing monitoring of GMOs once they are intentionally released into the environment. In addition, the EU regulations provide for a specific time period of validity (not to exceed 10 years) for the consent to any release.

In common with the Protocol, environmental risk assessment of GMOs is conducted on a case by case basis to identify and evaluate potential adverse effects of a GMO, not only on the environment, but also on human health. The EU principles for risk assessment of GMOs cover direct effects of the GMO; indirect effects that occur through a causal chain of events through mechanisms such as interactions with other organisms, transfer of genetic material, or changes in use or management; immediate effects; and delayed effects that become apparent as a direct or indirect effect some time after the initial use.

An important principle of the EU approach to risk assessment is that identified characteristics of the GMO and its use that have the potential to cause adverse effects should be compared to those presented by non-modified organism and its use in the same environment. Thus, comparison with the risks of a non-GMO alternative is a key part of the EU methodology. This comparison is not restricted to the intrinsic characteristics of the GMO and the non-GMO alternative, but also must include explicit consideration of effects that can be induced by differences in use. For example, the risk assessment of a herbicide resistant GMO would have to include consideration of the possible adverse effects caused by the increased herbicide application associated with the use of the GMO.

The EU directive specifies a number of potential adverse effects which should be addressed, though it is recognized that they will vary from case to case.

1. Human health through disease, alleregens, or toxins.
2. Effects on the dynamics and genetic diversity of species in the receiving environment
3. Altered susceptibility to pathogens that facilitate their dissemination or create new reservoirs or vectors.
4. Compromise of medical treatments through the presence of antibiotic resistant genes.
5. Effects on biogeochemistry, particularly carbon and nitrogen recycling through changes in soil decomposition of organic material
6. Increased persistence in agricultural habitats or increased invasiveness in natural habitats.
7. Any selective advantage or disadvantage conferred on the GMO.
8. Potential for transfer of the inserted genetic material to other organisms and any selective advantage or disadvantage thereby conferred.
9. Phenotypic or genetic instability
10. Interactions with target organisms including predators, parasitoids, and pathogens.
11. Interactions with non-target organisms, including interactions with affected target organisms.
12. Health effects on workers coming into contact with the GMO.
13. Effects on animal health and on the food chain of GMOs used as animal feed.
14. Changes in management, including agricultural practices

To support this analysis of the potential adverse effects, there is a set of required information about the GMO itself.

1. Description of methods used for the genetic modification.
2. Information on the sequences actually inserted or deleted.
3. Information on the expression of the insert during the lifecycle and the parts of the plant where expressed.
4. Detection and identification techniques for the GMO.

Information on where and how the GMO will be utilized is also required.

1. Description of where the GMO will be used and estimate of scale of use.
2. Description of climate, flora and fauna in release environment.

3. Distances to be maintained from any sexually compatible wild relatives or cultivated species that may be present.
4. Proximity to protected areas.
5. Precautions to prevent dispersal of reproductive organs.
6. Differences in use or management of GMO compared to similar non-GMO crops.
7. Monitoring plan for surveillance for unanticipated adverse effects.
8. Any proposed restrictions on use.
9. Measures for packaging, labeling, storage, and handling.

This thorough environmental risk assessment needs to include a clear conclusion on whether the GMO in question should be put on the market for release into the environment. This will be based not just on an enumeration of the potential adverse effects as noted above, but also on an evaluation of the magnitude and nature of the adverse consequences of each potential adverse effect. In addition, the likelihood of occurrence of each potential adverse effect needs to be evaluated. Major factors in these evaluations are the characteristics of the environment in which the GMO is intended to be released and the manner of the release.

Besides combining the estimated potential consequences of an adverse affect and the likelihood of its occurrence, the scientific risk assessment should also include a consideration of risk management strategies. Based on how to best manage the identified risks, a risk management strategy should be defined.

Thus, the evaluation of overall risk will contain a complete description of the GMO itself; information on the environment in which the GMO would be released and the practices with which it would be managed; an appraisal of the consequences of potential adverse effects and their likelihood of occurring; and the identification of any possible risk management strategies. It will also include a plan to monitor risks, including unanticipated risks.

Consistent with the precautionary approach, the decision criteria for release emphasize the availability of sufficient knowledge to ensure that "the GMO shall not present additional or increased risks to human health or the environment" that are not presented by the release of corresponding non-GMO organisms. The EU directive is clear that sufficient knowledge must be available about the GMO and its risks in order to justify release. Again, lack of knowledge that there would be adverse effects is not a sufficient basis for release. There must be sufficient knowledge that there are no adverse effects.

It is noteworthy, that while the Biosafety Protocol introduces the concept of an acceptable risk, EU policy appears to be categorical in non-acceptance of additional or increased risk to human health or the environment. Moreover, the Biosafety Protocol contains a provision for an analysis of the socio-economic benefits, but the EU policy does not appear to be open to taking possible benefits into account as part of the decision.

**USA Regulatory System**

Like the EU, the regulatory system of the United States is a useful model, both because of its role as a major global agricultural producer and exporter and also because of its widespread experience in regulating the use of GMOs. The US has more than a decade of experience in regulating bioengineered crops and food, and some 50 varieties of GMOs have passed through regulatory processes and thousands of foods containing GMOs are currently on the US market (U.S. Department of State 2000).

Consistent with this experience, the US regulatory system is more fully embodied in a specific institutional context then the Biosafety Protocol or the EU directive, both of which lay out a set of principles rather than an institutional blueprint for carrying them out. Institutionally, there are three actors in the US to regulate plant agricultural biotechnology: the Department of Agriculture Animal and Plant Health Inspection Service (USDA-APHIS); the Department of Health and Human Services' Food and Drug Administration (FDA); and the Environmental Protection Agency (EPA). Each agency, reporting to a different Cabinet Secretary in the government, is responsible for a particular aspect of GMOs. Separate approval from each of these independent agencies is needed in order to commercialize a GMO product.

A permit from USDA-APHIS is required to field test or to ship interstate any living organism produced through genetic engineering that could pose some risk. Similar to provisions in the Biosafety Protocol and the EU directive, field tests must be conducted in such a way as to prevent the escape of pollen or plants or plant parts that might reproduce. Likewise, the test fields must be monitored to insure that no volunteer plants have survived on the test plots.

Once a developer of a GMO decides to commercialize it based on the results of the controlled field tests, the developer petitions the USDA-APHIS to grant "non-regulated status" for the GMO. If the USDA-APHIS determines that the GMO poses no significant risk to other plants and that it is as safe to use as traditional varieties, then it grants non-regulated status. This allows the developer to release and commercialize the GMO, subject, of course, to approval by the FDA and the EPA. To make its determination the USDA-APHIS examines the potential environmental consequences including plant pest effects; effects on other organisms; and possible weed consequences.

Possible plant pest consequences can include a number of aspects.

1. An examination of the biology and genetics of the GMO.
2. Potential effects on other organisms and agricultural products
3. Possible plant risks such as creation of new viruses, or altered disease and pest susceptibilities
4. Potential for gene transfer to wild relatives

Possible consequences on other organisms must be considered.

1. Effects on wildlife, including birds and mammals that could feed on the GMO crop.
2. Effects on beneficial organisms such as bees, endangered species, and non-target organisms.
3. Consequences of new enzymes or changes to plant metabolism caused by adding a new gene.

Finally, possible weed consequences are examined through review of seed dispersal, survivability, and viability as well as an appraisal of whether new traits that have been introduced enhance the weediness of the GMO.

Whenever a GMO expresses a protein with pest control properties, then it is overseen by the EPA as a pesticide, similar to the procedures for inorganic pesticides. For pesticide registration, the EPA must consider evidence on all potential human and environmental risks. Available data must be sufficient to allow for a determination that there will not be "unreasonable adverse effects".

The EPA requires information on product characterization, health effects, non-target organism effects, the fate of the pesticide in the environment, and the likelihood of pests developing a resistance to the pesticide. Product characterization includes the source of the bioengineered gene, its expression, the biology of the recipient plant, and the nature of the pesticide.

Examination of health effects requires information from acute oral feeding studies from laboratory experiments with mice. Allergenicity and digestibility of the pesticidal protein is also studied. The EPA must determine whether a tolerance limit should be set on the amount of the novel protein in food obtained from the GMO and whether there is a need for associated product labeling.

Non-target species can be exposed to the pesticidal substances by feeding on the GMO. The EPA must appraise whether the GMO is toxic to wildlife, beneficial insects, fish or other organisms, and it must review the degree to which these organisms will be exposed to the GMO pesticide. Tests at doses with 10 to 100 times expected exposure levels are conducted with a range of insect, mammal, bird, and invertebrate species need to be conducted.

The review of the fate in the environment includes generation of data on the degradation of the pesticidal protein in plant tissue in the soil as well as the potential for gene transfer to weedy or wild relatives.

The likelihood of insects developing resistance to the bioengineered plant is also evaluated. Where needed, insect resistance management practices can be imposed. For example, for the purposes of insect resistance management, growers of Bt corn must plant proportional areas of non-Bt corn to provide a refuge which manages the genetics of pest insect populations to prevent the emergence of resistance.

The FDA oversees the safety of foods and feeds, though its role in the review of GMO based foods is one of voluntary consultation rather than statutory regulatory authority. Nonetheless, all GMOs released for food use in the US so far have in fact passed through FDA review. The FDA is planning to make the review of GMOs for food safety mandatory in the near future.

The type of information provided by developers to the FDA depends on the food product and the type of modification introduced by the GMO. The FDA consults with the developer to provide guidance about what types of information may be required. In general, the FDA seeks assurance that the new food contains the expected levels of nutrients as well as seeks information about possible toxins or allergens.

In the case of novel proteins introduced into a GMO, the FDA assesses whether it is substantially the same as other proteins commonly present in food and whether it is present in comparable amounts. If the new gene comes from a commonly allergenic food, such as milk, eggs, wheat, fish, tree nuts, or legumes, it is presumed to be an allergen unless demonstrated otherwise. In the absence of evidence that it is not an allergen, the FDA would either require labeling or not allow the marketing of the GMO as food. In addition, tests for rapid digestibility are conducted to minimize the likelihood that it is allergenic.

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### 1.1.3 User Participation in Watershed Management and Research - *by: N. Johnson*[1]*, H. M. Ravnborg*[2]*, O. Westermann*[3]*, and K. Probst*[4]

## Abstract

Many watershed development projects around the world have performed poorly because they failed to take into account the needs, constraints, and practices of local people. Participatory watershed management—in which users help to define problems, set priorities, select technologies and policies, and monitor and evaluate impacts—is expected to improve performance. User participation in watershed management raises new questions for watershed research, including how to design appropriate mechanisms for organizing stakeholders and facilitating collective action. Management of a complex system such as a watershed may also require user participation in the research process itself. An increasing number of watershed research projects are already participatory, however challenges remain to institutionalizing user participation in both watershed management and research.

## Introduction

To succeed, watershed management has to be participatory. This is one of the lessons coming out of decades of failures of centrally-planned watershed development projects through which local people have been either coerced or paid to undertake terracing, bunding, destocking and other technical measures that external experts believed would cure watershed degradation (IDB 1995; Kerr et al. 1996; Pretty and Shah 1999; Rhoades 1998). Thus, participation is expected to achieve what coercion and subsidies could not, namely to make watershed development more successful and sustainable.

Success will likely require that all stakeholders in watershed management—including users[5], policymakers, researchers, and others—recognize that participation is not simply

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another way to deliver the same technological solutions. Commitment to participatory approaches may demand significant changes in the way we think about both the theory and practice of sustainable watershed management. Participation implies that stakeholders will work together to set criteria for sustainable management, identify priority constraints, evaluate possible solutions, recommend technologies and policies, and monitor and evaluate impacts.

User participation clearly has implications for watershed management research, broadening the agenda in terms of technologies, institutional innovations, and methods of doing research. User involvement in setting priorities, evaluating technologies, and monitoring outcomes clearly implies their active participation in the research process as well.

This paper examines the role of resource users in watershed management and research. Section 2 summarizes the arguments for participatory watershed management, and identifies important research issues that arise from user participation. Section 3 introduces some concepts in participatory research and discusses their usefulness in different aspects of watershed research. Section 4 provides some empirical evidence on the current use of participatory methods in watershed management research projects, and identifies some challenges to increasing and institutionalizing the use of participatory methods. Section 5 summarizes and concludes.

## What does participatory watershed management imply for watershed management research?

### Why participatory watershed management?

Early soil and water conservation programs in the United States, Eastern Africa and South Asia promoted a very narrow range of technical solutions such as terracing and contour bunding to control soil erosion. Two key assumptions appear to underlie the design of such programs. The first is that soil conservation practices were universally-applicable, that what works in one place will work in another. The second assumption is that local farmers are unaware of erosion and ignorant of its causes and consequences (Pretty and Shah, 1999).

More often than not, both assumptions turned out to be false. Program technologies were frequently both ecologically and economically incompatible with local farming systems, especially with regard to labor availability. Moreover, by being imposed on people as *the* way to prevent erosion, they came to replace rather than supplement local methods of soil and water management in places where these had been practiced. Often, the result of these centrally-controlled soil and water conservation programs has been more erosion rather than less either because the new structures were not maintained or because they were simply technically inferior to existing practices (Pretty and Shah 1999; Kerr et al. 1996).

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[5] Users are defined as those who use watershed resources such as land, water, or trees. Farmers are a subset of users. Users can be located both inside and outside the watershed.

Disappointingly, these same assumptions are still evident in the design of many current watershed development projects, successors of the earlier large scale soil and water conservation programs. Farrington and Lobo (1997) report that in Indian context, where a great deal of emphasis has been placed on watershed development, 99 percent of watershed development projects are still based on conventional approaches emphasizing physical planning without attention to local economic, social, or ecological conditions.

However, a small but growing number of watershed development interventions are involving farmers and other users in the design of projects (Hinchcliffe, Thompson, Pretty, Guijt, Shah 1999; Farrington et al. 1999). By soliciting information from users about their understanding of resource degradation, the adequacy of current resource management practices, and their criteria for potential new technologies, these projects seek to improve appropriateness of resource management technologies and policies promoted by the projects.

As much as watersheds are more than the sum of their different patches of land and streams of water due to the biophysical processes through which they interact, watershed development is not just about individual farmers taking measures to improve productivity on their own plots. Managing a watershed involves taking into consideration the interaction in time and space not only of individual plots but also of the common pool resources such as forests, springs, gullies, roads and footpaths, and vegetative strips along rivers and streams (Swallow et al., this volume). Watershed resources provide different services to different users, and these users are differentially affected by resource use decisions. This implies that participatory watershed management will often involve a process in which stakeholders jointly negotiate how they will define their interests, set priorities, evaluate alternatives, and implement and monitor outcomes.

**Implications of participatory watershed management for research**

Involvement of users in watershed management has significant implications for watershed research, principally that improving the sustainability of watershed management will require not only better technologies and policies for resource use, but also better organizational mechanisms and processes through which stakeholders can come together to make decisions. There is a large literature on collective action in natural resource management. However, the size of the geographic area, the diversity of resources and users involved, and the combination of both common and private property make watersheds somewhat unique.

As noted in many of the cases of participatory watershed management from Asia, Africa, Latin America and Australia reported in Hinchcliffe et al. (1999), even in cases when watershed users stand to gain from coordinated management, collective or coordinated watershed management rarely emerges on its own. Campbell et al. (1999) describe a Landcare group that had successfully revegetated its watershed, yet acknowledged that it would probably not have done so if the group had not existed. “They knew something would need to be done eventually, but there were other priorities on individual farms. The opportunity to work together [created by the National Landcare Programme] has made them reconsider the importance of conserving the productive potential of their farms" (p. 346).

Three issues of particular relevance to organization for watershed management are 1) scales and boundaries, 2) the roles and costs of facilitation, and 3) development of indicators and monitoring systems so that the impacts of changes in land use can be assessed by the group. These areas could benefit from conceptual and empirical research, beginning with a systematization of past experience.

As noted by Rhoades (1998) and Guijt et al. (1999), watersheds[6] rarely coincide with any units of the 'social landscape'. As an example, in the Colombian Andes, there is a notorious mismatch between watersheds and socio-political units. People tend to settle along the mountain ridges, making rivers and depressions the borders between communities. In contrast, watersheds include both sides of rivers but are divided by mountain ridges. Moreover, communities may often be too big to constitute an effective forum for collective action in managing a resource, which to a large extent relies on face-to-face contact to build and maintain mutual trust and understanding (Cernea 1988; Uphoff 1996; Ravnborg, Guerrero & Westermann, 1999). Sustaining effective participation in watershed resource management may require flexibility in allowing watershed users to identify the boundaries and scales at which they prefer to organize themselves without insisting on geo-hydrological or existing social and political boundaries and scales. Second-level organizations may be required to reach watershed coverage.

The second issue where further research is needed relates to the roles and costs of facilitation – the transaction costs of participatory watershed management. In the presence of conflicting perspectives and interests within a group, third party facilitation can be instrumental to help foster and sustain public negotiation (Ravnborg , Guerrero & del Pilar 1999; Steins and Edwards 1999). Many of Australia's Landcare groups have opted to employ a group coordinator to network within the group, between the group and other organizations, and to sustain momentum of the group (Woodhill et al. 1999:358). Similarly, the Indo-German Watershed Development Programme described by Farrington and Lobo (1997) has apparently assumed a large part of the transaction costs involved in the establishment and operation of the Village Watershed Committees. Careful documentation and comparative analysis of the effectiveness, efficiency, and sustainability of external facilitation under different circumstances is necessary in order to establish its role in participatory watershed management.

In many ways, watershed management is about 'managing the invisible' in the sense that, up to a certain point at least, the outcomes of changes in natural resource management practices are incremental and often not immediately observable. Sustaining participatory watershed management when the outcomes of people's efforts are not visible is hard. Thus, an important contribution of research to participatory watershed management is, as

[6] While we use the term "watershed" to be consistent with the literature on participatory watershed management and research, we are technically speaking of catchments, as defined in Swallow et al. (this volume).

expressed by Woodhill et al. (1999) ‘to make the invisible visible’. This has been the aim of the Australian land literacy campaigns that have encouraged community groups and schools to learn more about their landscape in systematic and replicable ways (Woodhill et al. 1999:362).

Obviously, there are great differences between Australia and, for instance, sub-Saharan Africa when it comes to the infrastructure for launching such land literacy campaigns. Yet, the need for people to sense that their efforts actually produce an outcome in terms of e.g. more and cleaner water, less erosion and more water retained in the fields, less risk of flooding and landslides, is equally great. Thus research is needed on how to develop locally-relevant ways of teaching basic principles of agro-ecosystem behavior, as well as simple indicators and measurement methods that can be used to help users monitor the outcome of their management efforts. Farmer Field Schools are one methodology that has been shown to be effective in increasing farmer understanding of complex issues like pest ecology or integrated crop management (Rola et al. 2001; van de Fliert et al. 2001). Methodologies are also available for the development of local indicators of the quality of watershed resources such as soils (Turcios et al. 1999).

**Participatory research and its potential contribution to watershed management and research**

To address the technical and institutional challenges in participatory watershed management, new research approaches may be needed. Research outputs clearly need to be consistent not only with users’ economic demands and constraints, but also with their goals and social realities. This suggests that user input will be necessary in the research process as well.

