IMPACT ASSESSMENT

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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 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 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). • Results of impact analysis used in decision making and priority setting. • Economic and environmental impact of selected past research identified and quantified.	Scientific publications from BP-1 and other projects. Published planning documents of CIAT and partner organizations. Published minutes of planning meetings in CIAT (BoT, MT, Project Managers) and partner organizations. External reviews of CIAT. Data on use of CIAT-developed tools.	Adequate funding to agricultural research and extension. Decision makers willing to use economic analysis in research priority setting.
Output 1 Expected impact of future research estimated.	• Expected rate of return for potential research projects estimated. • Expected economic, distributional, and environmental impact identified and quantified.	CIAT technical publications. CIAT published planning documents.	Willingness of decision makers to use the information. No external shocks that invalidate the results.
Output 2 Impact of selected past CIAT research documented.	• Economic, social, and environmental impact of CIAT research outputs identified and quantified.	CIAT technical publications.	
Output 3 Tools developed to assess the impact of research, *ex ante* and *ex post*.	• Methodologies generated. • Databases compiled and maintained.	Scientific publications and other technical publications such as manuals and guidelines. Databases available on BP-1 sites on Internet, on CIAT's internal network, and in BP-1's data library. Site flow data from web sites. Data on registered users of BP-1 software. Citations of project publications and tools in technical publications.	Analysts willing to use the tools in their impact analyses. Data available for using the tools.
Output 4 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. Work plans of CIAT researchers. Research proposals submitted by projects. 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.

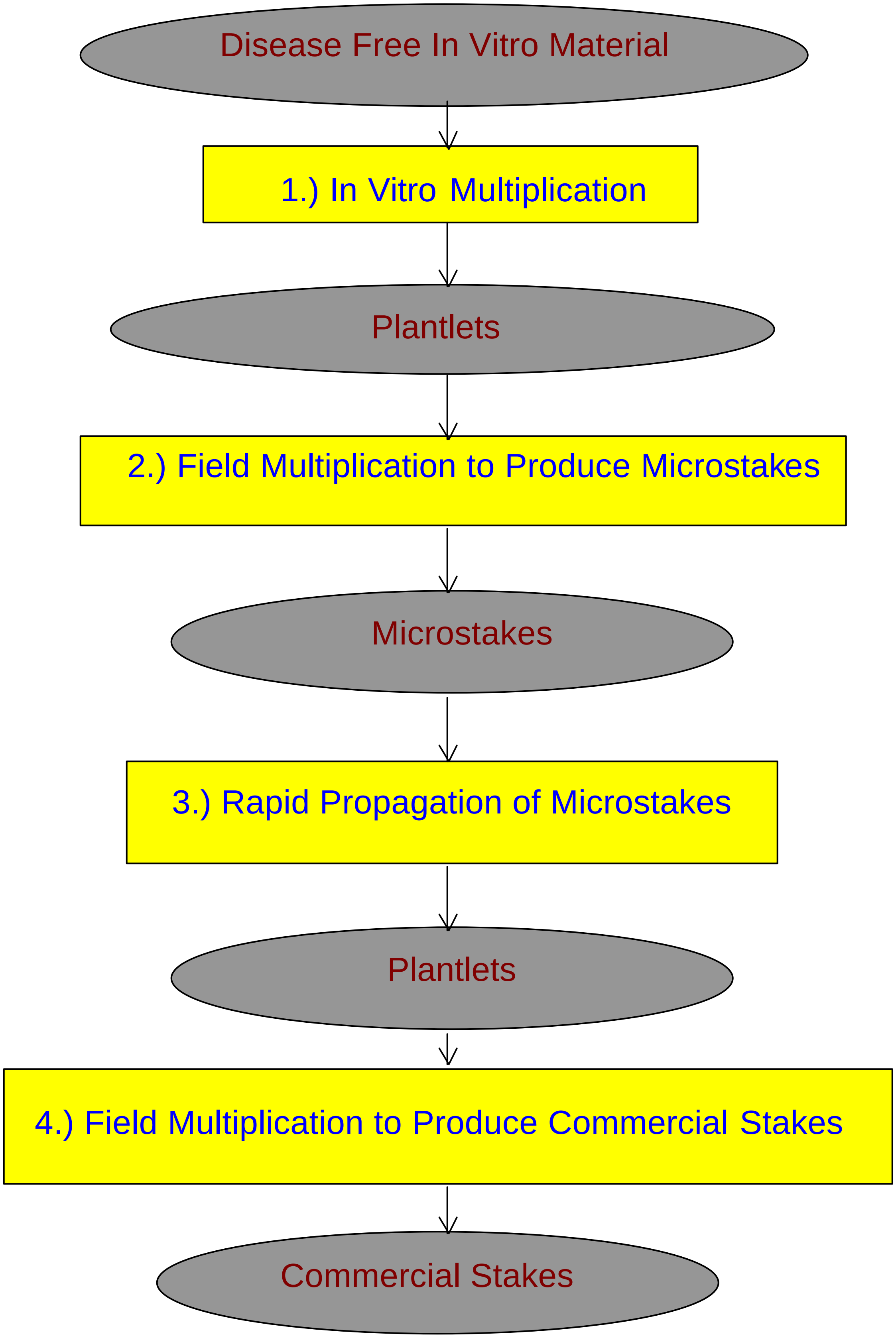
The second step of this process to produce commercial disease free cassava planting material is field multiplication of plantlets to produce microstakes. This stage of the process takes the 135 plantlets from the first stage and transplants the plantlets outdoors to normal field conditions. During the 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: <u>FIELD MULTIPLICATION TO PRODUCE MICROSTAKES (135 m^2)</u>

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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