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Methods for Diagnosing Research System Constraints and Assessing the Impact of Agricultural Research

Volume II: Assessing the Impact of Agricultural Research

Proceedings of the ISNAR/Rutgers Agricultural Technology Management Workshop, 6-8 July 1988, Rutgers University, New Jersey, USA

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INTEGRATED EX ANTE AND EX POST IMPACT ASSESSMENT IN THE GENERATION OF AGRICULTURAL TECHNOLOGY: CASSAVA IN THE ATLANTIC COAST OF COLOMBIA

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Abstract

Initially, strategies of technology development are based on ex ante judgments of potential impact, but information that arises as the technology is developed allows the chosen strategy to be readjusted. Consequently, impact assessment and technology development become integrated in a continuous interaction between social and technical disciplines, requiring scientists with economic as well as sociological skills to become involved. Their main role starts out as identifying constraints and opportunities for new technology, estimating potential impact, and designing methods for technology dissemination. As the technology-development effort evolves, their role comes to involve the revision of potential impact and of the development strategy, based on continuous monitoring. The present paper elaborates the concept of ex post and ex ante impact integration, describes possible impact assessment methodologies, and illustrates these with data from a joint CIAT/DRI project in the Atlantic Coast of Colombia. In this project, a cassava-drying industry was established, involving changes in production technology and the introduction of new processing and marketing methods. Ex ante analysis stressed the benefits of the project to the small farmer, while the monitoring effort measured distributional benefits and readjusted the project strategy. The continuous impact assessment allowed increased goal orientation and improved distributional and total effectiveness of the project.

Introduction

Efforts aimed at generating technology can be placed into two broad categories. The first concerns research, frequently seen as a creative process in which innovative solutions (out of the reach of nonspecialized people) are identified. The second category concerns development, the collection and application of these solutions to a specific situation. Development is more of a managerial than a creative process.

A second distinction with respect to technology generation is the *ex ante* versus the *ex post* measurement of impact. Ex ante impact measurement is linked with research, in order to define the pay-offs of alternative research strategies. Ex post impact measurement comes after research and development (R&D) and reviews the effectiveness of a given R&D effort. Ex ante impact evaluation has a speculative focus; ex post impact evaluation, an historic focus. In cases where both types of analysis are applied, the time span between one and the other could be considerable.

When development projects are similar to earlier projects, ex post evaluation of the earlier projects can be useful. With an original project, such information is available only after critical decisions have been made — too late for ex ante evaluation. However, because research projects are creative in nature, and therefore, original, similar projects are not available for ex post evaluation.

The distinction between research and development implies a certain rigor in technology generation. Research comes first; development takes the research results and applies them in a specific socioeconomic context. Unfortunately, in this situation, information feedback is constrained, and the flexibility of technology generation suffers severely. This problem has been recognized widely and has given rise to the development of on-farm research methods, among other things.

The present paper presents a case study on a project with more advanced integration of research and development (outside on-farm research). Ex ante and ex post evaluation are interwoven in a simultaneous and continuous socioeconomic monitoring process. What results is a project of a genuinely mixed nature, where research and development have creative as well as managerial characteristics. A continuous flow of new information leads to stepwise reassessment of earlier decisions, such as that based on ex ante knowledge. In turn, this leads to increased goal orientation and improved distributional and total effectiveness of the project.

The project described in this paper is located in the Atlantic Coast Region of Colombia and was executed in very close collaboration with the Colombian

Integrated Rural Development (DRI) Program. It focuses on one of the most important crops in this area, cassava.

Before the actual integration of research and development and ex ante and ex post evaluation in the project can be discussed, the efforts at generating technology must be classified. This classification can then be used to forecast the potential benefits of the project, providing the basis for the managerial choices made. These forecasts and decisions are then reviewed in light of the information that became available through socioeconomic project monitoring, and subsequent project redirection is discussed. Finally, we examine the feasibility of integrated project evaluation.

Generating Crop Technology and Its Usefulness for Cassava

Following Ruttan's (1982) classification, four dimensions in the process of generating cassava technology for the Atlantic Coast Region of Colombia were considered:

1. The geography. Although the Atlantic Coast Region was predefined, the heterogeneity of the region might require further attention in generating technology. The potential impact and the effects of equity are major criteria for region selection.

2. The range of product activities from which to choose. Both authors were members of CIAT's cassava program when the research reported here was undertaken. In the present study, this dimension was predefined (it will be clear that this was justifiable).

3. The commodity system. For every commodity, there is a set of integrated production, marketing, processing, and consumption activities. One should know in which activity technological improvements will have the greatest impact and how other parts of the system may modify this impact. This dimension proved to be of critical importance for this reported study.

4. The disciplinary organization of crop technology generation. On the one hand, technology generation requires researchers (who have a plant, soil, social, or economic orientation). On the other hand, it needs technology "diffusers" from a similar range of disciplines. The separation between diffusion and research is not always very clear, but decisions on disciplinary composition as well as on research versus extension are critical for any successful effort in generating technology.