**Some concepts from participatory research**

The field of participatory research looks at the involvement of the intended beneficiaries of research in the research process. While researchers rarely operate in total isolation from the potential users of their discoveries, the extent to which researchers have accurate information about the needs and priorities of users varies. Lack of information is most likely to be a problem when there is not direct accountability between researchers and beneficiaries, as is the case with most publicly-funded agricultural and natural resource management research. In such cases, incorporating beneficiary perspectives as part of the research process can improve the efficiency of research. Soliciting user knowledge and feedback regarding specific aspects of a research process is referred to as functional participation since its purpose is to improve the functioning of conventional research processes. Functional participation would be expected to have its largest impacts where research beneficiaries have unique knowledge or insights otherwise unknown to researchers (Ashby, 1996).

Others see the objective of incorporating users into the research process as a way to encourage changes among beneficiaries themselves. As a result of participation in the research process, users may improve their technical and analytical skills. Depending on how research is carried out, benefits can also go beyond strengthening human capital to the strengthening of social capital and community cohesiveness. Empowered users may not only adapt and adopt technologies and engage in spontaneous experimentation, they may also recognize the importance of research and begin to exert more effective demands on the public research and extension systems that exist to serve them. Empowering participation, as this type of participation is generally called, is concerned not only with generating appropriate technologies but also with developing capacity for innovation in individuals and communities over the longer term. Empowering participation would be expected to have the greatest impacts where there is high diversity and complexity among beneficiaries, and where substantial and continuous local adaptation of innovations would be expected. While functional and empowering participation are not necessarily mutually exclusive in their impacts, they do generally imply very different methods for organizing and implementing research.

**User participation in watershed management research**

As suggested above, the appropriate level of user participation in research depends on the specific goals and circumstances of the project and its expected beneficiaries. In the case of participatory watershed management, the research needs are diverse, and different levels of participation appropriate. For example, the systematization and comparative analysis of experiences with external facilitation in participatory watershed management called for in Section 2 is likely to be carried out primarily by researchers. To the extent that researchers are not able to identify all the types of costs, input from users, perhaps generated through cross-site visits, could be useful. Similarly, the development of new technologies and tools such as computer simulation models of the impacts of alternative land uses may involve some user input and feedback but are likely to be mainly driven by formal researchers due to their technical nature. At the other end of the research process, the adoption of soil conservation practices by farmers usually involves some adaptive research in which the technologies are tried out and adjusted to fit into specific economic, social, and ecological circumstances of individual farms (Bunch and Lopez, 1999). This process is usually carried out by users alone, though some scientist participation may improve the efficiency of the farmer adaptation and provide researchers with a better understanding of farmers needs and constraints.

While these researcher- and user-led innovations can make important contributions to the development of tools and technologies for sustainable management of watershed resources, a growing number of scientists argue that sustainable management of watersheds will require a fundamentally different and more empowering approach to participatory research. The reason is that watersheds are dynamic, complex systems, and our “ability to make precise and yet significant statements about their behavior” is limited (Zadeh, 1973 as cited in Campbell et al., 2000: p. 4). Conventional research methods may improve our understanding of certain aspects of these systems, but may not be sufficient to characterize watershed systems with enough precision to permit meaningful yet broadly applicable conclusions about how watershed resources should be managed.

Management of a complex system like a watershed must be associated with a process of individual and social learning (Campbell et al., 2000), which Pretty (2000, p. 2 ) defines as "a process that fosters innovation and adaptation … embedded in individual and social transformation." As users learn more about their ecological and social systems, they may change their ideas about desirable and feasible resource management alternatives. However, the actions and interactions of different stakeholders during the learning process have impacts—intended and unintended—on the systems, changing the set of desirable and feasible management alternatives. Such a system calls for adaptive management—defined as a continuous process of design, action, monitoring and evaluation, and reflection and revision. In addition to this process of action and reflection, social learning also incorporates political processes related to conflict management among a number of stakeholders (Maarleveld and Dangbégnon, 1999).

Research thus forms one part of a continuous cycle of problem identification, solution, action, and evaluation. "Ultimately, in the ideal scenario, there is no distinction between management and research" (Campbell et al., 2000, p. 4). If researchers want to play a direct role in supporting sustainable participatory management of watersheds—as opposed to producing innovations that may contribute to the improved management of specific watershed resources—they must become part of the social learning process, willing to learn along with other stakeholders and to recognize that their own presence will affect the system's evolution (Vernooy, 1996). Important research questions related to the goals of watershed management and the form and distribution of impacts may need to be addressed from within this social learning process.

**Using participatory research in a watershed management research program: an example from CIAT**

The International Center for Tropical Agriculture (CIAT) uses a combination of research methods to develop technological and institutional innovations for sustainable watershed management in the hillsides of tropical America. Integration of different research activities is obtained through stakeholder planning workshops, held annually at each of CIAT's reference micro-watersheds. These workshops convene stakeholders from inside and outside the watershed to come together to set goals, identify problems, define activities, and evaluate outcomes.

One critical aspect of making this approach successful is to assure local interest and capacity to participate actively. In the early 1990s, CIAT facilitated the formation of a consortium of stakeholders around a watershed in southwestern Colombia. The organization, known by it Spanish acronym CIPALSA, contained representatives of major stakeholders in the watershed, including research and development organizations, national and local government agencies, NGOs, and local groups. The idea was to improve the coordination among organizations in terms of priority setting and implementation of activities.

While CIPASLA as an organization functioned well, it became apparent that the quality of representation of all stakeholders within the group was not equal. Specifically, local resource users needed a stronger and more coherent voice in their negotiations with better organized internal and external organizations. This led to the formation of a watershed users group, FEBESURCA, which focused on concerns of local individuals and groups such as farmer groups, women's groups, schools, and village officials. The lesson from this experience was that an effective local organization was an important prerequisite to effective interactions with external organizations. When CIAT established a reference site in Nicaragua in 1996, it began working with the local people and organizations, with plans to move towards second-level organizations once local capacity is sufficient. The lessons learned from experience with local level organization is included in a methodological guide for facilitating local organizational processes (Beltrán et al., 1999)

One of the main natural resource management conflicts in the Rio Cabuyal watershed concerned conservation zones along principal watercourses (Ravnborg and Ashby, 1996). It was believed that deforestation along waterways in the upper watershed led to problems with water supply below. National policy required that forest cover along rivers be maintained, but these requirements were not enforced. Upper watershed residents were poorer than lower watershed residents, and did not see why they should forego income and production for the benefit of the better-off communities below. After CIPALSA took up the problem, CIAT scientists carried out a GIS analysis which found that small tributaries located throughout the watershed contributed as much to ground and surface water availability as the streams and rivers of the upper watershed (Knapp et al., 1994 and 2000 Ashby, Sanz, Knapp & Imbach, 1999). On the basis of this information, CIPASLA began to re-evaluate conservation policy. An agreement was reached with regional policy makers to permit narrower barriers along principal waterways, while additional conservation measures were taken up on small streams and springs.

While the new regulations did lead to forest conservation along rivers, at one point a mysterious fire burned down a large part of the protected area. It was later discovered that the fire was set by landless residents who depended on the riverine areas for forage and firewood (Ravnborg and Ashby, 1996). This incident showed that even the establishment of the watershed users association had not been sufficient to capture all local interests, and demonstrated the importance of being able to systematically identify all stakeholders in a particular problem before any action is taken. A method for stakeholder identification and analysis for collective action in natural resource management was subsequently developed (Ravnborg et al., 1999).

A traditional method for conduct on-farm technology testing was also adapted to suit a watershed focus. Initially, genetic resource and natural resource management scientists conducted their field trials independently within the reference watershed. In an attempt to better integrate that work over time and space, joint research plots were established, with a commitment to working over the long term and to analyzing interactions within and between plots. This idea has grown into what is now known as the Supermarket for Options for the Hillsides, or SOL. Today the SOL includes not only technologies from CIAT scientists, but also from other research and extension organizations such as national programs or NGOs, as well as locally-generated ideas.

Technologies tested in the SOL are available to local farmers to test on their own. To increase the utility of these farmer trials for both farmers and researchers, the SOL collaborates with local farmer research committees called CIALs (Ashby et al. 1999). These community-based committees carry out experiments with the support of a simple methodology for experimentation and an extension agent from national program or an NGO. The SOL and CIALs facilitate the process of developing and testing new technologies, ensuring that they are linked to local needs and that local communities play a role in selection and adaptation. The SOL and CIAL methodologies also help enhance the development of local knowledge and capacity. As local institutions, CIALs are represented in the local watershed users group, helping to maintain a connection between technology testing and broader watershed issues.

The sustainability of these efforts depends critically on their perceived success. Some obvious indicators include measurable increases in forest cover, adoption of CIAL- and SOL-recommended technologies, or the ability of organizations like CIPALSA to obtain internal and external funding for their activities. However impact should go further, improving living conditions and strengthening human and social capital at the community level. In 1999, CIAT began to work on a conceptual and empirical framework for documenting and understanding a broad range of impacts in the reference sites (Gottret and White, 2000; Gottret and Westermann, 2000). Using both conventional and participatory methods, the goal is to help both researchers and other stakeholders better understand the changes that are taking place and learn from the experience.

**Institutionalizing the use of participatory research in watershed research: Current practices and challenges**

**Current use**

A recent survey of international agricultural centers found that 8 of the 17 watershed research projects reported some user participation (www.cgiar.org/capri). This relatively high number suggests that researchers recognize the importance of user input in developing technologies and practices for watershed resource management. However few current watershed management research projects can be described as fully empowering, meaning that they do not share authority and responsibility with users at all or even most of the stages of the research process.

As part of the CAPRi-sponsored workshop on watershed research, a working group of scientists from international agricultural research centers discussed the type of participation used in watershed projects at their institutes (Table 1, Knox and Gupta, 2000). To facilitate the discussion, centers analyzed their projects using a typology of participation based on authority for decision making: consultative, collaborative and collegial (Lilja and Ashby 1999). In consultative research, users seek input from users but retain ultimate authority for decisions and for assessing outcomes. In collaborative participation, researchers and resource users share control over decisions and accountability for outcomes. In collegial participation, both responsibility and authority for project activities and outcomes rests with users, who seek input from researchers as needed. In this typology, consultative participation would be considered functional, while collaborative and collegial would be considered to be empowering.

Scientists at the workshop evaluated their participation at five stages of the research process—diagnosis, priority setting, planning, implementation, and monitoring and evaluation. Programs generally used more than one type of participation, but the tendency was for researchers to dominate the research process at most stages. Users were active in priority setting and project implementation, while diagnosis, planning, and monitoring and evaluation were dominated by researchers. This type of user participation is likely to improve the relevancy of project activities and in doing so increase the chance that they may be adopted to address specific problems. Such a process is not, however, likely to get significant user buy-in, nor generate a self-sustaining process of continuous innovation on the part of users.

**Challenges to increased use of participatory research**

If participatory research is going to realize its potential as a way to help organize and empower communities around sustainable management of watershed resources, users may need to be more actively involved in these activities. Yet, even among those committed to the principles of PR, there are many challenges to increasing participation in agricultural and NRM research, not the least of which is empirical demonstration that the promise can in fact be achieved (Rhoades 1998). In the remainder of this paper we complement that work by discussing several challenges that are particularly relevant to researchers and research organizations working on participatory watershed management. They include research methodologies, researcher skills and capacities, and role of different types of research organizations.

Participatory research is not new, and a wide variety of tools are available for doing it (Harrington, 1996; PRGA website: www.prgaprogram.org). This does not mean that new methodologies—especially for addressing issues above the plot level (Ashby et al. 1999)—are not needed. However there is also a need to systematize and assess experiences with existing tools and methods in order to document benefits and identifying best practices. Work is underway in this area, and within the next few years there may be much more information available with which to assess the appropriateness of different participatory (and conventional) methods. The CGIAR's Systemwide Program for Participatory Research and Gender Analysis (PRGA) is currently involved in inventorying and analyzing the use and impact of participatory methods in natural resource management research projects by national and international research centers, universities, NGOs and other organizations around the world, including watershed projects (www.prgaprogram.org).

Using participatory research methods, especially for empowering participation, is not always just a question on applying tools. Scientists may have to acquire new skills, either themselves or within their research teams, in order to work effectively in a participatory environment. We often use the term "facilitation" to describe scientists' contribution to what is needed to make multi-stakeholder partnerships work effectively, but as Hagmann

(2000) points out, more work is necessary to define and operationalize what we mean by it.

Finally, the need for greater participation does not imply that no division of labor exists among researchers. Different actors in the research process—international and national research centers, extension, NGOs, policy makers, local producer and user groups, farmers, etc.—have different skills and interests and would be expected to make different contributions. For participatory research to be broadly institutionalized, care must be given to defining these roles, both conceptually and in practice. Many researchers on natural resource management at international research centers are already reporting a shift in their roles and activities, especially an increase in their role as facilitators and providers of information (Probst et al. 2001). Such activities can be consistent with the strategic research mandate of the international centers, if they are coupled with rigorous comparative analysis of outcomes in order to draw lessons for policy and research.

One class of actors that appears to be under-represented in what scanty literature exists on participatory watershed research are the national agricultural research systems (NARS). The important role of NARS in applied and adaptive research and their connection, via the extension service, to local communities and farmers makes them a potentially very important actor in a research system where researchers play a significant role as facilitators and where the flow of information is two way between farmers and researchers. One reason that NARS may not be involved is that their agendas are generally focused on goals of agricultural production and poverty alleviation rather than improved resource management. In most countries, the agriculture ministry is responsible for soil erosion. Broader natural resource management is seen as the responsibility of a number of other ministries, especially environment, wildlife and tourism, water, energy, and local government. The multiple user, multiple user nature of watershed resources argues for inter-agency cooperation in watershed management and research. However government agencies confront the same conflicts of interest and high transactions costs as other watershed stakeholders in organizing for collective watershed management. Lessons on how to stimulate and structure cooperation are urgently needed, especially regarding the roles of internal vs. external and top-down vs. bottom-up pressure for change.

## Conclusions

User participation is increasingly being recognized as critical for success in watershed development and management projects. Local residents were often not considered in the formulation of top-down watershed projects, resulting in plans and technologies that were inconsistent with people's needs and ignorant of local peoples vast and detailed knowledge of land and land use practices. Empirical evidence suggests that giving users a role in managing their own watershed resources can lead to projects that are more efficient and effective than their top down predecessors.

User participation also has implications for watershed management research. In addition to changing the way technologies and practices are developed and disseminated, participation broadens the research agenda, bringing in new topics like organizational behavior, collective action and conflict resolution. There is a great need for further research on these topics as they relate to land and watershed management, beginning with a synthesis and comparative analysis of past experience in areas such as boundaries and scale, transactions costs of facilitation, and the development of indicators.

Participatory management that is not firmly linked to research—understood as a process of knowledge generation that supports technical and institutional innovation—is often hindered by a lack of appropriate technical options, information, and institutions. One way to provide that link is through participatory research methods, in which formal researchers and end users work together to define problems, evaluate solutions, and develop and disseminate technologies and other innovations.

The nature of the interaction between researchers and users will vary depending on the objectives of the research and the capacity and interest of different stakeholders. Establishing collective research or learning capacity in local communities may be particularly important to achieving sustainable participatory watershed management because of the importance of local institutions and collective action in the watershed environment. The research or learning process can be a way to united diverse stakeholders around common interests and goals.

The use of participatory methods in watershed projects is growing, but there is still a ways to go to institutionalizing use of participatory methods or achieving user empowerment through research. There is a need for both workable methodologies and systematic evaluation of the experience with existing methods and tools. Beyond methodologies, there is also a need for a re-evaluation of the implications of participatory research for the role of researcher and research organizations. New skills may be required for researchers and/or research teams. Institutionalization of participatory research and the ability to achieve widespread impact will depend on incorporating all stakeholders in appropriate roles.

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**Table 1. Type of Participation used by CGIAR Watershed Projects at different stages (percent of projects)***

| | **No Participation** | **Functional** | **Empowering** | | **No Participation** |
|---|---|---|---|---|---|
| | Contractual | Consultative | Collaborative | Collegial | Farmers Experimentation |
| Diagnosis (n=6) | 33 | 67 | 0 | 0 | 0 |
| Priority Setting (n=6) | 0 | 33.3 | 33.3 | 33.3 | 0 |
| Planning (n=5) | 20 | 60 | 0 | 20 | 0 |
| Implementation (n=12) | 8 | 17 | 33 | 33 | 8 |
| Monitoring and Evaluation (n=6) | 67 | 0 | 33 | 0 | 0 |

- participating centers included CIAT, IBSRAM, ICARDA, ICLARM and ICRISAT.

Number of observations varied because some centers used more than one approach and/or were only active at certain stages of the research process.

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## 1.2 PROJECT FUTURE IMPACT OF RESERACH

### 1.2.1 Assessing The Economic Impact of Biotechnology in Agriculture: The Case of Rapid Propagation for Cassava - *by: J. D. Quiñones, D. Pachico, R. H. Escobar, and J. Tohme*

### Introduction

The scientific revolution currently occurring through advances in biological sciences, in particular increased understanding of biological processes at the cellular or biochemical level known as biotechnology (Roca 1993), has an immense potential impact on human welfare. These impacts can be on human health, the environment, and economic, but these impacts are as yet only poorly understood. This paper attempts to contribute to a better understanding of the impacts of biotechnology by examining the potential economic impact of a biotechnological innovation in agriculture, specifically the impact of a rapid propagation method to produce disease free planting material of the tropical root crop, cassava.

Cassava cultivation is one of the few production alternatives which offers income and employment generating opportunities to small farmers in tropical areas with low rainfall and poor soils. Consequently, it is a very important food staple, especially in Africa and certain parts of South America where Brazil and Colombia are the two most important producers (Henry and Gottret 1996). Improvements in the productivity of cassava could have a major impact on the income and welfare of small farmers. However, despite the importance of cassava as a crop for small farmers in disadvantaged areas, the productivity of cassava has been largely stagnant (Plucknett et al 2000). Several different factors depress cassava productivity including poor soils, insect attacks, and diseases, and a significant scientific effort to overcome these constraints has been underway for nearly three decades (Cock 1985).

Biotechnology offers several alternatives for scientific breakthroughs that could have large impacts on the economic opportunities of small farmers in the tropics (National Academy of Science 2000; Oxfam 1999). There is little doubt that the development of transgenic crops has attracted the greatest popular attention not only for the potential scientific advances that they might imply, but also due to widespread concerns about the risks that transgenic technologies might imply. Transgenic crops obtain genetic material through means other than conventional sexual crossing, usually from other species (Roca and Beltrán 1984). By means of these transgenic techniques new crop varieties with agronomic and economically important characteristics such as insect resistance, disease resistance or herbicide tolerance are now grown on millions of hectares world wide (James 2000). Many other desirable plant characteristics are being developed through transgenic approaches, including for example rice with enhanced levels of vitamins. There are, though, considerable public concerns about possible negative impacts of transgenic crops. These risks include concerns about the possible impact on human health from the introduction of novel allergens into the human diet and concerns about the possible environmental impacts of transgenic plants. Speculation and some evidence point to risks to biodiversity, increased problems of crop pests and diseases, or to the development of “superweeds”.

However, biotechnology offers a wide of scientific tools that have great potential for crop improvement without encountering the concerns that have risen around transgenic crops (Escobar 1991). This paper makes a simple economic assessment of one such biotechnological innovation, the use of tissue culture systems to rapidly produce large quantities of disease free planting material for cassava that could lead to increased incomes for cassava farmers in the low income tropics.
This paper will briefly describe the biotechnological innovation of rapid propagation of disease free cassava planting material (Toro n.d.). Next, the costs of implementing this innovation on a commercial scale will be estimated. Finally, the potential economic impact of this biotechnological innovation on small farmers growing cassava in southwestern Colombia will be considered.

**A Biotechnological Approach to Reduce Disease in Cassava**

Diseases are a major cause of lost productivity in cassava. Not only do diseases attack cassava plants once in the field, for example through insect vectors or wind borne spread of spores, but many cassava plants are seriously infected with disease from the moment they are sown. This is especially problematic because cassava is a vegetatively propagated plant. Cuttings from stems from a previous crop of cassava are planted to grow a new crop of cassava. These stem cuttings, called “stakes” are infected with any disease, usually viral pathogens, that the previous crop of cassava suffered. Thus, over generations of planting diseased cassava stakes there is a build up of “inherited” plant virus diseases in cassava that depress the growth and productivity of cassava from the very moment of initial sowing.

It was shown two decades ago that cleaning up of cassava stakes to eliminate the diseases in the stakes used to plant cassava could lead to a very substantial increase in yields of cassava. This process of producing disease free cassava requires a process of cultivating cultures of cassava cells in test tubes and treating them with heat to kill diseases. This process has been available for some time, but it has not been economically feasible to take advantage of it because farmers can not plant test tubes of cell cultures in their fields. More recently, though, new systems for propagation of disease free planting material for cassava have been refined. This system is portrayed in Figure 1.

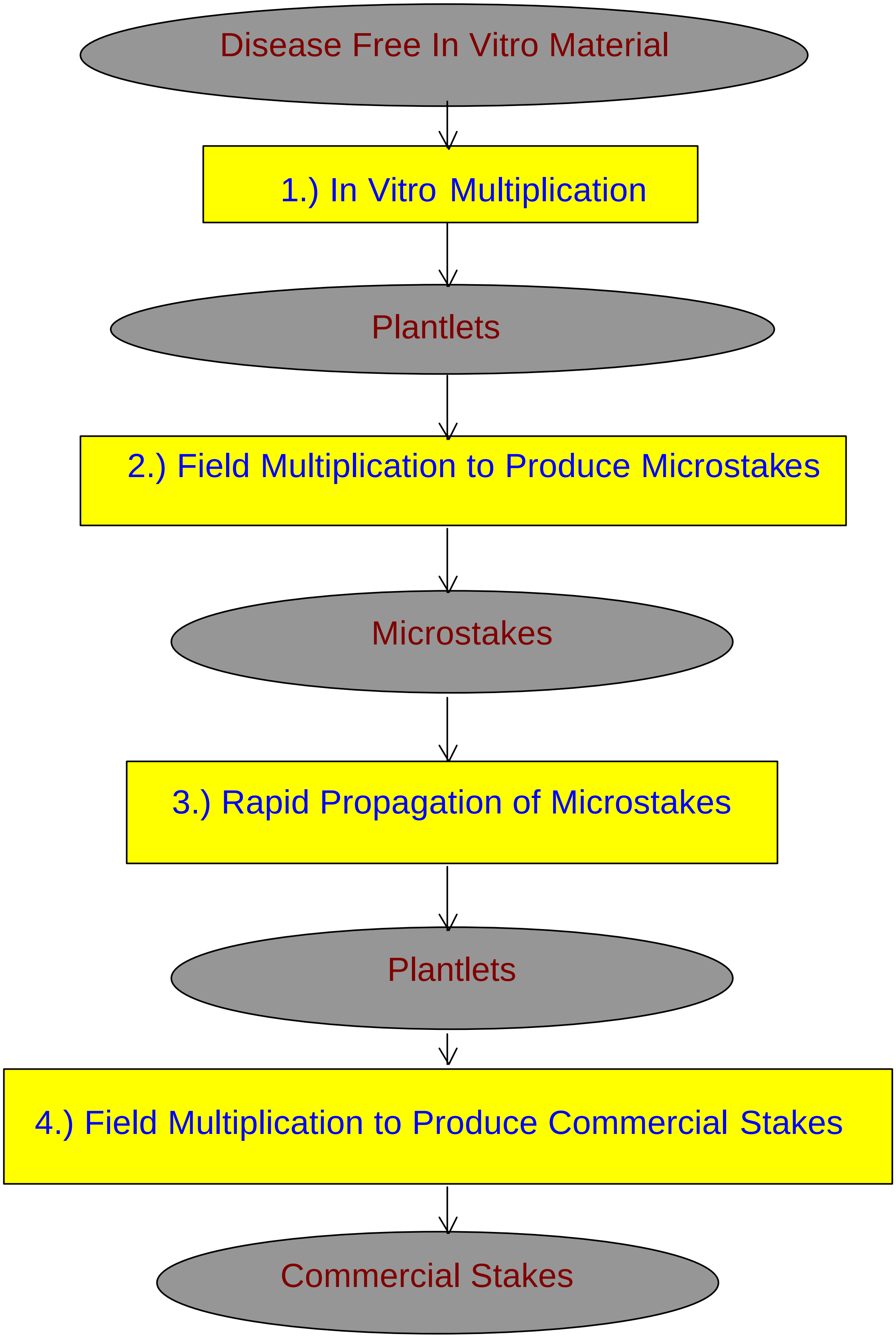
The second step of this process to produce commercial disease free cassava planting material is field multiplication of plantlets to produce microstakes. This stage of the process takes the 135 plantlets from the first stage and transplants the plantlets outdoors to normal field conditions. During the first two months in the field these plantlets need to be irrigated almost until a full root system is developed. After this transition, they are treated essentially as any normal crop of cassava. In about 12 months these plants can be harvested and they yield 100-150 two bud micro-stakes from each of the original 135 cassava plantlets.

The third step of this process is the rapid propagation of the microstakes to produce a multiplied number of plantlets. The rapid propagation technique begins with the seeding of the microstakes inside rooting chambers which are cement rectangles containing layers of rock or gravel, and sand. These chambers are covered with a wooden or aluminum structure, which is covered with a transparent plastic. The microstakes start to produce new shoots. These shoots are cut and are put to grow under a specified growth media and under controlled conditions. They are transplanted into plastic bags containing soil after they have reached 2 to 3 months of age, thus reproducing a new generation of plantlets.

Over a six month period the 13,500 microstakes produced in the preceding stage can be multiplied into 290,000 disease free plantlets.

The fourth step of the process to produce commercial disease free cassava planting material is the field multiplication of plantlets, this time to produce commercial stakes for sowing by farmers. This step essentially repeats the process of the second step, which also involved the field multiplication of plantlets. Again, after the two month period of irrigation and care the transplanted plantlets are treated like any normal crop. However, at harvest in twelve months some 7 stakes are produced per plant rather than the 100-150 two bud microstakes in the second step. These stakes are larger and harder than the microstakes and they constitute the normal commercial planting material that farmers use. Because of the process that has been followed these stakes, unlike normal stakes from farmers own fields, will be disease free. Because they are disease free, the plants grown from these stakes will be higher yielding than conventional stakes.

**Figure 1: Flow Diagram of the Process to Produce Disease Free Cassava Planting Material**



**Costs of Producing Disease Free Cassava Planting Stakes**

To assess the impact of disease free cassava planting stakes on the income of small cassava growers, we will first estimate the cost of producing commercial cassava stakes. This will be done for the case of Colombia. Cost data for laboratory processes were obtained through extensive interviews with scientists conducting these processes in the Biotechnology Laboratory of the International Center for Tropical Agriculture in Cali, Colombia. Costs of materials, labor, land, capital and all items used for producing disease free cassava stakes are thus based on prices in Colombia. Although all the original data were collected in Colombian pesos, costs here are presented in US dollars at the exchange rate prevailing at the time of initiation of this study.

The process of producing the original disease free material through heat treatments is estimated to cost $57.27 for a total cost of $286 (Table 1A). These are then multiplied in vitro to produce cassava plantlets, as described above. The growth media needed for cultivating the plant tissues in test tubes actually is very cheap due to the extremely small amounts of chemicals that are consumed. The total cost of growth media for the in vitro multiplication is only $7.32, (Table 1A) assuming no wastage of the chemicals.

A wide variety of laboratory materials are also required at this stage, and the cost of these materials amounts to $243 (Table 1A). Labor is a much more significant cost. With current systems this process is estimated to require 2080 hours of work of laboratory technicians over a six month period. At the prevailing wage rate of $1.60/hour for this type of labor in Colombia, the total labor cost would be $3,324 (Table 1A). Labor is clearly a major cost component and the commercial costs of this system would be highly sensitive to different labor costs, for example, in different countries.

Utilities, principally electricity, are also an important cost, amounting to $1,644 in order to run the equipment needed during the in vitro process. Total variable costs for the first stage of in vitro multiplication thus amount to $5,505 (Table 1A).

Fixed and financial costs are shown in Table 1B. Costs of machinery and equipment are based on the estimated depreciation rate calculated as an annual per cent over the useful life of the item, multiplied by the original purchase price of the equipment, and converted from an annual to an hourly basis. The number of hours of utilization of the equipment is specified for each item, thereby yielding a total cost of utilization for each equipment. The costs of building as facilities such as incubation rooms, greenhouse, and laboratories are computed on the same basis. Thus, costs of machinery and infrastructure are calculated on the basis of having these items in a multi-purpose facility where they are utilized for other uses when not involved in the in vitro multiplication. Costs presented here are only for actual amounts of utilization of equipment and infrastructure. If these were obtained and utilized solely for the cassava in vitro multiplication, then costs would be higher. Charging only for actual utilization time, costs of machinery would be only $8.40 and building space only $16.38.

Financial costs are, in contrast, a major cost element, (Table 1B). Prevailing commercial interest rates in Colombia are about 35% for loans in pesos. This is extremely high by international standards. To some extent it is a product of an inflation rate that has been running at 8-10% per year and a devaluation of the peso versus the dollar that has also been running over 10%/year. Although the real rate of interest in Colombia is high by international standards, to avoid the possibility of inflating the financial costs, these will be presented here at the conventional rate of 10% per year. Since the finished commercial product emerges only two years after the initiation of the first stage of the in vitro multiplication, this financial charge as the opportunity cost of capital is calculated over a two year period on the total variable and fixed costs involved in the in vitro multiplication. This amounts to $1,161 (Table 1B).

The total cost of producing 135 disease free plantlets is thus $6,691 (Table 1B). Labor is the largest share of this cost, comprising about 50% of the total while the opportunity cost of capital would comprise some 17% of total costs and utilities would cost about 25%. Clearly improved labor efficiency would be the most important strategy for seeking to lower the cost of this process.

As discussed in the previous section, the next step to produce disease free cassava planting stakes after the in vitro multiplication is to field multiply the 135 plantlets obtained from the in vitro multiplication. The costs of this initial field multiplication are shown in Table 2. This field multiplication follows essentially the same steps as the normal field production of cassava but it is done on a very small plot of only 135 square meters. For a plot this small all operations must be done by hand. In addition, the plantlets need special care when transplanted to the field, so there is an additional cost of watering the plants daily for the first two months in the field. Nevertheless, the plot that is planted is so small, that with the relatively modest cost of agricultural field labor in Colombia, $0.50/hour, the total costs of this field multiplication is only $87.

Table 3 shows the costs of the next step to producing commercial disease free cassava planting stakes. In this stage two-bud micro-stakes are rapidly propagated in special propagation chambers and greenhouses. Machinery and equipment costs are minor, at $13. Inputs form a larger portion of the costs, with potting soil being used in quite large quantities, and forming the bulk of the $7,323 cost of inputs.

Infrastructure, in particular the propagation structures, sum to an important cost of $2,025. The use of permanent buildings, especially greenhouses, are another significant cost of $2,982. Labor is another major cost, amounting to $6,648, while financial costs add up to $949. Overall, the total cost of the rapid propagation of microstakes to produce plantlets is $19,939.

The costs of the three steps needed to arrive at the production of 290,000 plantlets are summarized in Table 4. The in vitro multiplication cost $6,691 the field production of microstakes cost $87, and the rapid propagation of microstakes cost $19,939 for a grand total of $26,717. This amounts to a cost of $0.09 per plantlet.

The costs of the final stage of field multiplication of plantlets to produce commercial disease free cassava planting stakes are shown on a per hectare basis in Table 5. Here the costs of the previous stages are carried forward by including a seed cost of $0.09 per plantlet, which amounts to $900 per hectare. Apart from the costs of watering the plantlets during the first two months after transplanting to the field, the rest of the costs are the standard commercial costs of producing a hectare of cassava. The cost of land at $55 is a relatively minor cost, while labor is the largest cost at $1360. Finance costs amount to $233. Inputs of herbicide and fertilizer add little to the total costs as they amount to only $71. The total cost of producing 70,000 disease free commercial planting stakes of cassava is $2,618. This works out to $0.04 per stake.

**The Impact of Disease Free Cassava Stakes on Cassava Production**

An analysis of the economic impact of disease free stakes on cassava production is summarized in Table 6. Here the commercial cassava stakes are estimated to cost $0.06 each. This is comprised of the previously explained cost of $0.04 each for producing the cassava stakes, and a 50% marketing margin is added for the distribution of the stakes. Thus, for a commercial cassava farmer the cost of purchasing disease free cassava stakes is expected to be some $600 per hectare, making it the largest single component of production costs. Labor would cost $310/ha, chemical inputs only $71, land $55 and the opportunity cost of capital would amount to $104. Total per hectare production costs with the more expensive disease free cassava stakes would be $1,139, considerably higher than the conventional costs of production of $589.

The disease free cassava stakes would, however, lead to higher yields, estimated at 14.67 tons/ha based on farm trials conducted with disease free stakes (Coral 1984). This compares quite favorably with current average cassava yields of about 10 tons/ha (Vélez 2000). Thus, the value of production with disease free stakes would rise to $2,867/ha compared to $1,954/ha with conventional stakes that are viral infected. Net income with disease free stakes would be $1,728/ha compared to $1,365. Marginal revenue per hectare to the use of disease fee stakes would be $913, while marginal costs would be $550 so that the marginal returns to investment would be a highly attractive 166%.

This economic analysis indicates that the potential impact of disease free stakes on cassava farmers would be quite favorable indeed. Is it feasible to obtain this very positive impact on cassava farmers income? Though in principle it would be economically highly favorable to purchase disease free cassava stakes, in actual practice many cassava farmers will have difficulty in purchasing the cassava stakes from their own resources, and may face important constraints in obtaining capital. Nominal interest rates in Colombia start at about 35% for commercial credit, and can reach 50% in local rural capital markets. This presents a more difficult investment decision than would be faced with the conventional 10% finance charge used in the dollar analysis.

Moreover, the price of cassava is highly variable. At the average price of cassava the use of disease free stakes is profitable, but in years of low cassava prices, losses could be significant. Thus, capital constraints could impede many poor small cassava farmers from making this high return investment in disease free cassava stakes, while price variability could also make it quite a risky investment. Investment in disease free cassava stakes may not by feasible for many farmers.

The feasibility of establishing a commercial system to produce disease free cassava stakes is also questionable. It requires an integrated system of laboratory in vitro culture, field multiplication, and the use of special, though simple, infrastructure for the rapid propagation phase. It is a complex system to manage, and requires three years from its initiation to the production of commercial disease free stakes. Again, in principle this would be economic, it may be exceedingly difficult to actually manage such a system. Finally, cassava farmers do not now buy planting stakes, they simply save diseased stakes from their current crop. The very concept of purchasing an input that is now seen by farmers as essentially a free good, could be very difficult to introduce. The lack of a current market for cassava stakes, and the uncertainty whether many farmers would be able to purchase cassava stakes, or willing to undertake such a novel investment, would be a very discouraging prospect for an entrepreneur considering the establishment of a complex process to produce cassava stakes that would take three years before it could yield a return.

Thus, disease free cassava planting material is technically feasible, and could in principle be economic. It is, though, an endeavor of such complexity requiring such a high level of innovation both by farmers and the putative producers of disease free cassava stakes, that it is not easy to be confident that this system could in fact lead to a favorable impact for cassava farmers.

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**TABLE 1A: COSTS OF VARIABLE INPUTS TO MULTIPLY IN VITRO DISEASE FREE MATERIAL INTO CASSAVA PLANTLETS**

**1.) Clean In Vitro Planting Material**

| | Quantity | Unit Cost(US $ / plant) | Total Cost(US $) |
|---|---|---|---|
| Disease free in vitro material | 5.00 | 57.27 | 286.35 |

**Sub Total Clean In Vitro Planting Material Costs (US $)** **286.35**

**2.) Growth Media and Other Inputs**

| | Quantity (kg) | Unit Cost(US $ / kg) | Total Cost(US $) |
|---|---|---|---|
| NH4NO3 | 0.001650000 | 57.500000 | 0.055976 |
| KNO3 | 0.001900000 | 56.925000 | 0.063813 |
| MgSO4 7H2O | 0.000370000 | 54.970000 | 0.012000 |
| KH2PO4 | 0.000170000 | 81.190000 | 0.008143 |
| H3BO3 | 0.000006200 | 49.680000 | 0.000182 |
| MnSO4 H2O | 0.000022300 | 60.260000 | 0.000793 |
| ZnSO4H2O | 0.000008600 | 76.820000 | 0.000390 |
| NaMoO42H2O | 0.000000250 | 300.150000 | 0.000044 |
| CUSO4 5H2O | 0.000000025 | 83.260000 | 0.000001 |
| CoCl2 6H2O | 0.000000025 | 445.050000 | 0.000007 |
| Kl | 0.000000830 | 308.200000 | 0.000151 |
| CaCl2 2H2O | 0.000440000 | 65.090000 | 0.016897 |
| Na2EDTA-Fe | 0.000050000 | 203.550000 | 0.006005 |
| Thiamin | 0.000000100 | 438.150000 | 0.000026 |
| m-inositol | 0.000100000 | 253.460000 | 0.014954 |
| Agar | 0.008000000 | 28.750000 | 0.135700 |
| ANA | 0.000000020 | 501.400000 | 0.000006 |
| BAP | 0.000000040 | 11,730.000000 | 0.000277 |
| GA3 | 0.000000050 | 20,286.000000 | 0.000598 |
| Sucrose | 0.020000000 | 0.022540 | 0.000266 |
| Fungicide | 0.000000161 | 5.000000 | 0.000001 |
| Insecticide | 0.000000161 | 11.750000 | 0.000002 |
| Plant product(fertilizer) | 0.000007732 | 5.750000 | 0.000044 |
| Soil | 1.790000000 | 0.012000 | 0.021480 |
| Sand | 3.620000000 | 0.008000 | 0.028960 |
| Alcohol 96 % | 4.000000000 | 6.900000 | 6.900000 |
| Water | 2,160.000000000 | 0.000025 | 0.054000 |

**Sub Total Growth Media and Other Inputs Costs (US $)** **7.32**

**3.) Materials**

| | Quantity | Unit Cost(US $) | Total Cost(US $) |
|---|---|---|---|
| Metallic stands | 1.00 | 26.00 | 26.00 |
| Scalpel | 1.00 | 1.23 | 1.23 |
| Forcep | 1.00 | 26.22 | 26.22 |
| Forcep | 1.00 | 17.02 | 17.02 |
| Forcep | 1.00 | 11.62 | 11.62 |
| Petri dish | 2.00 | 2.18 | 4.36 |
| Magenta(3 x 3 ") | 5.00 | 0.84 | 4.20 |
| Jiffy pott | 135.00 | 0.09 | 11.83 |
| Seed tray | 8.00 | 1.06 | 8.48 |
| Barretón | 1.00 | 6.05 | 6.05 |
| Shovel | 1.00 | 3.40 | 3.40 |
| Bunsen burner | 2.00 | 23.35 | 46.69 |
| Scientific calculator | 1.00 | 20.00 | 20.00 |
| Markers | 10.00 | 2.13 | 21.30 |
| Transference pipette std | 5.00 | 2.21 | 11.05 |
| Spatula | 1.00 | 8.90 | 8.90 |
| Spatula | 1.00 | 7.80 | 7.80 |
| Styrofoam cup | 135.00 | 0.05 | 6.75 |
| Cotton wool | 1.00 | 0.40 | 0.40 |