With cassava, technologically induced increases in production have often led to a decrease in farmers' incomes due to constrained markets. Projects have been located in areas without sufficient production potential. Often, the available technology (especially for processing) has not been compatible with the scale of production. And production costs have limited the possibility of expansion in stagnant areas where nothing really happened. Such experiences, among others, have indicated the need for a new, integrated vision of cassava development. The distinction made by Ruttan (1982) will be instrumental for developing this vision.

Integrated Generation of Cassava Technology in the Atlantic Coast Region of Colombia

The Atlantic Coast Region of Colombia is a tropical region, approximately 120,000 square kilometers in area, with low to moderate rainfall. Its population totals some five million souls, of whom 70% are living in urban areas. Land distribution in the region is highly skewed, a consequence of the prolonged colonization process (Spijkers 1983). More than 85% of the land is in the hands of fewer than 20% of the land owners. While large farmers mainly involve themselves in cattle production, small farmers need more intensive, but also riskier, crop activities to earn their living. Because cassava can tolerate the erratic rainfall and the intermediate fertility of the region better than other crops, it is important in small-farm agriculture.

The decision to research cassava for this region is an obvious one, given its importance in small-farm production on the one hand and human consumption on the other. Cassava is rarely grown in monoculture in the region — it is usually found in fairly complex associations with maize, maize and yams, or maize, millet, and pigeon peas. When possible, cassava farmers allocate parts of their land resources to cattle holding. The cattle serve as a risk absorber, a source of nutrition, an instrument of savings and cash flow, and a flexible labor activity. (For detailed information on how cassava development in the region has affected other crops, see Janssen [1986].)

The commodity system proved to be the most critical factor for the generation of cassava technology in the region; therefore, the ex ante forecasting focused on this dimension. Human consumption of fresh cassava is and was the major utilization of the crop. Consumption of fresh cassava is significantly lower in urban than in rural areas because it is a difficult product to market. The on-going urbanization in the country has resulted downwards pressure on cassava demand. At the same time, market channels for nontraditional food crops has improved (e.g., potatoes from the Andean region), exerting additional negative pressure on cassava demand. Also, many producers in the region market their supply very narrowly, subject to strong price fluctuations, and where only the better roots are acceptable for sale. Initial diagnosis of the cassava system suggested that low productivity was related to price instability and deteriorating demand. Amplification and diversification of the market was most needed, rather than any improvement in productivity.

Two technological solutions to the market problem were suggested. The first involved improving cassava's marketability by packaging it in a plastic bag. The plastic bag, in combination with some harmless fungicide, inhibits physiological and microbial deterioration (Janssen and Wheatley 1985). This means that traders would have less waste from deterioration and consumers could buy larger quantities.

The second solution involved developing a drying industry that would sell cassava chips to the rapidly growing animal-feed sector. In this market, cassava prices are linked to government-supported sorghum prices, and sorghum is the main animal feed ingredient in Colombia. In this paper we will discuss forecasting for the cassava-drying industries and the ex ante evaluation of developing the drying industry versus improving the market for fresh cassava. For reasons of brevity, specific issues involved in improving the market for fresh cassava will not be discussed here.

For the ex ante forecaster, the challenge is how to integrate processing and marketing technology with production and consumption, considering the possibilities of substitution with other products or activities at different levels of the product chain. The exercise undertaken here was also complicated by the absence of reliable time series on production, consumption, and price.

Ex ante Impact Estimation Procedures

Two major questions needed to be resolved in order to obtain good forecasts on the development of cassava-drying industries. These questions concern market risk and its influence on production patterns, and the development of demand for fresh cassava versus dried cassava. Given the hypothesis that changes at one level of the product chain might have consequences at other levels, the individual answers to these questions were not considered to be sufficient. It was deemed necessary to integrate the basic mechanisms with respect to these questions in a simulation model.

Assessing Market Risk and Its Impact on Agricultural Production

Does market instability really increase the risks the farmer faces? The traditional hypothesis is that prices are high when supply is low, in which case market instability compensates price instability (Robinson 1975). However, for individual farmers, or subregions, production conditions in a specific year can differ considerably from the average. That is, aggregation to market level eliminates the variability and insecurity that a single farmer faces. Market instability, then, should be studied at the individual level.

An interview procedure with flash cards was designed to match production expectations with market expectations. Table 1 presents the average results of these interviews. It is clear that price expectations and yield expectations are not significantly related. Consequently, the coefficient of variation of income is 0.36, while the coefficient of variation of yield is 0.33. Market instability increases the farmer's income risk, and one might suspect that it also influences production decisions.

Table 1. Subjective Yield and Price Probabilities for Cassava

	Expected Yield good year (10.5 tons/ha)	Expected Yield normal year (7.3 tons/ha)	Expected Yield bad year (4.2 tons/ha)	Average probability
Expected price good market (US$ 0.114/kg)	0.07	0.12	0.17	0.36
Expected price normal market (US$ 0.83/kg)	0.16	0.14	0.07	0.37
Expected price bad market (US$ 0.055)	0.18	0.08	0.02	0.28
Average probability	0.41	0.34	0.26	
Expected price =	US$ 0.085/kg		C.V. = 0.28	
Expected yield =	7.8 tons/ha		C.V. = 0.33	
Expected income=	US$ 653/ha		C.V. = 0.36	

In the same interview procedure, it was established that market prices present too favorable an impression on cassava's profitability. This is because some 13% of cassava was not acceptable for fresh markets and because the farmer had high transportation and market arrangement costs. The cassava price obtained by the farmer was some 24% higher than the price corrected for selection and marketing costs.

The next question was to assess the effect of cassava's market instability on production. Two methods were used to answer this question, a normative and a positive one. The positive method consisted of an elicitation approach with respect to planting behavior at contracted prices. The normative method consisted of the development of a quadratic programming (QP) model that evaluates price instability. Appendix 1 provides methodological detail on these methods, as well as their advantages and disadvantages. Table 2 summarizes the main features of these methods, along with other methodological procedures used in this paper.

Table 2. Main Features of ex ante Technology Development and Impact Assessment Methods Used in Atlantic Coast Region of Colombia

Forecasting/ Project Management Method	Sources of Information	Main Focus of Method	Methodological Complexity	Disciplinary Orientation	Expected ex ante Reliability	State of the Art of Comparable Methods
Assessment of market risk	Personal interviews	Partial supply-side analysis	High	Fare economics	Intermediate	Sophisticated for production risk Less developed for market risk
Estimation of alternative demand	Mail questionnaires	Possibility of project growth	Intermediate	Market economics	Good	Well developed (marketing)
Simulation models	Previous analytical studies	Ex ante impact comparisons	Very high	Agricultural economics	Bad in absolute sense Good in comparative sense	Methodologies available Applications rare in ex ante framework
Selection of region	Secondary data	Efficient project design	Low	Geography	Good	Simple
Estimation of institutional strength	Key informants	Expected project growth rate	High	Organizational sciences	Bad	Absent

The expected production changes per farm, resulting from the market stabilization caused by the development of a cassava-drying industry are given in Table 3. The elicitation approach forecasted larger changes in area planted than the quadratic programming approach. This is because the QP model overestimated the initial area planted. The absolute difference in area planted for the two methods is very similar, except for small farms. In any case, both methods forecast considerable allocation shifts if cassava markets were to be stabilized through a drying industry. Both methods forecast bigger shifts for large farms, compared to small.

Table 3. Expected Effect of Price Stabilization (Occurring as a Result of Establishment of Cassava-Drying Plants) on Area Planted to Cassava

	Area Planted (ha)			
	Existing Situation	Expected Situation	Absolute Difference	Percentage Difference
Small Farm (3 ha)				
Elicitation approach	1.54	1.96	0.42	27
Quadratic programming	1.76	1.93	0.17	10
Middle-Sized Farm (8 ha)				
Elicitation approach	1.90	3.09	1.19	56
Quadratic programming	2.84	3.97	1.13	40
Large Farm (15 ha)				
Elicitation approach	2.23	3.83	1.60	72
Quadratic programming	3.08	4.25	1.17	38

The hypothesis that market problems constrain cassava production, as well as that a drying industry might increase the role of the crop in the region, was clearly supported. Effective cassava development thus became dependent on the adequate integration of marketing and production. The question became one of how to arrange access for small farmers to the large-volume animal-feed market. Small-scale natural drying plants, organized through farmers' associations appeared to be the answer, as will be discussed in more detail in the project design section of this paper.

Since quality restrictions in the animal-feed market were less stringent than in the fresh cassava market, the introduction of high-yielding, but less culinary, varieties could ease this problem. The analysis suggests that drying plants should be concentrated in areas with low-quality cassava, where large amounts are discarded and prices are low.

The forecasts show considerable production increases among all farm groups, but most with larger farmers. Also, given the need to finance drying plants, it was concluded that drying projects should be directed to the larger of the small farms and to those areas where land is available to expand production. The economic forecasts demonstrated that cassava projects could be focused on poor farmers but that some resource availability would enhance their potential. The resulting conclusion was that cassava projects are only one component of rural development. Especially if small farmers are to be effectively included in these projects, other components, such as production and processing credit, must be in place.

Since the expected benefits at this stage of the analysis were measured as a function of cassava production, farmers with the ability to increase production showed up as the most feasible target group. One can conclude that the chances of improving cassava productivity appeared good — once the spell of the unstable and nontransparent fresh cassava market was broken.