**Sub Total Materials Costs (US $)** **243.30**

**4.) Labor**

| | Quantity(Hours of Work) | Unit Cost(US $ / hr) | Total Cost(US $) |
|---|---|---|---|
| Laboratory workers | 2,080.00 | 1.60 | 3,323.84 |
| **Sub Total Labor Costs (US $)** | | | **3,323.84** |

**5.) Electricity and Water**

**5.1) Electricity**

| | Quantity(Hours of Operation) | Electricity consumption(kWH) | Total Cost(at .07 US$/KWH) |
|---|---|---|---|
| Autoclave | 1.50 | 15.00 | 1.58 |
| Flow chamber | 6.00 | 1.50 | 0.63 |
| Ph meter | 0.36 | 0.03 | 0.00 |
| Digital balance(200 g) | 6.00 | 0.06 | 0.03 |
| Fridge | 4,320.00 | 0.15 | 45.36 |
| Incubation room | 4,320.00 | 4.84 | 1,463.62 |
| Greenhouse | 720.00 | 0.33 | 16.63 |
| Laboratory | 1,440.00 | 0.96 | 96.77 |
| **Sub Total Electricity Costs (US $)** | | | **1,624.61** |

**5.2) Water**

| | Quantity($m^3$) | Unit Cost(US $ / $m^3$) | Total Cost(US $) |
|---|---|---|---|
| Laboratory | 240.00 | 0.08 | 19.2 |
| **Sub Total Water costs (US $)** | | | **19.2** |
| **Sub Total Electricity and Water Costs (US $)** | | | **1,643.81** |
| **Sub Total Variable Costs (US $)** | | | **5,504.61** |

**TABLE 1B: INFRASTRUCTURE COSTS TO MULTIPLY IN VITRO DISEASE FREE MATERIAL INTO CASSAVA PLANTLETS**

**1.) Machinery and Equipment**

| | Depreciation Rate(US $ / hr) | Utilization Rate(hr) | Total Cost(US $) |
|---|---|---|---|
| Autoclave | 0.1040 | 1.50 | 0.156 |
| Flow chamber | 0.0342 | 6.00 | 0.205 |
| Ph meter | 0.0100 | 0.36 | 0.004 |
| Digital balance(200 g) | 0.0112 | 6.00 | 0.067 |
| Fridge | 0.0011 | 4,320.00 | 4.932 |
| 40 w fluorescent lamps | 0.0002 | 1,440.00 | 0.247 |
| Temperature controller | 0.0019 | 1,440.00 | 2.788 |
| Gas pipette | 0.0003 | 15.00 | 0.004 |
| **Sub Total Machinery and Equipment Costs (US $)** | | | **8.40** |

**2.) Buildings**

| | Depreciation Rate(US $ / hr) | Utilization Rate(hr) | Total Cost(US $) |
|---|---|---|---|
| Incubation room space | 0.00003 | 4,320.00 | 0.13 |
| Greenhouse space | 0.01910 | 720.00 | 13.75 |
| Laboratory space | 0.00058 | 4,320.00 | 2.50 |
| **Sub Total Buildings Costs (US $)** | | | **16.38** |
| **Sub Total Fixed Costs (US $)** | | | **24.78** |
| **Sub Total Variable Costs (From table 1A) (US $)** | | | **5,504.61** |
| **Sub Grand Total Costs of Cassava Plantlets (US $)** | | | **5,529.39** |
| **Financial Costs (FC) (10 % for 2 years in US $)** | | | **1,161.17** |
| **Grand Total Cassava Plantlets Costs (US $)** | | | **6,690.56** |

**TABLE 2: FIELD MULTIPLICATION TO PRODUCE MICROSTAKES (135 $m^2$)**

**1.) Direct Costs**

**1.1) Activities**

| | Quantity(hr) | Unit Cost(US$ / hr) | Total Cost(US $) |
|---|---|---|---|
| Land preparation (manual) | 18.80 | 0.50 | 9.40 |
| Irrigation (manual) | 30.00 | 0.50 | 15.00 |
| Sowing (manual) | 10.44 | 0.50 | 5.22 |
| Labor herbicides application | 1.28 | 0.50 | 0.64 |
| Labor in weed control | 21.80 | 0.50 | 10.90 |
| Fertilizer application | 3.24 | 0.50 | 1.62 |
| Harvest | 30.24 | 0.50 | 15.12 |
| Packing | 3.58 | 0.50 | 1.79 |
| **Sub Total Activities Costs (US $)** | | | **59.69** |

**1.2) Inputs**

| | Quantity(kg) | Unit Cost(US$ / kg) | Total Cost(US $) |
|---|---|---|---|
| Fertilizer (10-20-20) | 0.41 | 13.00 | 5.27 |
| Herbicides | 0.14 | 31.50 | 4.26 |
| **Sub Total Inputs Costs (US $)** | | | **9.53** |
| **Sub Total Direct Costs (US $)** | | | **69.22** |

**2.) Indirect Costs**

| | Quantity(ha) | Unit Cost(US $ / ha) | Total Cost(US $) |
|---|---|---|---|
| Financial costs (FC) (10 % for 1.5 years in US $) | | | 10.73 |
| Rent of land | 0.14 | 55.00 | 7.43 |
| **Sub Total Indirect Costs (US $)** | | | **18.16** |
| **Grand Total Field Multiplication to Produce Microstakes Costs (US $)** | | | **87.38** |

**TABLE 3: RAPID PROPAGATION OF MICROSTAKES**

**1.) Machinery and Equipment**

| | Quantity | Unit Cost(US $) | Total Cost(US $) |
|---|---|---|---|
| Ph test strips | 10.00 | 0.17 | 1.70 |
| Gas stove | 1.00 | 10.00 | 10.00 |
| Kettle | 1.00 | 1.28 | 1.28 |
| **Sub Total Machinery and Equipment Costs (US $)** | | | **12.98** |

**2.) Inputs and Materials**

**2.1) Inputs**

| | Quantity(kg) | Unit Cost(US $ / kg) | Total Cost(US $) |
|---|---|---|---|
| Water | 21666064.00 | 0.00002 | 541.65 |
| Fungicide | 6.66 | 4.99700 | 33.28 |
| Plant product(fertilizer) | 6.66 | 5.74625 | 38.27 |
| Balastro | 36864.00 | 0.03000 | 1,105.92 |
| Potting soil | 349056.00 | 0.01200 | 4,188.67 |
| Sand | 55296.00 | 0.00800 | 442.37 |
| **Sub Total Inputs Costs (US $)** | | | **6,350.16** |

**2.2) Materials**

| | Quantity | Unit Cost(US $) | Total Cost(US $) |
|---|---|---|---|
| Styrofoam cup | 2,240.00 | 0.050 | 112.00 |
| Razor | 50.00 | 0.750 | 37.50 |
| Cotton wool bag | 1.00 | 0.400 | 0.40 |
| Plastic bag | 293,760.00 | 0.003 | 822.53 |
| **Sub Total Materials Costs (US $)** | | | **972.43** |
| **Sub Total Inputs and Materials Costs US $)** | | | **7,322.59** |

**3.) Infrastructure**

**3.1) Non Depreciable Infrastructure**

| | Quantity($m^2$) | Unit Cost(US $ / $m^2$) | Total Cost(US $) |
|---|---|---|---|
| Rent of land | 1,000.00 | 0.024 | 24.00 |
| Propagation chamber structure | 92.16 | 13.58 | 1,251.20 |
| Rooting chamber | 22.50 | 33.33 | 750.00 |
| **Sub Total Non Depreciable Infrastructure Costs (US $)** | | | **2,025.20** |

**3.2) Depreciable Infrastructure**

| | Depreciation Rate(US $ / hr) | Utilization Rate(hr) | Total Costs(US $) |
|---|---|---|---|
| Propagation chamber floor space | 0.29 | 4,320.00 | 1,250.00 |
| Certified material greenhouse space | 0.40 | 4,320.00 | 1,731.50 |
| **Sub Total Depreciable Infrastructure Costs (US $)** | | | **2,981.50** |
| **Sub Total Infrastructure Costs (US $)** | | | **5,006.70** |

**4.) Labor**

| | Quantity(Hours of Work) | Unit Cost(US $ / hr) | Total Cost(US $) |
|---|---|---|---|
| Field workers | 4,160.00 | 1.60 | 6,647.68 |
| **Sub Total Labor Costs (US $)** | | | **6,647.68** |
| **Sub Total Rapid Propagation of Microstakes Costs (US $)** | | | **18,989.95** |
| **Financial Costs (FC) (10 % for 0.5 years in US $)** | | | **949.49** |
| **Grand Total Rapid Propagation of Microstakes Costs (US $)** | | | **19,939.45** |

**TABLE 4: COSTS OF PRODUCING DISEASE FREE PLANTLETS**

| Activity | Total Cost (US $) |
|---|---|
| In vitro multiplication of disease free Material into cassava plantlets | 6,690.56 |
| Field multiplication to Produce microstakes | 87.38 |
| Rapid propagation of Microstakes | 19,939.45 |
| Sub total | 26,717.39 |
| Plant production | 293,760.00 |
| Cost / plantlet | 0.09 |

**TABLE 5: FIELD MULTIPLICATION TO PRODUCE COMMERCIAL STAKES (Per hectare)**

**1.) Direct Costs**

**1.1) Activities**

| | **Quantity(hr)** | **Unit Cost(US $ / hr)** | **Total Cost(US $)** |
|---|---|---|---|
| Land preparation (manual) | 140.00 | 0.50 | 70.00 |
| Irrigation (manual) | 2,100.00 | 0.50 | 1,050.00 |
| Sowing (manual) | 112.00 | 0.50 | 56.00 |
| Labor herbicides application | 9.50 | 0.50 | 4.75 |
| Labor in weed control | 161.50 | 0.50 | 80.75 |
| Fertilizer application | 24.00 | 0.50 | 12.00 |
| Harvest | 116.00 | 0.50 | 58.00 |
| Packing | 26.50 | 0.50 | 13.25 |
| Post-harvest seed treatment | 30.00 | 0.50 | 15.00 |

**Sub Total Activities Costs (US $)** **1,359.75**

**1.2) Inputs**

| | **Quantity(kg)** | **Unit Cost(US $ / kg)** | **Total Cost(US $)** |
|---|---|---|---|
| Herbicides | 2.00 | 15.75 | 31.50 |
| Fertilizer (10-20-20) | 150.00 | 0.26 | 39.00 |

**Sub Total Inputs Costs (US $)** **70.50**

**1.3) Seed**

| | **Quantity** | **Unit Cost(US $)** | **Total Cost(US $)** |
|---|---|---|---|
| Cost of seed | 10,000.00 | 0.09 | 900.00 |

**Sub Total Seed Costs (US $)** **900.00**

**Sub Total Direct Costs (US $)** **2,330.25**

**2.) Indirect Costs**

| | **Quantity(ha)** | **Unit Cost(US $ / ha)** | **Total Cost(US $)** |
|---|---|---|---|
| Financial costs (10 % for 1 year in US $) | | | 233.03 |
| Rent of land / ha-year | 1.00 | 55.00 | 55.00 |

**Sub Total Indirect Costs (US $)** **288.03**

**Grand Total Field Multiplication to Produce Commercial Stakes Costs (US $ / ha)** **2,618.28**

**Number of Stakes / ha** **70,000.00**

**Grand Total Field Multiplication to Produce Commercial Stakes Costs (US $ / stake)** **0.04**

**TABLE 6: COSTS AND RETURNS TO SMALL FARMERS OF DISEASE FREE AND CONVENTIONAL STAKES**

| | Disease Free Stakes | Conventional Stakes |
|---|---|---|
| Seed costs (US $ / ha) | 600.00 | 100.00 |
| Labor costs (US $ / ha) | 309.75 | 309.75 |
| Chemicals costs (US $ / ha) | 70.50 | 70.50 |
| Land costs (US $ / ha) | 55.00 | 55.00 |
| Financial costs (10 % in US $) | 103.53 | 53.53 |
| Total costs (US $ / ha) | 1,138.78 | 588.78 |
| Yield (ton / ha) | 14.67 | 10.00 |
| Value of production (US $ / ha) | 2,866.52 | 1,954.00 |
| Net income (US $ / ha) | 1,727.74 | 1,365.23 |

### 1.2.2 Income Employment Effects of Transgenic Herbicide Resistant: Cassava in Colombia. *by: D. Pachico, Z. Escobar, L. Rivas, V. Gottret and S. Pérez*

**Outstanding results**

? The study shows high yield varieties would lead to greater producer and consumer benefits than would herbicide resistant varieties or the mechanization of cassava in Colombia.

? These results at the national level mask important differences among regions. Because of differences in resource endowments and cost structures between the different regions, no single technology is clearly more attractive in all regions. This suggests that research should aim to produce a variety of technical options that will have differing impacts in different regions.

? In addition to considering development costs as well as potential economic benefits, a full analysis of these options would have to also include wider environmental and health issues. For example, the herbicide resistant cassava would lead to a different pattern in herbicide use, which could have negative consequences, but by reducing the frequency of soil tillage it would contribute to reducing the risks of soil erosion.

? In all cases employment would be greatest with current technology. Transgenic herbicide resistant would displace more labor from cassava production than would mechanize planting and harvesting.

? Clearly, these issues of costs and environmental and health risks need to be incorporated before drawing conclusions about the relative desirability of the different cassava innovations considered in this paper.

**Progress report**

This study makes an economic comparison of the development of a transgenic herbicide resistant cassava in Colombia with current technology and with two alternative strategies for increasing cassava productivity: improved yield potential through conventional breeding, and the mechanization of cassava planting and harvest. Cassava growers generally constitute some of the poorest of the rural poor in some of the most disadvantaged regions of the low-income tropical countries, including Colombia (Henry and Gottret 1996). Typically there are few other crop alternatives in the low rainfall regions with poor soils where most of cassava is grown. Cassava farmers critically need cost reducing technology to keep cassava a competitive food in markets where consumers increasingly have many other alternatives, including other cheap food staples that can include imports as the Colombian economy opens further to economic globalization. Without more productive, lower cost cassava that could compete in the market, the income and employment prospects of cassava producers will be highly circumscribed. The potential economic benefits of three strategies for improving cassava productivity are assessed here: transgenic herbicide resistance; improved yield potential through conventional breeding; and mechanization of cassava planting and harvest. Due to its slow establishment and long growing period, weed control is one of the major costs of cassava production. Moreover, since weeding is done almost exclusively by hand, seasonal labor bottlenecks are critical constraint on any expansion of cassava production. It has been suggested that a particularly promising avenue of reducing the cost of weed control in cassava, thereby opening up vast new income opportunities for poor cassava growers, would be the introduction of herbicide tolerance into cassava. This would permit low cost herbicides to be substituted for expensive manual weed control.

Transgenic herbicide tolerant crops are now being cultivated on a massive scale in temperate agricultural systems. In 1999 this included 21.6 million hectares of soybean, 3.6 million hectares of maize, 3.5 million hectares of canola - rapeseed, and 2.4 million hectares of cotton (James 2000). Previous studies have assessed the impacts of transgenic crops (Pray et al 2000) Whether a similar transgenic herbicide tolerant cassava for the tropics should be developed depends upon a number of considerations, among them its potential contribution to food security, any environmental risks, and any potential hazards to human health. This paper endeavors to make an initial assessment of the potential income and employment impacts of transgenic herbicide resistant cassava for the case of the north coast region of Colombia.

Such an approach is necessarily partial. For example, the environmental consequences of increased herbicide use are not specifically analyzed. These could include potential negative effects of increased use of toxic herbicide and potential positive effects that could result from reduced soil losses to erosion because the substitution of herbicide for manual weeding would reduce soil disturbance. Likewise, though there are no demonstrated human health risks from transgenic herbicide resistant crops, neither has it been proven that there are no potential health risks. Other potential environmental risks would have to be considered in a complete analysis, such as gene flow from transgenic cassava to wild South American relatives that could create herbicide resistant plants, or the potential emergence of herbicide tolerance in weeds due to increased levels of exposure to herbicide over time. Thus, the findings of this paper are limited to assessing some potential economic consequences of transgenic herbicide resistance in cassava, and as such, this paper can not provide a complete basis for assessing whether or not transgenic cassava should be deployed.

There are important alternatives to improving transgenic cassava through other approaches. Improved yield potential through conventional breeding has had an immense impact on the productivity of other tropical crops (Evenson et al 2000), and this is a strategy for cassava improvement that has been followed for some time (Cock 1985). The deployment of such technology has not raised the same level of human health and environmental concerns as has been the case with transgenic crops. Nevertheless varieties derived from conventional breeding can also have environmental affects such as higher nutrient demands from the soil or induced changes in natural pest populations.

Improved labor productivity through mechanization has been a major development path for agriculture in the high-income temperate countries, and is likewise spreading in the tropics. Mechanization of cassava sowing and harvest requires both the development of appropriate machinery, essentially adapted from similar machinery for potatoes. It also requires the development through conventional breeding of upright erect cassava with little branching in order to produce cassava stakes for planting that are straight and even enough for mechanized sowing. Mechanized rather than manual sowing regularizes the distances at which cassava is planted thereby making mechanized harvest also possible. While the combination of mechanized sowing and harvest is a potentially feasible way of lowering costs, and increasing productivity, including the returns to labor, there are concerns about labor displacing technologies exacerbating unemployment. In Colombia, for example, unemployment is already on the order of 20% in the urban economy and even higher in rural areas. Consequently the economic analysis in this paper will look not only at economic surplus but also at changes in employment associated with the three technologies.

An economic model based on surplus analysis is used in this paper to estimate the changes in equilibrium output and prices and consumer and producer benefits that would accrue from alternative changes in cassava technology in Colombia. This paper will proceed by first briefly reviewing the model used here. The data sources are briefly noted. Differences in the costs of cassava production of with the different technologies are considered. Next consumer and producer surplus are estimated for the alternative technologies, and differences in employment are also estimated. Conclusions will suggest some possible further extensions of this research.

**The Model**

The Dynamic Research Evaluation Model (DREAM) is used in this paper. The theory underlying this model has been described in detail (Alston et al 1995) and a user manual is available (Wood and Baixt 1998). This model is similar to the MODEXC model ( Rivas et al 1999), but offers greater ease in handling multiple regions.