Alternative Demand Estimation and Its Integration with Fresh Cassava Demand

The previous section suggests that it is feasible to integrate small farmers in animal-feed markets. The potential benefits of such a strategy depend to a large extent on the future demand for dried cassava. An assessment of the animal-feed industry's demand for dried cassava was therefore needed.

The animal-feed industry can be considered a very rational consumer of raw materials. Quality differences of raw materials are reflected in price differences. In fact, most animal-feed industries use minimum-cost, linear programming models to decide on the purchase and utilization of raw materials.

On the basis of the procedure reported in Appendix 2, a potential national demand of some 140,000 tons of dried cassava was estimated. This equals 350,000 tons of fresh cassava, 50% of existing production. Some 30% of this demand was located in or near the Atlantic Coast Region. A price elasticity of -3.18 was found, which is a very high value, but it is in accordance with the fact that the animal-feed industry is very price sensitive.

At the same time, equations for calculating the market demand for fresh cassava for human consumption were estimated in a region-wide survey. Margin marketing behavior was determined, and coupled with final consumer demand, farm-gate demand functions were derived. Demand for dried cassava at the animal-feed factory was converted into fresh cassava equivalents at the farm gate. The different demand functions were added into a total demand function.

It appeared that the demand for dried cassava could provide an incentive for cassava production. The high price elasticity confirmed the expected price stability in this market, as long as sorghum prices were stable. Attention, therefore, turned to the development and implementation of technology for small-scale processing so that dried cassava of sufficient quality could be produced at a minimum cost to the producer.

The absorption capacity of the regional dried-cassava market appeared sufficient for rapid initial development of a drying plant. Research to reduce transport costs was only considered necessary in the intermediate term. The large potential for national demand suggested that research on the utilization of dried cassava was not needed. Linking small farmers with the animal-feed market through small-scale drying plants appeared an excellent means to convert resource-poor peasants into entrepreneurial farmers.

One useful side benefit was the contacts established with potential purchasers. Afterwards these were consolidated in a client data base, which could be used to establish sales contacts. Impact forecasting thus had direct managerial input as well.

Integrated ex ante Forecasts of Cassava Development through Simulation Models

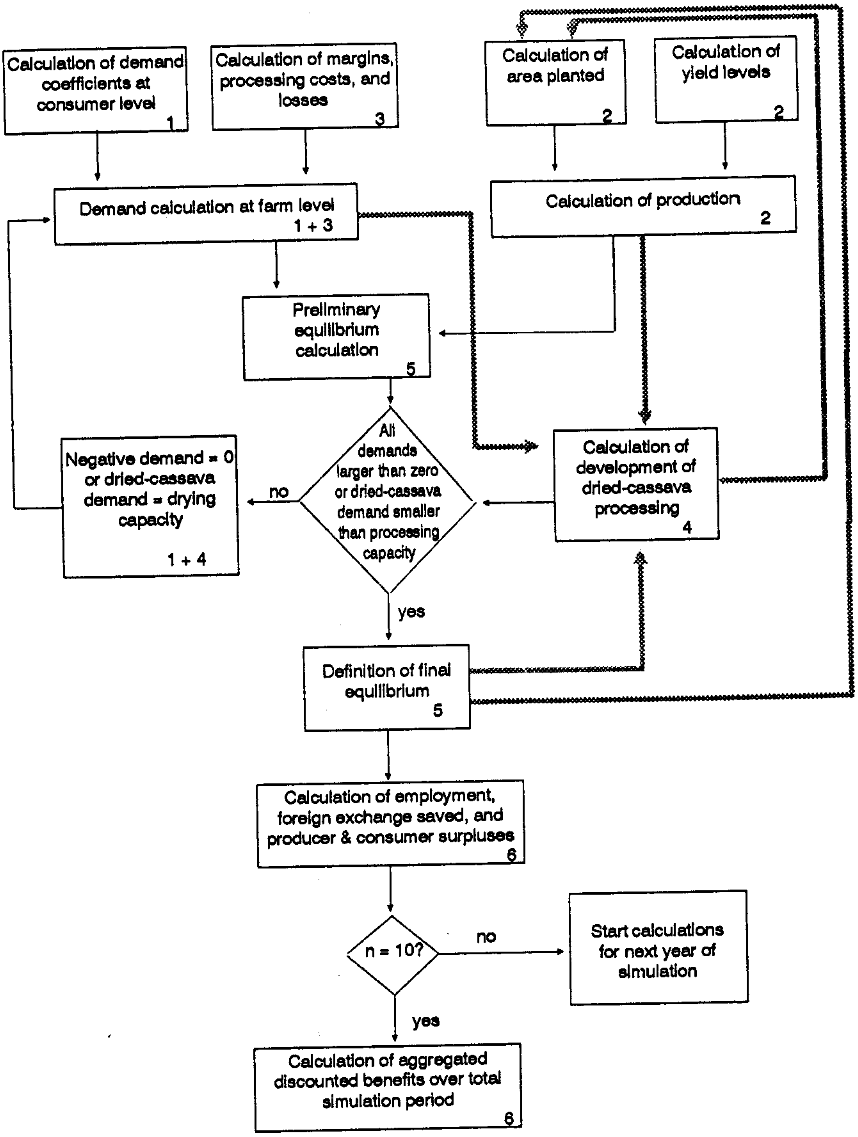
The first parts of this analysis forecasted supply and demand for a cassava-drying industry. Extensive marketing and consumption studies on fresh cassava and marketing and processing studies on dried cassava were also made (Janssen 1986) but are not reported here. While providing an insight into the mechanisms determining the *potential* of cassava development, these studies did not shed much light on the *dynamics* of that development. They provide estimates on production and consumption shifts per individual but not on overall expected developments in commodity systems. To estimate regional production and consumption shifts as well as the different benefits of cassava development, a simulation model had to be developed.

The model is recursive, with a 10-year horizon, and interprets the static results of the former analysis in a dynamic context. Demand equations include population and income growth, a distributed lag specification is chosen for cassava supply, and the development of the cassava-drying industry is endogenous to the model. A schematic presentation of the model is given in Figure 1; a brief explanation is given in Appendix 3.

The model was first used to evaluate the development of a cassava-drying industry versus the development of fresh-market storage methods, in comparison with no development of the cassava system. The model was also run at different assumptions, including expected cassava productivity, growth in the drying industry, and growth in demand for dried cassava. A summary of results is presented in Table 4.

The first outcome of the model is that without the development of economical drying or storage, the cassava industry essentially stagnates at current levels of production and consumption. The effect of the growing population is also countered by rural-urban migration and the substitution of cassava with more convenient foods.

The development of a drying industry, along with storage, significantly changes the prognosis. With a drying industry, production would increase



Notes: Solid lines indicate the effect within one year of simulation; broken lines indicate the effect from one year to the next. The influence of exogenous variables has been omitted from the diagram. Numbers at the bottom of the blocks correspond to model components as explained in the text.

Figure 1. A schematic representation of the Atlantic Coast cassava system simulation model

Table 4. Results of Simulation for the Cassava System in the Atlantic Coast Region of Colombia: Production, Consumption, and Social Benefit Parameters

	1985	A 1994	B 1994	C^1 1994	C^2 1994	C^3 1994	C^4 1994
Total production/year	480,878	497,001	551,886	666,137	682,471	698,738	678,255
Average yield (tons/ha)	6.82	7.1	7.44	8.2	8.5	8.35	8.25
Area planted (ha)							
—large farm	26,801	26,398	28,743	32,496	32,078	33,710	32,956
—medium farm	21,142	20,916	22,301	24,708	24,472	25,433	24,972
—small farm	22,502	22,344	23,076	23,699	23,583	23,983	23,821
On-farm cassava price (US$/kg)	0.085	0.076	0.088	0.082	0.81	0.85	0.85
Cassava consumption/capita (kg)							
—Urban population	29.9	21.6	39.4	21.1	21.2	21.0	21.9
—Rural population	80.6	63.7	83.3	62.2	62.6	62.7	61.5
Consumption of dried cassava (tons)	4,089	4,681	3,494	80,108	84,880	95,797	88,593
Rural employment in cassava-related work (person-years)	21,608	21,541	23,740	27,422	27,530	28,597	27,927
Producers' surplus (million US$)	n.a.	—	20.6	33.3	33.1	50.8	35.8
Consumers' surplus (million US$)	n.a.	—	40.0	-5.7	-4.3	-8.3	-6.5
Animal-feed industry surplus (million US$)	n.a.	—	-1.9	7.2	8.5	8.1	7.0
Total surplus (million US$)	n.a.	—	58.7	34.8	37.4	50.6	36.3

Note: 1985 = Situation at the start of the model.
A = No development of drying industry, no development of fresh storage (base run).
B = Technology for storage of fresh cassava successfully introduced.
C^1 = Successful development of cassava-drying industry.
C^2 = Yield increase 50% above estimated increase.
C^3 = Drying industry grows at double the expected rate.
C^4 = Demand for dried cassava grows at double the expected rate.

at 3.7% per year. Improved storage would induce a growth rate of some 1.5% per year. In both cases, the expected decline in the farm-gate price would be countered, but improved storage would have a greater impact on this. Although cassava is mainly grown by small farmers, drying would favor the larger small farmers the most. The development of a drying industry would have the greatest impact on area planted and yield than would improved storage of fresh cassava.

The impact of the development of alternative markets on traditional markets is a major point of interest. Cassava drying would slightly reduce fresh cassava consumption, but it would almost completely generate its own supply. Improved storage of fresh cassava would firmly reverse the present trend in declining consumption.