For region i and year t the model specifies linear equations of supply and demand

1. $$Q_{it} = a_{it} + bPP_{it}$$

2. $$C_{it} = g_{it} + d_i PC_{it}$$

where

$Q_{it}$ is the quantity produced in region $i$ in period $t$
$PP_{it}$ is the producer price in region $i$ in period $t$
$C_{it}$ is the quantity consumed in region $i$ in period $t$
$PC_{it}$ is the consumer price in region $i$ in period $t$

Other parameters are defined as follows:

3. $$b_{i0} = {e_{i0}Q_{i0}} / {PP_{i0}}$$

4. $$a_{i0} = (1 - e_{i0})Q_{i0}$$

5. $$d_{i0} = {h_{i0}C_{i0}} / {PC_{i0}}$$

6. $$g_{i0} = (1 - h_{i0})C_{i0}$$

where

subscript 0 refers to observed values in the initial time period

$e_i$ is the elasticity of supply

$h_i$ is the elasticity of demand

Technical change is modeled through a shift in the supply function

7. $$K_{it} = c_i A_{it} PP_{i0}$$

Where

$c_i$ Is the reduction in unit costs in region $i$

$A_{it}$ Is the per cent of farmers adopting the cost reducing technology

Labor employment in the absence of technical change is defined as:

8. $$E_{itl} = Q_{it} L_{itl}$$

Where

$E_{it}$ is the level of employment in period $t$

$L_{itl}$ is the amount of labor per ton of production with existing technology

so that the amount of labor employed with technical change is $E_{itm}$

9. $$E_{itm} = Q_{it}(1 - A_{it})L_{itl} + (Q_{it}A_{it})L_{itm}$$

Where

$L_{itm}$ Is labor use per ton of production with improved technology.

**The Data**

All the data for this model are from Colombia. Prices and quantities are taken from various government sources (reported in Perez 2001). Production quantities are reported for six different regions. Costs of production for cassava in the six regions were developed through a combination of secondary sources and key informant interviews (Perez 2001). Changes in production from the potential new technologies were developed based on interviews with cassava scientists. Elasticities and rates of adoption are from Escobar 2001.

**Costs of Cassava Production**

Table 1 presents costs of production per hectare for cassava under current technology and for three potential alternative technologies for the north coast region of Colombia. Similar costs of production for all four technologies were developed for five other regions (Perez 2001), but for brevity, only the costs for the north coast are reported here. All costs were originally calculated in Colombian pesos, but are here converted into US dollars at the exchange rate prevailing at the time of the study.

Total costs per hectare are greatest with high yielding varieties developed through conventional breeding, $734/ha. Compared to $583/ha with current technology. The largest part of this increased cost is more expensive seed that needs to be purchased in order to obtain the new high yielding variety. In addition, because yield per hectare increases, there is a need for greater labor at harvest. The higher yields, 18 tons per hectare compared to 11 tons per hectare with current technology, more than compensate for the increased cost per hectare so that the cost of production per ton fall from $51 with current technology to $42 with the high yield variety. This represents a 17.9% decrease in unit costs, and this figure is used as $c_i$ to estimate the shift in the supply function caused by new technology as shown in equation 7. Due to greater labor at harvest the days of labor needed per hectare rises from 62 with current technology to 70 with higher yielding varieties. However, in terms of labor per ton of cassava produced, used in equations 8 and

9 to estimate the employment effects of the alternative technologies, this falls from 5.4 days per ton with current technology to 4.0 per ton with higher yielding varieties from conventional breeding.

Herbicide resistant transgenic varieties would reduce the costs of land preparation and weed control. Weed control costs would fall because the use of relatively inexpensive herbicides would substitute for the intensive use of labor for manual weed control. Land preparation costs would also fall substantially because the herbicide resistant transgenic varieties would permit the use of minimum tillage. Consequently the per hectare costs of the herbicide resistant varieties would be $556 compared to $583 with current technology. The costs of production per ton would fall 15.6%, from $51 with current technology to $43 with the transgenic herbicide resistant varieties. Because this cost reduction is achieved principally through a reduction in manual weed control, labor per hectare fall substantially with this technology, 46 days per hectare with transgenic herbicide resistant cassava compared to 62 days per hectare with current technology.

The third potential new technology appraised here is mechanized sowing and harvest of cassava. The major part of the cost saving from this technology comes from reduced harvest costs, which drop from $99/ha with current technology to $56/ha when mechanized. Planting costs with mechanization fall to $58/ha compare to $92/ha with current technology. Effective yields are also expected to rise slightly with mechanized harvest, which is anticipated to be more thorough than manual harvest. Total costs per hectare with mechanization are $530 compared with $583 with current technology, while costs per ton, which provide the estimate of $c_i$ which shifts the supply function, falls 19.6.% to $41from $51 with current technology.

Similar costs of production have been developed for all four technologies for five other cassava production regions in Colombia (Perez 2001). Table 2 presents the per cent reduction in unit costs for the three potential new technologies compared to current technology for six cassava producing regions in Colombia. As noted above, these provide the estimates of $c_i$ which drives the shift in the supply function in equation 7. Because the structure of production costs and yields differ among the six regions, the changes in per cent cost reductions also vary among regions for the three technologies. These differences notwithstanding, the mechanized planting and harvest leads to the largest cost reduction in average for all regions. High yield varieties lead to greater cost reductions than mechanization in the more favored production zones-the eastern plains, the coffee zone- while in Santanderes region, mechanization leads to a greater cost reduction than improved yield potential.

**Economic Surplus and Employment Effects of New Technologies**

Based on the model described above, economic surplus to producers and consumers due to the supply shifting effect of new technologies were calculated along with the estimated total amount of labor in cassava production. Economic surplus benefits are presented in Table 3.

High yield varieties yields the greatest total surplus benefits of the three technologies, estimated at a present value of $316 million at a 5% discount rate over the period 2002-2016. The transgenic herbicide resistant cassava produce a present value of benefits of us$ 297 million Mechanized technologies would produce a present value of benefits of $222 million. In all cases consumers would receive approximately 40% so that for consumers, the high yield varieties cassava would result in the largest benefits, some $134 million, while consumer benefits from mechanized planting and harvest and herbicide resistant varieties are $95 million and $124 million respectively.

Among producers, seven groups are shown: six are the regions that would benefit from the potential new technologies while the seventh region is comprised of cassava producers elsewhere in Colombia who are assumed not to be able to utilize or adopt the new technologies. Necessarily, these non-adopting farmers scattered elsewhere in Colombia would be net losers from any of the technical changes because their competitors would be benefiting from cost reducing technology while they retained their current cost structures. High yield varieties would lead to the greatest level of benefits from all three technologies in the North Coast, Eastern plains and Coffee Zone. In Cauca-Valle, Huila -Tolima and Santanderes region, would gain most from herbicide resistant varieties.

Estimated employment in cassava production in 2016 for the four technologies in the six adopting regions is presented in Table 4. In all cases employment would be greatest with current technology, though it must be stressed that this greater level of employment would come at the cost of forfeiting all the producer and consumer surplus benefits found in Table 3. It is hardly surprising that employment is estimated to fall with transgenic herbicide resistant cassava, which would displace labor from land preparation and manual weed control. Likewise it is to be expected that mechanization of planting and harvest, which would substitute for labor in both these activities would also reduce employment compared to current technology. Between the two, transgenic herbicide resistant would displace more labor from cassava production than would mechanize planting and harvesting.

Perhaps surprisingly, high yielding cassava varieties would be similarly displacing of labor and is estimated to lead to actually a lower level of employment than mechanized planting and harvest even though labor use per hectare would rise with the high yielding cassava due to increased labor at harvest. This occurs because labor use per ton of cassava production would fall with the high yielding cassava as shown in Table 1. Thus, with high yielding cassava the area needed in cassava production to supply the market would fall and this effect would overwhelm the small increase in per hectare employment with high yielding technology.

Thus, any of the proposed new production technologies would lead to benefits to producers and consumers, but a lower level of employment. Although lower employment in cassava production might appear to risk jeopardizing the welfare of workers in an economy already characterized by high unemployment, labor productivity, and thus in principle wages, would rise with any of the new technologies. Economic development can not occur without increases in labor productivity, and in fact increased labor productivity is crucial to improved welfare. Hence, though employment would fall in cassava production, this is an almost essential characteristic of improved labor productivity. The welfare issue should perhaps be seen as the overall macroeconomic performance of the economy with respect to employment creation instead of a matter that can be resolved through a single line of production like cassava.

**Conclusions and Needs for Further Research**

This study has compared the potential benefits from different technologies to improve the productivity of cassava in Colombia. The study shows high yield varieties would lead to greater producer and consumer benefits than would herbicide resistant varieties or the mechanization of cassava in Colombia. Compared to current technology, all the technical innovations would lead to a reduction in employment in cassava, more or less on the same scale though the herbicide resistant cassava is the most labor displacing of the alternatives considered.

These results at the national level mask important differences among regions. Because of differences in resource endowments and cost structures between the different regions, no single technology is clearly more attractive in all regions. This suggests that research should aim to produce a variety of technical options that will have differing impacts in different regions.

An important limitation of this study is that it only attempts to estimate the benefits of alternative technologies. A more complete analysis would have to include the different costs of developing the technical innovations, including the amount of time required to develop the technologies and the differing probabilities of success in achieving the different innovation.

Moreover, in addition to considering development costs as well as potential economic benefits, a full analysis of these options would have to also include wider environmental and health issues. For example, the herbicide resistant cassava would lead to a different pattern in herbicide use, which could have negative consequences, but by reducing the frequency of soil tillage it would contribute to reducing the risks of soil erosion. Likewise, high yielding varieties are certainly going to be more demanding of soil nutrients, and this could risk soil depletion or lead to a greater use of chemical fertilizers which might have undesired secondary effects.

Heightened awareness of the need to include these environmental and potential health consequences in an assessment of transgenic crops has led to the development of new regulatory systems and requirements for transgenic crops. This is embodied both in international convention and national regulatory systems (Convention on Biodiversity 2000; US Department of State 2000). These regulations require, for example, assessment of possible effects on organisms in the environment; potential to become a weed; potential allergenicity and digestability. These assessments have not been a requirement for genetic modifications achieved through conventional breeding. Therefore, the high yielding cassava and the cassava more suitable for mechanization considered in this paper would not be subject to regulatory review before their use, but considerable research on these environmental and health issues would be required before a transgenic herbicide resistant cassava could be released into the environment. This in turn would raise the total research costs to the development of transgenic cassava. Clearly, these further issues of costs and environmental and health risks need to be incorporated before drawing conclusions about the relative desirability of the different cassava innovations considered in this paper.

**Table 1. Cassava production Cost using Different Technologies in Colombia North Coast.**

| Items | Current Technology | High Yield Varieties | Herbicide - Resistant Varieties | Mechanized Plant and Harvest |
|---|---|---|---|---|
| Land preparation | 78 | 78 | 17 | 78 |
| Seed and planting | 92 | 147 | 154 | 58 |
| Fertilization | 47 | 47 | 47 | 47 |
| Weed control | 99 | 99 | 10 | 99 |
| Pest and disease control | 0 | 22 | 22 | 22 |
| Harvest | 99 | 132 | 110 | 56 |
| Financial cost | 115 | 156 | 145 | 117 |
| Land Rental | 53 | 53 | 53 | 53 |
| Total Cost (Us$/ha) | 583 | 734 | 556 | 530 |
| Yield (Mt./ha) | 11.4 | 17.5 | 12.9 | 12.9 |
| Unit Cost (Us$/Mt.) | 51 | 41.9 | 43.2 | 41.2 |
| Cost Reduction (%) | - | 17.9 | 15.6 | 19.6 |
| Number of work days/ha | 62 | 70 | 46 | 39 |

**Table 2. Estimated Cost Reduction of Cassava Production in Colombia Compared to Current Technology** (%)

| Region | High Yield Varieties | Herbicide - Resistant Varieties | Mechanized Planting and Harvest |
|---|---|---|---|
| North Coast | 17.9 | 15.6 | 19.6 |
| Eastern Plains | 25.1 | 20.8 | 20.2 |
| Coffee Zone | 24.4 | 21.9 | 0.0 |
| Cauca - Valle | 16.1 | 22.3 | 21.6 |
| Huila - Tolima | 23.0 | 23.7 | 23.7 |
| Santanderes | 24.7 | 25.5 | 33.5 |
| Other regions | 0.0 | 0.0 | 0.0 |
| Colombia | 16.2 | 15.0 | 17.3 |

**Table 3. Estimated Present Value of Benefits 2002-2016 from Improved Cassava Production Technologies in Colombia** (us$ millions, 5% discount rate)

| Region | High Yield Varieties | Herbicide - Resistant Varieties | Mechanized Planting and Harvest |
|---|---|---|---|
| North Coast | 41.1 | 32.4 | 31.0 |
| Eastern Plains | 61.9 | 49.2 | 29.7 |
| Coffee Zone | 11.7 | 10.4 | -2.1 |
| Cauca - Valle | 8.0 | 14.0 | 8.3 |
| Huila - Tolima | 12.5 | 13.3 | 8.4 |
| Santanderes | 73.5 | 78.1 | 70.3 |
| Other regions | -26.3 | -24.4 | -18.7 |
| Consumers | 133.6 | 123.9 | 94.7 |
| Total Colombia | 316.0 | 296.9 | 221.6 |

**Table 4. Estimated Employment in Cassava Production in Colombia under Different Technologies in 2016** (thousands of days)

| Regions | Current Technology | High Yield Varieties | Herbicide Resistant Varieties | Mechanized Planting and Harvesting |
|---|---|---|---|---|
| North Coast | 5415 | 4456 | 4100 | 4305 |
| Eastern Plains | 1307 | 1175 | 1044 | 1135 |
| Coffee Zone | 327 | 266 | 263 | 327 |
| Cauca - Valle | 438 | 408 | 364 | 358 |
| Huila - Tolima | 319 | 290 | 251 | 275 |
| Santanderes | 3438 | 2478 | 1735 | 2818 |
| Total | 11244 | 9073 | 7757 | 9218 |

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## 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*

[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]

[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

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. | Low, even in empowering participation. | Important impacts within and beyond the projects. Limited impact on NARS. | Cost increase compared to conventional, but empowering was not more costly than functional. |
| | 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. | | Empowering participation not necessarily better than conventional. | 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

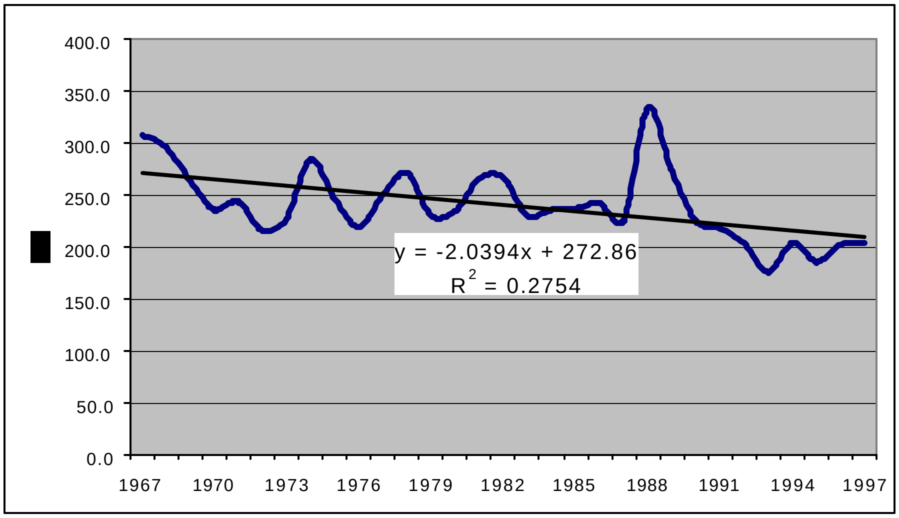
Los resultados de la evaluación se expresan en términos de los beneficios sociales recibidos por consumidores y productores y que se originan en el crecimiento de la productividad y en la reducción de los precios reales en los mercados de arroz.

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

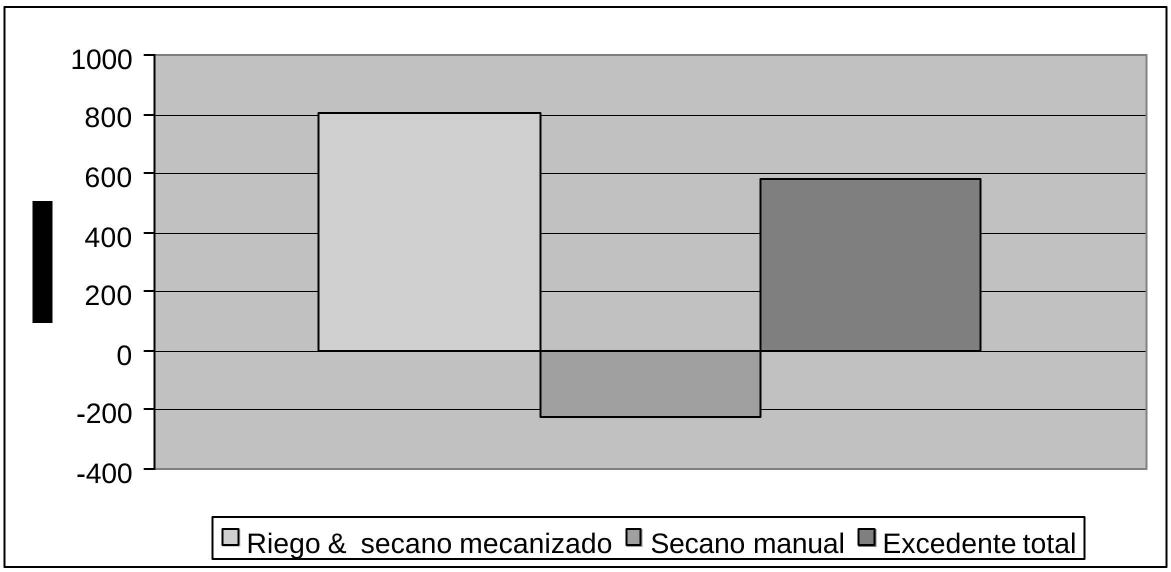
| Región 1/ | Equilibrio Inicial 2/ | | Elasticidades precio | | Crecimiento autónomo (%) | | Desplazamiento de la oferta (%) | | Valor presente de los beneficios tecnológicos us$ millones (i=10%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cantidad '000 tm | Precio '000$/tm | Oferta | Demanda | 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,

[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.

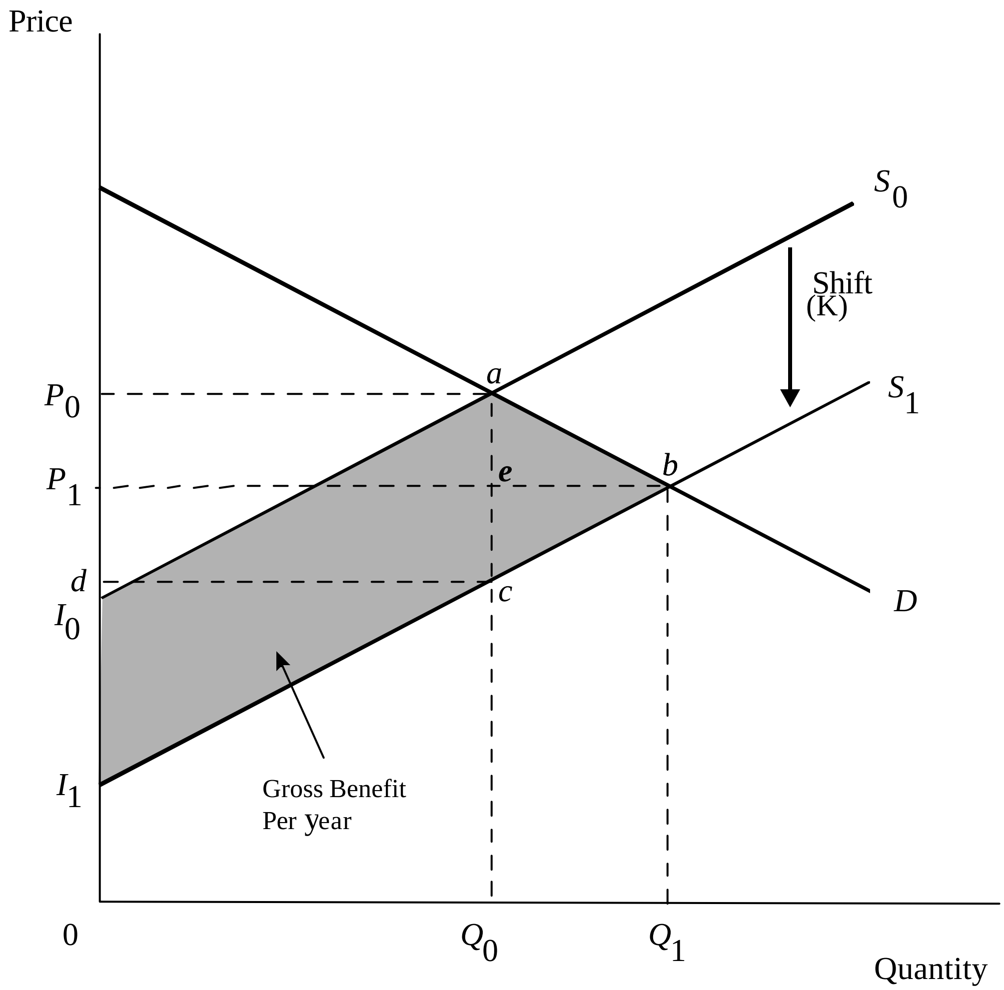
The total (annual) benefit from the research-induced supply shift is equal to the area beneath the demand curve and between the two supply curves ($\Delta TS$ = *area* $I_o abI_1$).

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* $I_o acI_1$) 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* $Q_o abQ_1$ – less the total cost of the increment to production – *area* ($Q_o cbQ_1$) --. Alternatively, is possible to portion the total benefits into the benefit to consumers in the form of the change in consumer surplus (*DCS*= $P_o abP_1$) and benefits to producer surplus (*DPS* = *area* $P_1 bI_1$ minus area $P_o aI_o$).

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.

[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.

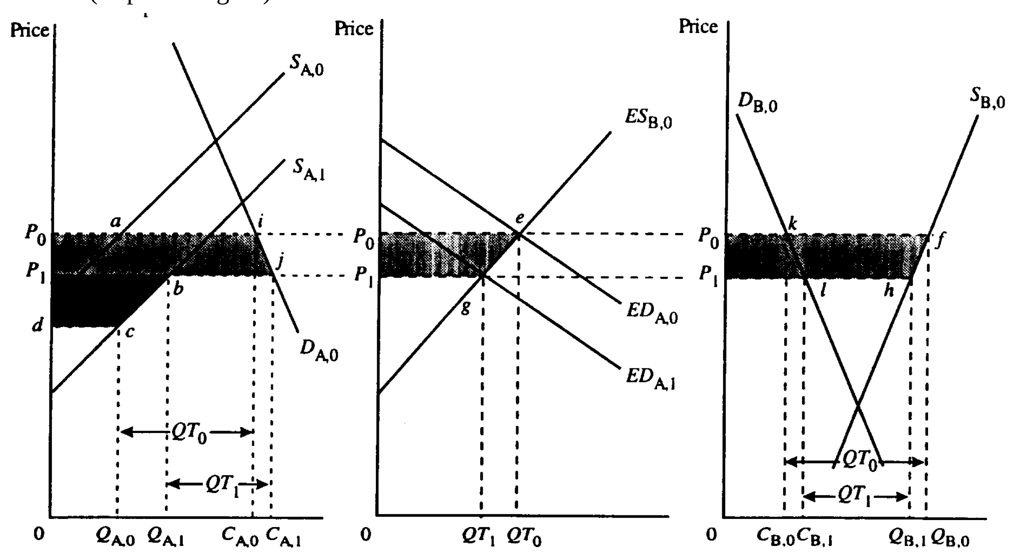
This framework also has the capacity to represent multiple regio ns (markets) and interacting with each other through trade. Figure 2 shows the case of two regions. Under the assumption of free trade it is not necessary to have internal equilibrium conditions in each region.

**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

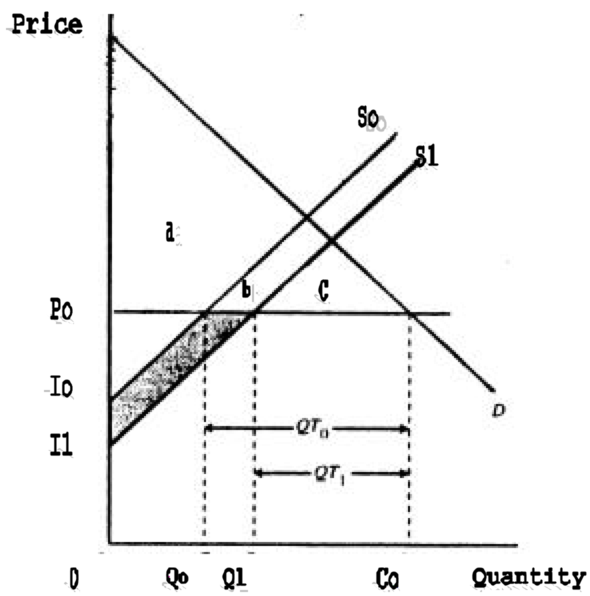



Region A Quantity　　Trade Quantity　　Quantity ROW

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.

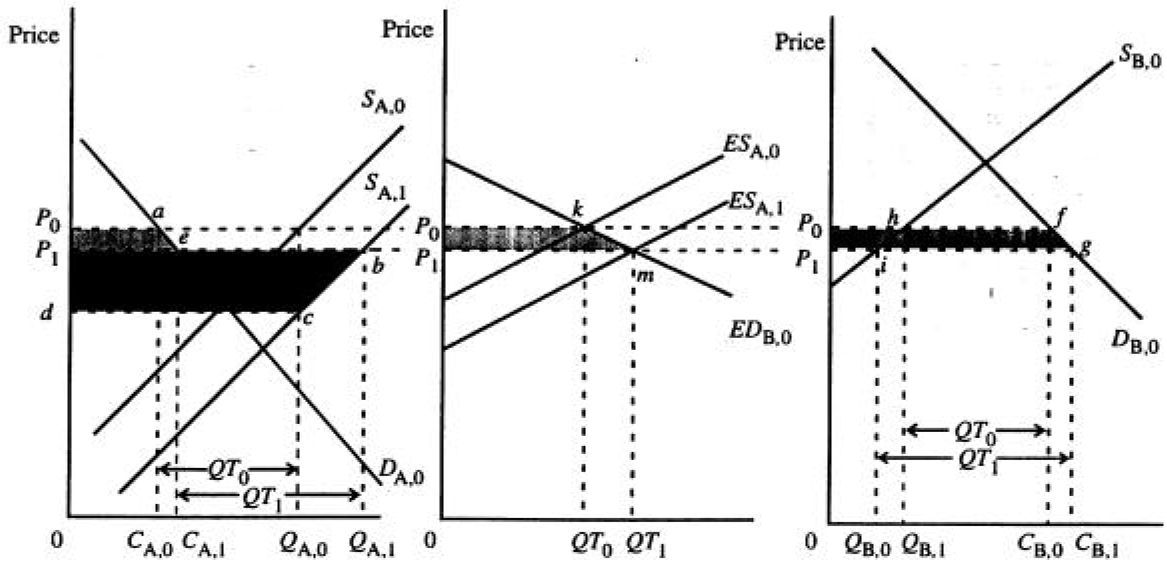
The global equilibrium price in the market, $P_o$, is determined where the export production surplus in the region A corresponds to the deficit of region B, ($Qt_o$).
If region A adopts new technology, the supply curves shifts and there will be more production available for internal consumption and trade. 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)




Region A Quantity

Traded Quantity

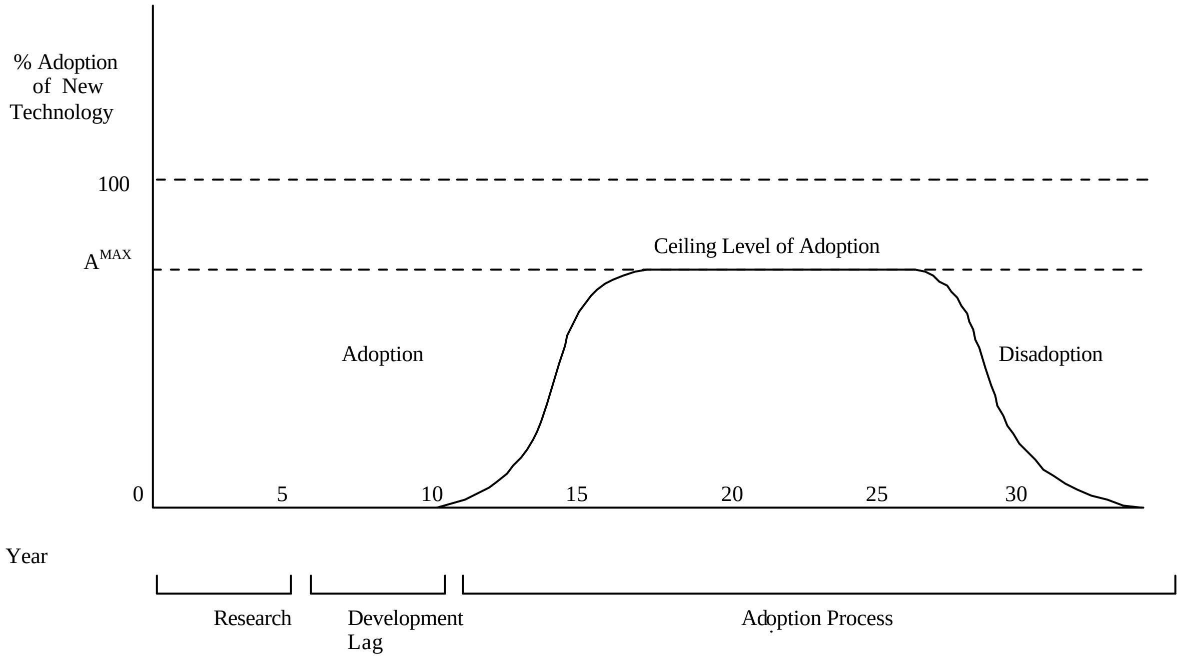
ROW Quantity

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, $\Delta PS_t$, changes in producer surplus $\Delta PS_t$, and total change in surplus $\Delta TS_t$, and can be calculated as followed:

$$DCS_t = P_oQ_o Z_t (1 + 0.5 Z_t n)$$

$$DPS_t = P_oQ_o (K_t - Z_t) (1 + 0.5 Z_t n)$$

$$DTS_t = DCS_t + DPS_t = P_oQ_oK_t (1 + 0.5 Z_t n)$$

$P_o$ 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 $K_t \,.\, P_0$.

**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:

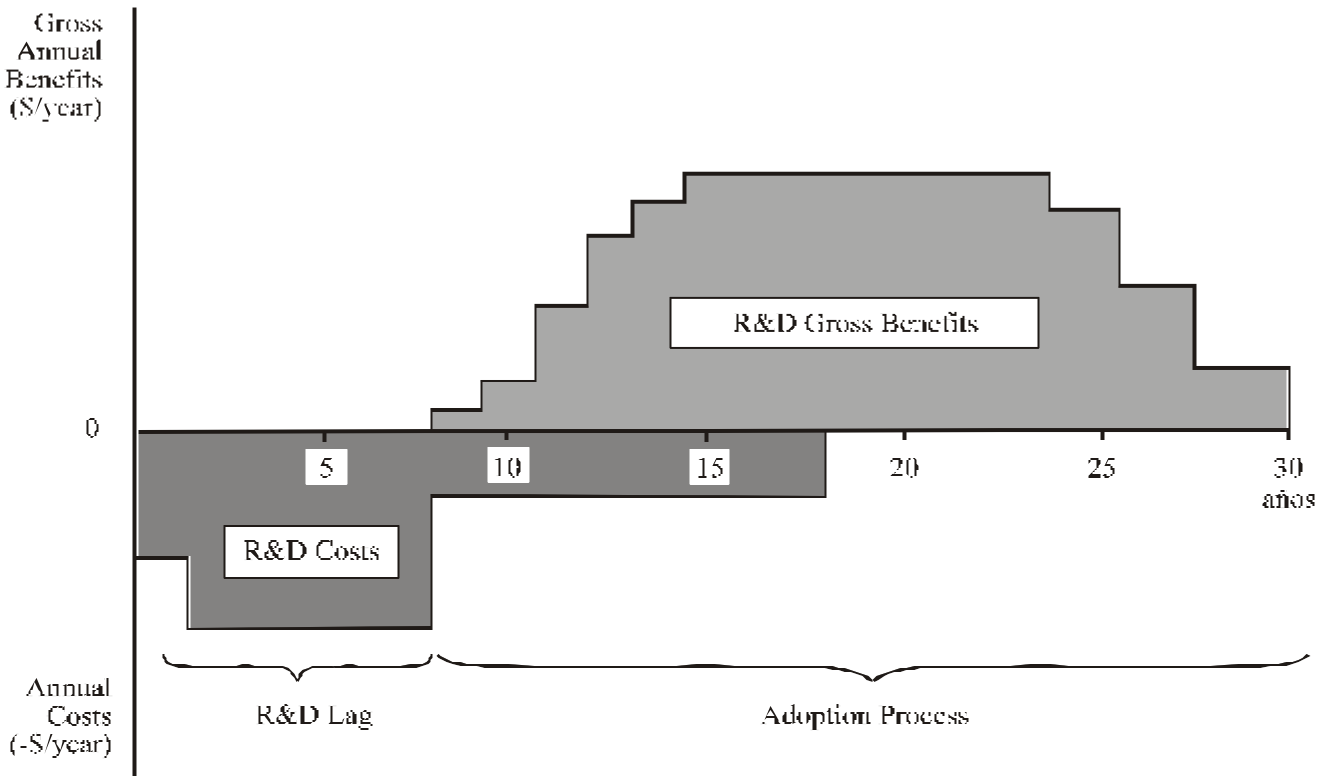
$$NPV = S_t (DTS_t - C_t) / (1 + r)^t$$

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 (2$^{nd}$ semester) and 1998 (1$^{srt}$ 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.

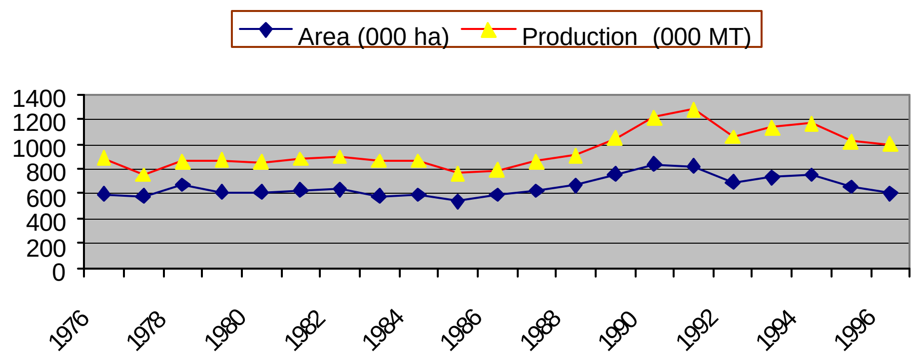
## RESULTS

### 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**



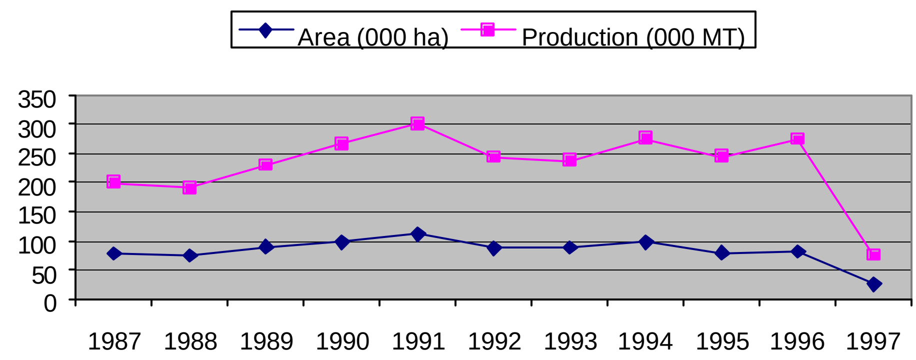

At one extreme, small scale semi-subsistence producers grow maize primarily as a food crop, some producers plant local varieties with low yield as a food crop; most of these producers plant local varieties with low yield potential, high yield stability, and moderate resistance to local pest and diseases. 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%.