The benefit parameters show that cassava drying would create significant rural employment as well as rural income (as measured through the producer's surplus), more so than improved storage of fresh cassava would. The technology for improved storage would generate more consumer benefits in the form of reduced consumer prices. Drying may be considered a rural strategy, while improved storage is an urban strategy.

Although total benefits in the case of storage are greater, this strategy appeared riskier and was not oriented towards redressing the structural unbalance in rural-urban development. For this reason, the development of a drying industry was given priority.

The size of the total benefits that would result from developing a cassava-drying industry were more sensitive to growth in drying capacity than to growth in either productivity or demand for dried cassava. In fact, benefits to producers are barely affected at all by differences in productivity growth; the animal-feed industry is the area that benefits most. A more rapid increase in the demand for dried cassava would mainly affect urban consumers but would not give cassava producers greater benefits.

A simulation model always responds to the assumptions on which it is constructed. Some conclusions were logical extensions of the previous analyses, such as the size of the benefits accruing to large versus small farmers from the development of a drying industry. Other conclusions, however, could not have been derived without the capacity of such a model to integrate and compare complex mechanisms at different levels of the commodity system. The overwhelming importance of building a drying plant versus developing production had not been foreseen. The impact of improved storage of fresh cassava was larger than expected and gave rise to some small-scale storage projects.

A major conclusion from the simulation was that emphasis should not be put on improved utilization of dried cassava (e.g., by nutritional research), nor on pursuing rapid increases in productivity. The greatest benefits could be gained by focusing on developing a drying industry. In more abstract terms, growth in neither productivity nor demand would be the key factor for improving the role of the crop in the region — it would be the linkage of demand with production.

The simulation model suggested that cassava's development depends on the capacity to redefine the role of the crop in the rapidly changing structure of

Colombian agriculture. Whereas for traditional rural consumers, decreases in production costs would enhance the dietary role of the crop, improvements in marketability would have the greatest impact for the growing group of urban consumers. With respect to the animal-feed industry, 20 years ago it was nonexistent, but now it could provide an opportunity for long-term growth in production and income for cassava farmers. The simulation model became the ex ante proof that the integrated analysis of the cassava commodity system could provide adequate parameters for technology design that could not be obtained in more isolated production analysis. The model also showed that crop development should not depend only on solving the technological problems of today, but even more so, must depend on the anticipation of future problems and opportunities.

Issues in the Design and Transfer of Cassava Technology

The ex ante forecasts reported in the previous section provided a considerable number of design criteria, which were especially useful in defining organizational concepts: the ownership of the cassava-drying plants, the selection of the region, and the disciplinary composition and institutional strength of the project team.

The Organizational Concept

The risk assessment of the cassava market made it clear that drying plants could stabilize markets and help increase production. Why, then, had this development not taken off by itself? Timing appeared to be one reason. The slow deterioration of the market for fresh cassava, coupled with the recent arrival of a rural development program and a rapidly growing market for animal feed, provided the conditions in the early '80s to foster the development of a cassava-drying industry in the region.

Another reason for the absence of spontaneous development was the price illusion in the market for fresh cassava, where only good-quality cassava could be sold. The availability of low-quality cassava would be a significant force in the development of a cassava-drying industry. The ability to sell commercial-quality cassava to a drying plant in years of poor market conditions for fresh produce would form a secondary force. A successful drying industry could depend on the establishment of close relationships between farmers and drying plants, and the development of small-scale drying plants appeared to be the most appropriate solution.

It was decided that a pilot drying scheme in one area would be started before development on a larger scale was stimulated. Such a pilot project would allow for technology adaptation at the processing level, could be the basis for establishing commercial contacts, and could also help in finding locations for agronomic experiments on increasing cassava productivity. The pilot project would hopefully provide insights into previously unresearched issues. It could also serve to test the possibilities of linking small farmers with the large market for animal feed. The pilot project is expected to provide a small-scale, neutral prototype for cassava development that can be easily copied in other parts of the region.

Ownership of Drying Plants

Drying plants could be owned by private entrepreneurs, individual farmers, groups of farmers, or state organizations. State organizations were ruled out because this implied long-term government involvement and in some ways contradicted the assumption that cassava drying would be profitable

The choice between farmers and entrepreneurial ownership was based on the expected character of the drying plants, as arising from the market assessment. In their initial stages, cassava-drying plants were expected to play an important role in stabilizing the market fresh for fresh produce. This implied that in years with very high prices for fresh cassava, drying activity might be very low. In such a situation, the income from cassava processing would be rather unstable and would not offer a sufficiently secure profit to private entrepreneurs. Drying plants would allow farmers to play their market with more success by selling either in the fresh or the dried market, so ownership would be most attractively located with the cassava producer.

Nevertheless, small, individual cassava growers would not produce enough to enter the large-scale animal-feed market, nor would they have sufficient capital or credit to build their own plants. The organization of farmers in associations appeared to be the best form for obtaining a minimum processing capacity as well as sufficient credit and capital. Farmers' associations would also be able to provide the labor to run the plant from their own ranks (Bode 1986).

Region Selection

The Atlantic Coast Region is too large and diverse for an overall effort to generate technology. Once the pilot phase was passed, the selection of target regions for developing drying plants was seen as one of the first requirements for rapid initial development of the industry. The relevant part of the region is divided into four subregions, and these were taken as the basis for selection. Although the borders of these subregions do not completely reflect ecological differences, they form political boundaries for all rural development in the region and appeared to be the best reflection of the regional dimension of technology generation.

Three criteria for region selection were identified. The first two criteria, production and processing potential, defined the suitability of the region and were largely based on the outcomes of the market risk assessment and the simulation model. The third criteria, the project's impact on the selected area, attempted to maximize social pay-offs.

For each criterion, a number of determinants were fixed. The resulting decision scheme is shown in Table 5. After recollection of regional data, Table 6 resulted. The subregion of Cordoba is ranked as the best place to develop a cassava-drying industry, and Sucre is the second best. Between the two other subregions, no clear choice could be made. Equity considerations favored Bolivar, but processing feasibility favored Atlantico. The choice was left to the government officials in charge. Since scores on all determinants were known, they had all the tools for an easy decision available.

Disciplinary Composition and Institutional Strength

Plant development and market linkage appeared to be the critical factors for developing a cassava-drying industry in the region. Therefore, the initial bias in disciplinary input was towards processing, marketing, and economics. Production research was supposed to become useful only after new or improved markets for cassava had been opened. Agronomic experiments were begun, but the lag time for adoption of new technology was expected to be several years.

After the pilot phase, when the project was supposed to cover more areas in the region, institutional strength was expected to be a critical variable. It was also assumed that government institutions would assist in the formation of farmers' associations, to arrange credit and provide technical assistance in the first year of operation. Afterwards, because of the profitability of cassava drying, farmers' associations were expected to expand their operations at own initiative.

It was expected that with existing institutional resources, some 20 plants could be formed, each with the capacity to process 250 tons of dried cassava per year. Considering the autonomous expansion by older drying associations, the ability to form 20 new associations per year was considered sufficient. It was decided that the project could be developed with existing resources and did not need additional manpower.

By systematically analyzing the role of cassava in the rural economy of the Atlantic Coast Region of Colombia, it was possible to specify alternative areas for technology development and to choose between them. Ex ante project feasibility and impact estimations produced clear guidelines for conceptual structure, organizational form, and most feasible target regions,

Table 5. The Potential for Establishing Cassava-Drying Industries

Major Criteria	Defined by	Reasons	Measurement	Explanation
Production potential	Availability of land	More land is needed	Farm size	Land available to farm defines expansion potential
			Types of land tenure	Secure land tenure increases continuity of production
	Possibility of mechanization	If partial mechanization possible, production can increase	Availability of tractors	Defines access of farmers to means of mechanization
			Land topography	Defines feasibility of mechanization in the region
	Potential productivity	Alternative way to increase production, strong effects on net income	Cropping system	System must allow increases in cassava productivity
			Soil quality	Soil quality influences gains in productivity
Processing potential	Market competition for fresh cassava	Vigorous market demand = strong competition for roots	Present market access	Farmers with good market access will not be interested in development of alternative markets
			Quality of fresh cassava	Farmers with low-quality cassava face more problems in fresh market
	Length of dry season	Length of dry season limits feasibility of sun-drying	Number of dry months	Plant usage increases by 8% for each additional month of dry weather
	Institutional presence	For successful formation of farmers' associations and establishment of plants	Number of officials in the zone	Proposed development relies on institutional intervention
Impact of project on region	Importance of cassava within the region	Project benefits more people where cassava is already important	Absence of other crops; Climatic/edaphologic conditions	In some regions, cassava is the only way to earn a living in agriculture
	Present institutional support	Forgotten zones benefit more from cassava development	Historical presence of government institutions	If the region has been involved in many other projects, cassava projects will bring only marginal benefits

Table 6. Scoring Used to Define Regional Feasibility for Establishing Cassava-Drying Plants

	Atlantico	Bolivar	Sucre	Cordoba
Production potential				
Farm size	0	4	1	3
Type of land tenure	3	2	3	4
Availability of tractors	3	0	4	2
Land topography	1	0	3	3
Cropping system	3	3	1	1
Soil quality	1	2	2	3
Subtotal	2	2	3	4
Processing potential				
Access to markets for fresh cassava	1	3	2	3
Quality of fresh cassava	2	2	2	2
Length of dry season	3	1	2	2
Number of government officials	3	1	3	2
Subtotal	3	2	3	3
Impact on region				
Absence of other crops	3	2	2	1
Off-farm employment	2	2	3	4
Historical presence of government institutions	1	3	2	2
Subtotal	2	3	3	3

Note: **Scores on all factors are high if the score favors developing a drying plant in the region. Scores are low if there is any obstacle to development.**

as well as disciplinary composition and institutional strength. The knowledge base at the start was well developed, which allowed conscious decisions to be made and suggested a prosperous future for this effort in technology generation.