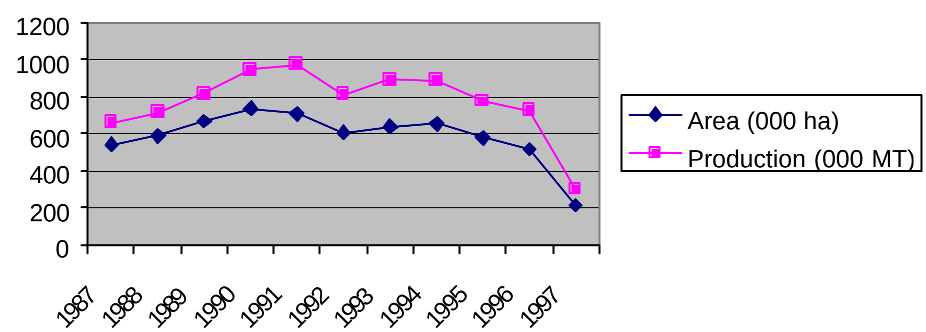
In average in the last thirty years, the yield of technical maize in Colombia has increased from 2.43 ton/ha to 3 ton/ha, that is, an increase of 0.57 ton/ha or 23,46% in roughly thirty years (Figure 8). The lowest value was in 1976 with a yield of 1,89 ton/ha, and the highest in 1997 with 3,01 ton/ha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

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

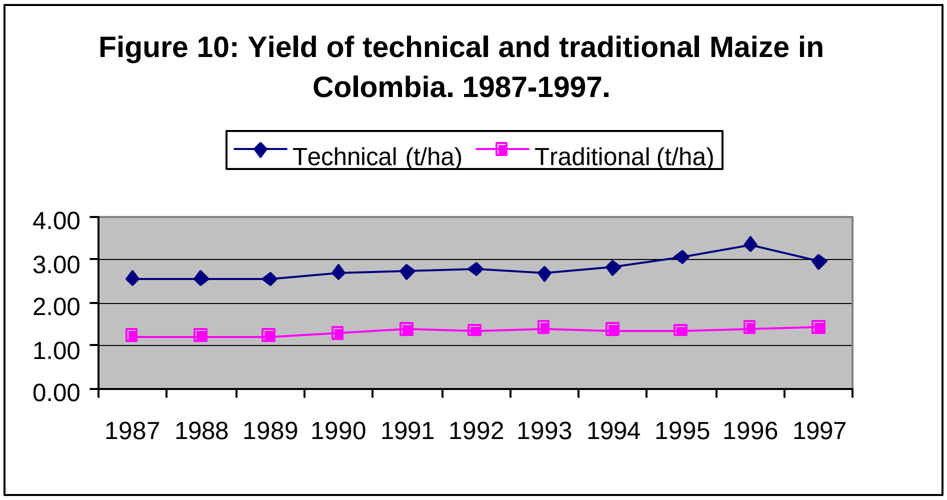



Traditional maize production in Colombia, in spite of the reduction in the amount of sowing hectares, falling from 560,300 hectares in 1970 to 489,520 hectares in 1997, increased due to yield improvements (Figure 9 and 10). In 1970 production stood at 631,300 metric tons but by 1997 had reached 723,652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



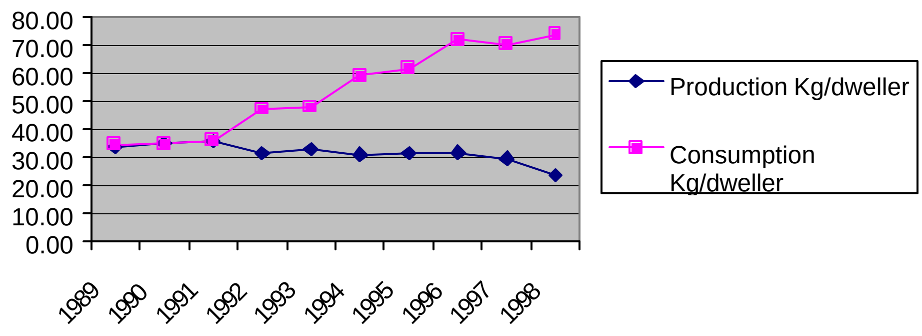

## Consumption trends

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**

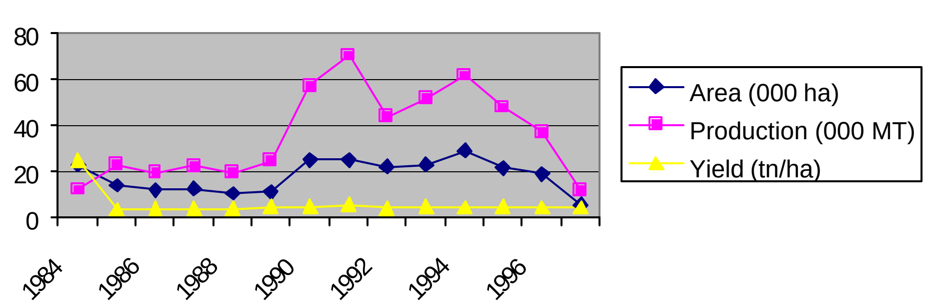



### Meta Department

**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**

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

| Region | K Pot. | Prob.of Success | Max. Adopt | Price | K Max | Shift Type | K Var | Time Lags R&D | Time Lags Adopt | Time Lags AtMax | Time Lags Aband | Adopt 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

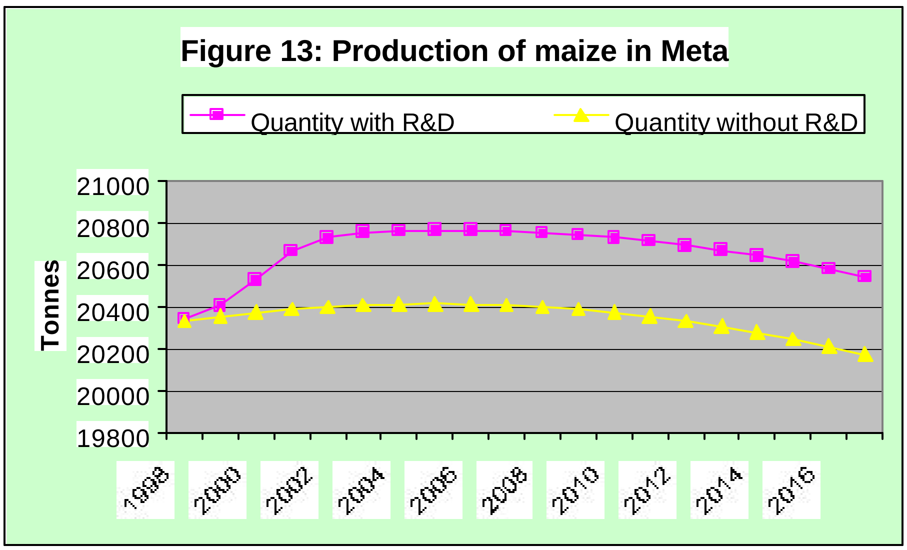
Notes.

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.

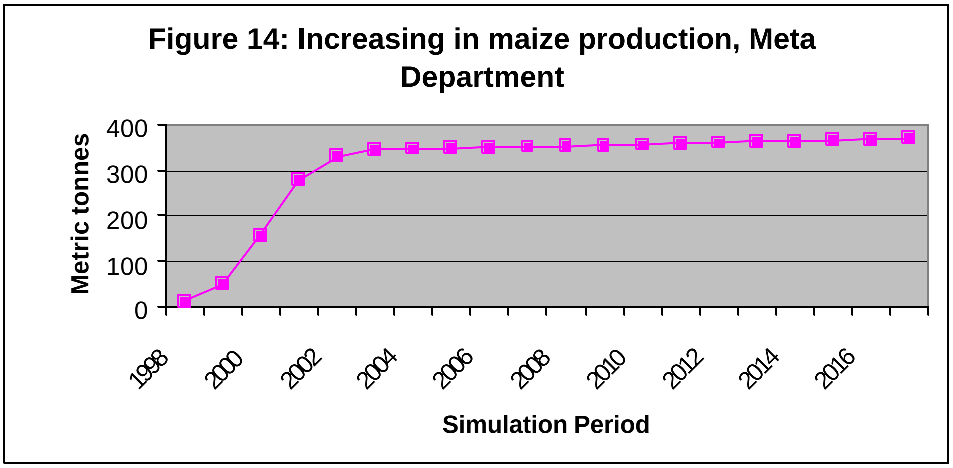
**Dynamics of Market**

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).




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).

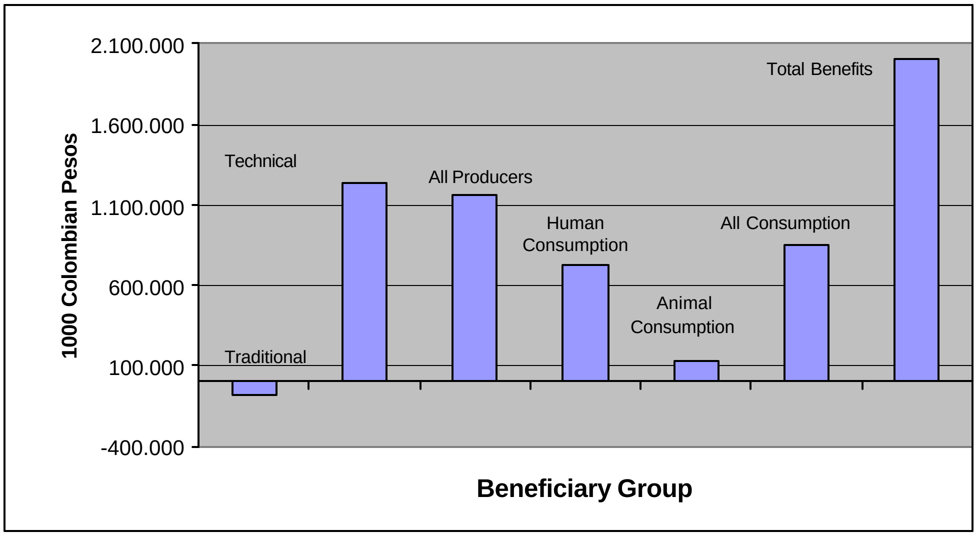
**Benefits by Region**

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**

| Region | Producer | Consumer | Government | Total | Costs | Returns (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**

| Region | Producer | Consumer | Government | Total | Costs | Returns (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**

| Region | Producer | Consumer | Government | Total | Costs | Returns (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**

| Region | Producer | Consumer | Government | Total | Costs | Returns (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 | --.-- | --.- |

(In each table, Producer, Consumer, Government and Total fall under "Present Value of R&D Benefits"; Returns comprise (B-C), B/C and IRR.)

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**

| Region | Producer | Consumer | Government | Total | Costs | Returns (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 | --.-- | --.-- |

Column groups: ---------- Present Value of R&D Benefits ----------> (Producer, Consumer, Government, Total) <---Costs---> <------ Returns ------------> ((B-C), B/C, IRR)

**Annual Benefit Summary Across All Regions in the Scenario**

| Year | Producer | Consumer | Government | Total |
|---|---|---|---|---|
| | <--------------- Benefits | | ----------------> | |
| 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. | | | |
| Year | Price | Quantity | Price | Quantity | Benefits | Price | Quantity | Price | Quantity | Benefits | "Prod" | "Cons" | Benefits | Research 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 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | R&D change in | | Value of | Benefits | R&D change in | | Value of | Benefits |
| Year | K Total | K Base | K Spill | K 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 |

## 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.

Donor: Interamerican Development Bank

[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

**People and Institutions Involved:**

- Stanley Wood, IFPRI (Environment and Production Technology Division)
- Rob Schipper, Wageningen Agricultural University (Department of Development Economics)
- CIAT (Impact Assessment Unit)

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# OUTPUT III: DATA BASES AND METHODS

## 3.1 Data base and web page development - *by: J.A. García*

### Data Base Development

Durante 2001 se continuó la labor de recolección, actualización y adición de datos (datos del año 2000) a las diferentes series de datos almacenadas en los sistemas de información que desde hace algunos años el proyecto BP1 viene manteniendo con el propósito de disponer de información clave que sirva de apoyo tanto para estudios propios como para estudios de colaboradores.

Dado que los programas de mejoramiento genético en el CIAT y en otros centros de investigación han venido trabajando con miras a incrementar el contenido de algunos micro-nutrientes en diferentes cultivos, es importante conocer la situación de los diferentes países de América latina en lo que respecta a su nutrición y a los problemas de deficiencia a micro-nutrientes que se están presentando en la población.

Por lo anterior, a la base de datos de América Latina se le incorporó información sobre el consumo de alimentos por parte de la población en los diferentes países, información sobre el contenido de micro-nutrientes de que disponen los diferentes alimentos e información sobre el estado de los países latinoamericanos en lo que respecta particularmente a deficiencia de Vitamina A y a deficiencia de Hierro.

En lo que hace referencia a la base de datos de Colombia se actualizaron un año todas las series de datos en ella incluida; es decir que a la fecha se dispone de información hasta el año 1999. Igualmente se adicionaron nuevas series de datos (cuadro-1) relacionadas con el cultivo de la Yuca y otros cultivos suplementarios o complementarios a la yuca en la elaboración de concentrados para la alimentación de animales.

**Cuadro 1: Series de datos relacionadas al cultivo de la Yuca que fueron adicionadas a la base de datos de Colombia.**

| Variable | Serie |
|---|---|
| Precio al Productor (Yuca Fresca) | 1975-2000 |
| Precio Consumidor (Yuca Seca, otros productos) | 1981-2000 |
| Precio de Importación (Maíz) | 1981-2000 |
| Precio de Venta (Almidón agrio) | 1977-2000 |
| Precio de Venta (Almidón Dulce) | 1975-2000 |
| Producción Yuca Seca | 1981-2000 |
| Producción Almidón Dulce | 1975-1989 |
| Producción Almidón Agrio | 1987-1995 |
| Rendimiento promedio por tamaño de finca por Región | 1980-2000 |
| Tamaño promedio de finca (grande, mediana, pequeña) por región | 1980-2000 |
| Valor Jornal por región | 1980-2000 |

## WEB Page Development

El CIAT emprendió durante 2001 el ajuste de su página web a nuevos estándares de diseño, más gratos a la vista y con características comunes a todas las páginas que identifican claramente la institución y que facilitan la navegación al visitante. Como parte de la gran web CIAT, las páginas correspondiente al proyecto BP1 (Evaluación de Impacto) fueron ajustadas a los nuevos patrones de presentación como puede observase en la figura-1.


Figura-1: Nueva Página Web de Impacto.

Como se observa en la figura anterior, la parte superior de cada página muestra un menú horizontal cuyas diferentes opciones despliegan submenús que le permite al usuario ir a cualquiera de las áreas institucionales.

De igual manera, cada página muestra en su margen izquierda un menú que le permite al usuario ir a cualquiera de las áreas de información del respectivo proyecto. En el caso de la página de Impacto, con esta facilidad el usuario podrá moverse entre tópicos como bases de datos, Modexc, recursos de información, etc.

En el presente año, la página web de impacto también fue adicionada con tablas de tendencias (Trends-2001) en la producción de los productos de interés del CIAT y con información correspondiente a los costos de producción del cultivo de la yuca en seis regiones de producción en Colombia.

**Visitas al Web y utilización de recursos disponibles vía Internet:**

El sistema de información sobre uso de la página web de Impacto reporta que durante el período 21/Sep/2000 al 27/Sep/2001, la página fue visitada en 2883 ocasiones, lo que significa un incremento del 187.1% con respecto a período similar en el año inmediatamente anterior durante el cual se realizaron 1541 visitas.

En la medida que la página se hace más conocida por la comunidad afín a nuestros intereses, el número de visitas es cada día mayor como puede observarse en la figura-2.

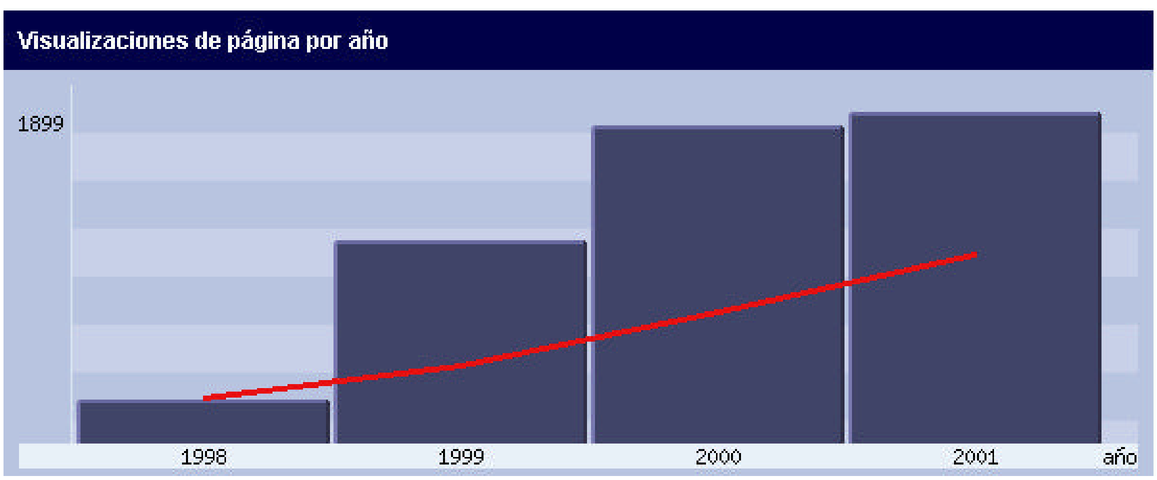



Figura-2: Visualizaciones de página por año desde el 20 de Octubre de 1998.

Faltando aún el cuarto trimestre del presente año, se observa que el año 2001 superará considerablemente al año anterior.

En lo que respecta al origen de las visitas, la figura-3 muestra que el sistema no ha podido determinar el origen del 27.4% de ellas, pero de aquellas identificadas, el 38.9% corresponde a visitas originadas desde el continente americano, el 17.3% corresponde a visitas desde organizaciones sin ánimo de lucro en el mundo, el 11.4% a visitas desde países europeos y el 5.0% restante a visitas desde los continentes Asia, Australia y África. Al descontar las visitas de origen desconocido, los porcentajes antes relacionados se convierten respectivamente a : 53.5%, 23.9%, 15.7% y 6.9%.

| Continente de origen | | | |
|---|---|---|---|
| 1. | EEUU y Canadá | 910 | 17.7 % |
| 2. | .net y .org | 890 | 17.3 % |
| 3. | Sudamérica | 768 | 15.0 % |
| 4. | Europa | 586 | 11.4 % |
| 5. | Centroamérica | 316 | 6.2 % |
| 6. | Asia | 165 | 3.2 % |
| 7. | Australia | 57 | 1.1 % |
| 8. | Africa | 35 | 0.7 % |
| | Desconocido | 1407 | 27.4 % |
| | Total | 5134 | 100.0 % |

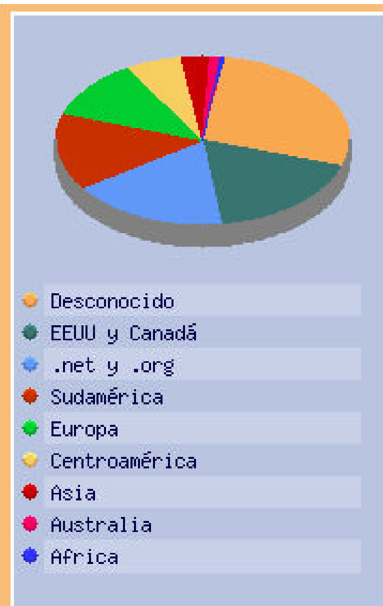



Figura-3 : Origen de visitas a la página Web por continente.

El cuadro-2 muestra la lista descendente por número de visitas de los 20 primeros países con mayor frecuencia de visitas. El grupo de visitantes de organizaciones sin ánimo de lucro ocupa el primer lugar seguido por Estados Unidos, Colombia y México. Las instituciones Educativas y Comerciales de Estados Unidos ocupan también un lugar importante en la lista.

Un total de 77 países (12 más que el año anterior) a través de los diferentes continentes, aparecen registrados con usuarios que han visitado nuestra página web.

En cuanto al uso de las bases de datos del proyecto BP1 vía Internet, las estadística del sistema de información muestran que durante el presente año se realizaron 2347 consultas a la base de datos de América Latina, 944 a la base de datos de Colombia y 52 consultas a la base de datos de variedades.

Cuadro-2: Origen de visitas a la página Web por País de Procedencia.

**País de procedencia**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. | Organización sin fines de lucro | 767 | 14.9 % | 11. | Brasil | 84 | 1.6 % |
| 2. | Estados Unidos | 466 | 9.1 % | 12. | Canadá | 77 | 1.5 % |
| 3. | Colombia | 384 | 7.5 % | 13. | Perú | 76 | 1.5 % |
| 4. | EEUU Instituciones Educativas (.edu) | 224 | 4.4 % | 14. | España | 66 | 1.3 % |
| 5. | México | 194 | 3.8 % | 15. | Japón | 60 | 1.2 % |
| 6. | EEUU Comercial (.com) | 124 | 2.4 % | 16. | Argentina | 56 | 1.1 % |
| 7. | Red | 123 | 2.4 % | 17. | Países Bajos | 54 | 1.1 % |
| 8. | Inglaterra | 122 | 2.4 % | 18. | Francia | 49 | 1.0 % |
| 9. | Alemania | 106 | 2.1 % | 19. | Australia | 49 | 1.0 % |
| 10. | Venezuela | 95 | 1.9 % | 20. | Bélgica | 42 | 0.8 % |

## Output IV. Institutional Capacity for Assessment Enhanced

### 1.1 Monitoreo y Evaluación de la Investigación en la Orinoquia y la Amazonia de Colombia - *L. Rivas.*

**Meta para 2001**: Diseño un sistema de monitoreo para el Convenio de Cooperación Científica y Técnica MADR - CIAT

**Resultados sobresalientes**

**?** Dentro de un esquema teórico de rutas críticas para lograr impacto se evaluó y analizó el Convenio MADR – CIAT en su conjunto y en términos de sus componentes o metas. El análisis se centro alrededor de las actividades desarrolladas por cada componente y los productos/resultados técnicos esperados.

**?** Este fue el paso inicial, para la elaboración de un marco conceptual de referencia que incluye la estructuración y articulación de las diferentes metas y los resultados esperados del Convenio, así como también elementos conceptuales relacionados con los procesos de adopción y difusión tecnológica y los métodos y herramientas para el monitoreo y la evaluación del impacto.

**?** Se identificaron los productos y resultados tecnológicos del Convenio durante los dos primeros años de ejecución, 1999-2000. Dada la gran heterogeneidad de los resultados científicos, que van desde conocimientos básicos de apoyo a la actual y futura investigación, pasando por nuevas metodologías y procedimientos hasta productos terminados listos para ser utilizados como son las bases de datos o los nuevos cultivares, ellos se agruparon en 7 clases o categorías.

**?** Se contabilizaron 152 productos/resultados tecnológicos aportados por las nueve Metas que conforman el Programa de Investigación. Más de la mitad de ellos (55.9%) se agrupa en dos categorías: a) nuevos conocimientos científicos y b) desarrollo de cultivares y sistemas de producción.

**Informe de Avance:** El Convenio de Cooperación técnica y científica suscrito en 1998 entre el Ministerio de Agricultura y Desarrollo Rural de Colombia (MADR) y el Centro Internacional de Agricultura Tropical (CIAT), para ser ejecutado en el período 1999-2003, tiene como objetivo el desarrollo de nuevas alternativas para la producción agropecuaria en la Orinoquia y Amazonia del país.

Este acuerdo busca aprovechar al máximo la dilatada experiencia de trabajo del CIAT en la región objetivo en los temas de desarrollo de germoplasma de cultivos y de pastos y en el manejo de los recursos naturales, para promover un desarrollo agropecuario regional diversificado, eficiente y sostenible.

Adicionalmente el Convenio busca complementar y fortalecer las actividades de investigación y desarrollo realizadas por otras instituciones en la región de referencia.

En la actualidad dicho acuerdo registra avances que se expresan en numerosos productos/resultados técnicos y científicos logrados durante los años 1999 y 2000 los cuales se detallan en este estudio.

El trabajo de investigación del Convenio está estructurado alrededor de 9 Metas o subproyectos, las cuales se articulan y complementan para lograr el objetivo de dinamizar el crecimiento económico regional, mediante generación y utilización de nuevas alternativas y formas de producción apropiadas, mientras se mantiene y/o mejora la base de recursos naturales.

Una de las Metas es la evaluación del impacto económico, la cual se propone monitorear y evaluar los efectos económicos de los desarrollos técnicos logrados. La relevancia del trabajo de esta Meta radica en el hecho de que cada vez es mayor la escasez de recursos públicos, por lo cual es imperativo justificar ante la sociedad la inversión de esa clase de recursos en investigación agropecuaria. Para ello es preciso asegurar la pertinencia, eficiencia y eficacia de las acciones de investigación ejecutadas.

Dentro de este contexto el trabajo de monitoreo y evaluación se plantea como una herramienta que permite retroalimentar el sistema de investigación y apoyar el proceso de toma de decisiones.

Este estudio tiene como propósito presentar un marco conceptual para el diseño de un sistema de monitoreo e incluye los siguientes tópicos: 1) Rutas críticas para lograr impacto sobre el desarrollo. 2) Estructuración del Convenio MADR – CIAT en términos de Metas y logros esperados. 3) Etapas secuenciales del monitoreo y la evaluación del impacto. 4) Articulación de las Metas del Convenio y sus relaciones con los objetivos generales. 5) Identificación y categorización de los productos/resultados científicos obtenidos en el período 1999-2000. 6) Monitoreo de los resultados logrados y enfoques metodológicos para el monitoreo y la evaluación

Para establecer un marco conceptual de referencia el estudio plantea esquemáticamente el camino o ruta que deben seguir los productos/resultados tecnológicos generados por el Convenio, para finalmente lograr un efecto significativo sobre la meta social más importante, que es acelerar los procesos de crecimiento y desarrollo económico. En la figura 1 se presentan las rutas críticas, para alcanzar el impacto, de los productos tecnológicos que se esperan obtener del trabajo de investigación del CIAT, en el agroecosistema de sabanas, en el cual se enmarcan la mayoría de las actividades de investigación que adelanta el Convenio MADR – CIAT.

Las 9 metas o subproyectos que conforman el Convenio, para efectos del análisis, se agrupan en tres grandes áreas de investigación a saber: 1) Recursos genéticos. 2) Herramientas de apoyo para la toma de decisiones de investigación y para la planeación del desarrollo y 3) Diseño y ajuste de sistemas de producción y actividades de capacitación. En la figura 2 se ilustra como se articulan y complementan estas metas y áreas de trabajo, para obtener como resultado final nuevas opciones de germoplasma en términos de variedades e híbridos, nuevos y más eficientes sistemas de producción de diverso grado de complejidad que involucran distintos componentes de pasturas, cultivos y árboles.

Igualmente se espera que las actividades del Convenio en el área de referencia permitan obtener nuevos conocimientos científicos y metodologías que posibiliten al mismo tiempo, tanto acelerar los procesos de investigación como obtener más y mejores productos tecnológicos para el área de referencia y para otras zonas agropecuarias del país.

Adicional a la evaluación de la estructuración del Convenio en su conjunto, el estudio incluye un análisis particular para cada una de las metas, en términos de actividades a desarrollar y productos/resultados técnicos a lograr.

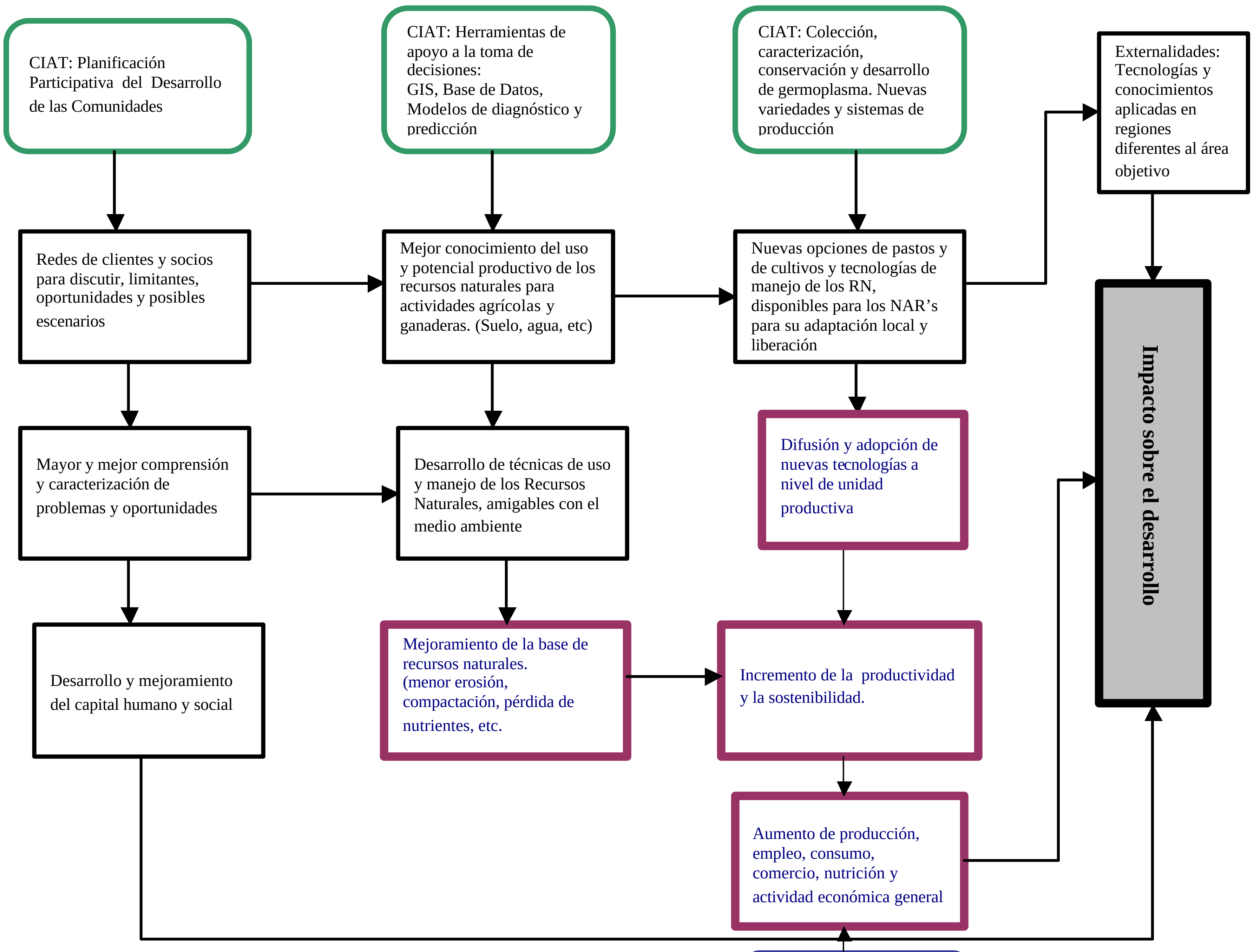



**Figura 1. Rutas del Impacto sobre el Desarrollo en el Agroecosistema de Sabanas**

En el trabajo se hace particular énfasis en la dimensión de tiempo dentro del proceso de monitoreo y evaluación y se plantea que existe un *continum* entre las actividades de investigación y desarrollo de nuevas tecnologías, los procesos de adopción y difusión y las actividades de evaluación del impacto del cambio técnico. Se enfatiza en el hecho de que el impacto de la investigación agropecuaria sobre el desarrollo no es inmediato: Debe transcurrir cierto tiempo entre el momento en que los productos técnicos son liberados por los centros de investigación, se adoptan y difunden entre los productores hasta que finalmente se observan mejoras en los indicadores de desarrollo tales como consumo por habitante, niveles de pobreza, uso de los recursos naturales, etc.

Con base en la revisión de los planes de trabajo y de los informes de avance se identificaron 152 productos/resultados científicos generados por las actividades adelantadas por el Convenio en el período 1999-2000. Estos se agruparon en 7 categorías a saber: 1) Nuevos conocimientos científicos. 2) Avances en recursos genéticos. 3) Desarrollo de cultivares y de sistemas de producción. 4) Investigación y validación en fincas. 5) Desarrollo de bases de datos y fuentes de información. 6) Capacitación y divulgación y 7) Liberación de cultivares.

En el Cuadro 1 se incluye una síntesis de la producción científica del Convenio en el período de referencia. Se identificó un total de 152 resultados/productos tecnológicos, los cuales se agrupan por meta y clase de producto/resultado técnico.

Más de la mitad de los mismos (56%) se concentra en las categorías 1 y 3, referidas a la generación de nuevos conocimientos y al desarrollo de germoplasma y de sistemas de producción.

Se plantea que los productos/resultados técnicos que liberan los centros de investigación para su utilización por productores/usuarios, son susceptibles de seguimiento para conocer el grado de difusión y los factores positivos o negativos que la condicionan, para finalmente evaluar su impacto sobre variables sociales y económicas críticas como producción, productividad, consumo, nutrición, pobreza, etc.

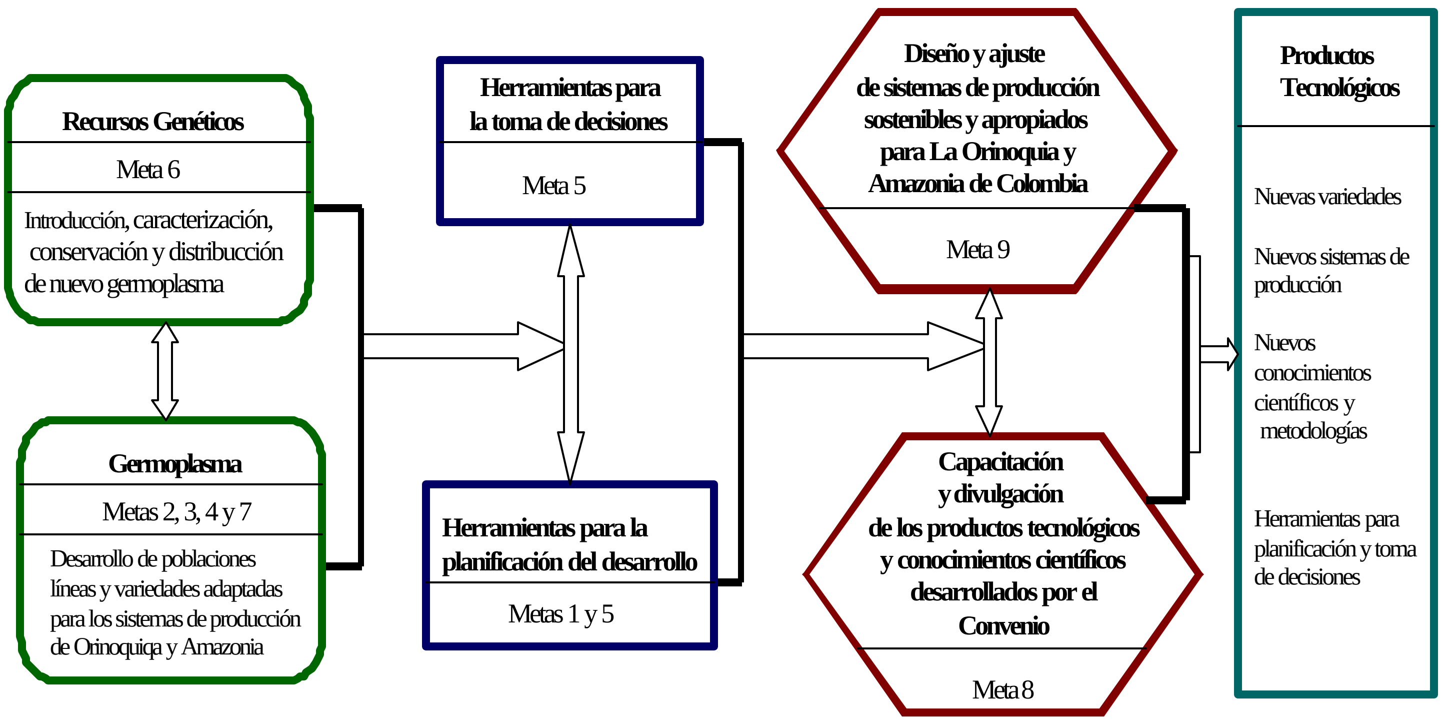
Se señalan los enfoques e instrumentos metodológicos más frecuentemente empleados para el monitoreo y la evaluación del impacto y se sugiere que para una eficiente retroalimentación es indispensable ordenar y sistematizar la información obtenida en una base de datos que incluya los siguientes elementos: 1) Información general sobre la estructura del Convenio, sus metas y objetivos. 2) Las actividades planeadas anualmente por cada una de las Metas. 3) Los informes de progreso de cada una de ellas. 4) Un inventario de los productos/resultados tecnológicos producidos anualmente. 5) Los resultados de los estudios de seguimiento y de evaluación del impacto.

En el Cuadro 2 y dentro del contexto del proceso de investigación – adopción – impacto, se incluyen los diferentes elementos de importancia crítica para las actividades de monitoreo, en cada una de las fases de dicho proceso.

## Figura 2. Convenio MADR - CIAT

### Estructuración del trabajo de Investigación

*Metas y Logros*



Cuadro 1 **Producción científica del Convenio MADR – CIAT, según meta y clase de resultado**

Número de resultados: 1999 - 2000

| Producción científica | Metas | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Biotecnología frutas | Arroz secano | Gramíneas y leguminosas | SIG Suelos y aguas | Recursos genéticos | Maíz | Capacitación/ Divulgación | Impacto | Carimagua | Total |
| 1. Nuevos conocimientos científicos: | | | | | | | | | | |
| - de apoyo a la investigación | 6 | 9 | 11 | 3 | 1 | 1 | | | 5 | 36 |
| - de aplicación por productores/clientes | | 1 | 6 | 2 | | | | 1 | | 10 |
| 2. Avances en recursos genéticos | 5 | | | | 8 | | | | | 13 |
| 3. Desarrollo de cultivares y de sistemas de producción | | 5 | 7 | | | 7 | | | 20 | 39 |
| 4. Investigación y validación en fincas | 3 | | 4 | | | | | | | 7 |
| 5. Diseño de bases de datos y fuentes de información | | | 1 | 10 | 1 | | | 3 | | 15 |
| 6. Capacitación y Divulgación * | 3 | 7 | | 2 | 6 | | 6 | | | 24 |
| 7. Liberación de cultivares | | 4 | 2 | | | 2 | | | | 8 |
| Total | 17 | 26 | 31 | 17 | 16 | 10 | 6 | 4 | 25 | 152 |

## Principales Conclusiones

Para efectos del diseño de un sistema de monitoreo, como paso inicial, se elaboró un marco conceptual de referencia que incluye la estructuración y articulación de las diferentes metas y los resultados esperados del Convenio, así como también elementos conceptuales relacionados con los procesos de adopción y difusión tecnológica y los métodos y herramientas para el monitoreo y la evaluación del impacto

Se identificaron 152 productos/resultados de la ejecución del Convenio durante el período de análisis, los cuales se agruparon en las siguientes categorías: ) Nuevos conocimientos científicos que incluye dos grupos: a) De apoyo a la investigación y b) De aplicación inmediata por productores/usuarios. 2) Avances en recursos genéticos. 3) Desarrollo de cultivares y de sistemas de producción. 4) Investigación y validación en fincas. 5) Diseño e implementación de bases y fuentes de información. 6) Capacitación y divulgación y 7) Liberación de cultivares.

Si bien la cantidad de logros representa una medida de la actividad del Convenio durante el período de observación, no hay lugar a comparaciones entre los distintos resultados, por tratarse de productos de muy variada naturaleza.

Las funciones de monitoreo y evaluación del impacto son claramente aplicables a esta clase de resultados técnicos. Sin embargo no es posible efectuar un seguimiento y evaluación de todos los productos tecnológicos obtenidos, por diferentes razones: 1) Es muy amplia y variada la gama de resultados obtenidos. 2) La adopción y el impacto en algunos casos solo son visibles varios años después de culminado el proceso de investigación. 3) La limitada disponibilidad de recursos para desarrollar estas funciones. Se plantea que la alternativa más viable es efectuar un seguimiento y evaluación selectivos del impacto en los casos de resultados tecnológicos en los cuales se observe cierto grado de adopción antes de la culminación del Convenio, p. e., variedades liberadas, metodologías entregadas.

Un elemento esencial para la retroalimentación es la organización, sistematización y disponibilidad para consulta de la información obtenida. Para este propósito se propone la implementación de una base de datos que incluya 1) Información general sobre la estructura del Convenio, sus metas y objetivos. 2) Las actividades planeadas anualmente por cada una de las Metas. 3) Los informes de progreso de las diferentes metas. 4) Un inventario de los productos/resultados tecnológicos producidos anualmente. 5) Los resultados de los estudios de seguimiento y evaluación del impacto.

**Donante:** Ministerio de Agricultura y Desarrollo Rural de Colombia. Convenio de Cooperación Técnica y Científica MADR –CIAT

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## Donors supporting research reported in this document

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- Germany (BMZ) (through Systemwide Participatory Research and Gender Analysis Program, PRGA).
- Latin American Consortium for Cassava Research (CLAYUCA)
- Norway (through Systemwide Program for Collective Action and Property Rights, CAPRI)
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