Technology management, however, does not end when the development strategies have been made. Project monitoring is the logical extension of ex ante feasibility and impact assessment studies. From a theoretical perspective, monitoring is also instrumental in reviewing the ex ante forecasting methods and their conclusions, as will be clearly shown in the next section.

Project Monitoring and Adjustment

Ex post impact assessment implies that the effect of the technology has worked its way through the economic system. Such a concept suggests that there is little analysis to be done between the ex ante and the ex post assessments; moreover, it assumes that new technology autonomously diffuses through the crop sector along a specific path, fixed by the characteristics of the technology and the structural features of the sector.

The diffusion of new technology for cassava processing (and its impact on production technology) follows from a very different concept. First, significant technology diffusion through project management is necessary before the market is sufficiently consolidated for further autonomous diffusion. Second, key interventions, through what may be termed *social technology*, can alter the diffusion path and the resultant distribution of benefits. Third, technology transfer and initial diffusion are organized within a project framework and can easily be linked to development activities. Within this concept, ex post impact assessment becomes a continuous activity, synonymous with monitoring in the project literature, and involves the translation of the ex ante results into an actual field situation.

Thus, in the case of cassava, there is a major amplification at the stage of adaptive research and transfer, compared to other crop research programs. Adjustments to processing technology, to production technology, to technology-delivery systems, and to farmers' organizations radically extend the boundaries of adaptive investigation as currently defined by farming-systems research. These adjustments are made not just on the basis of a technology-testing activity but also on an evaluation of institutional resources, deployment of plant management, of differential production responses by farmers, and of the distribution of benefits. Monitoring is a key activity when the focus of technology transfer expands beyond production to encompass processing and farmers' organizations.

The diffusion of technologies for cassava processing and production on the Atlantic Coast of Colombia has not yet reached the autonomous growth stage. What are analyzed here are issues that have arisen in the project-monitoring phase and the degree to which they were predicted in the ex ante planning phase. Since the design and implementation of the monitoring system are still evolving, these results are only preliminary, but they do suggest the value of a continuous evaluation of the technology-transfer process.

Region Selection

Project implementation adopted a different strategy in locating processing plants from that recommended by the ex ante analysis. The project did focus on Sucre and Cordoba in developing plants (Table 7); however, Sucre superceded Cordoba, which had been given the first priority in the planning phase, because of much better institutional development and a problem in timing the harvest and drying in Cordoba. And although Sucre and Cordoba

Table 7. Change in the Number of Drying Plants, by Subregion

	Number of Drying Plants						Drying area
Subregion	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	(m^2)
Cordoba	—	1	1	4	9	9	6,379
Sucre	1	3	3	7	12	12	12,252
Bolivar	—	—	—	2	3	3	1,516
Atlantico	—	1	1	3	4	4	3,000
Magdalena	—	2	2	3	4	4	4,420
Cesar	—	—	—	1	2	2	1,320
Total	1	7	7	20	34	34	28,925

had been given the two highest priorities, the project decided to set up plants in all the other subregions of the Atlantic Coast. A strategic decision was made to make the project truly regional. Plants were developed in other subregions as demonstrations of the technology and to act as catalysts for developing institutional capacity.

Nevertheless, the setting of regional targets was confirmed. Performance indicators for the plants were much higher for Sucre and Cordoba than for Bolivar and Atlantico. In the latter two subregions there was greater competition for raw supplies with the market for fresh produce, as well as more severe constraints on expansion in cassava production. This confirmed the hypothesis that some regions would have a comparative advantage in processed cassava and that this "demand" for technology would be determined by the constraints on or high costs of access to established cassava markets. Regional stratification was therefore a necessary step in developing an efficient technology-transfer system.

Farmers' Production Response

A critical hypothesis within the project was that stabilizing access to cassava markets would provide a major incentive for expanding production, through both area expansion and yield improvement. An early validation of the ex ante results was essential to project expansion, especially in defining the rate at which new plants could be established. However, the evaluation of the farmers' production response to plant establishment was not easy, as it became difficult to control for other factors affecting production response.

There was no firm basis for a sampling frame for cassava production in the region as a whole and little institutional support outside the area of influence of the plants. Production monitoring thus focused initially on farmers who sold to the plants, and a list of these farmers was developed by monitoring the plants. This meant there was no control group. Moreover, credit, yearly price variation in cassava and competing crops, the relative incentive between being a member of a plant association or only selling to a plant, and differences in efficiency between plants all introduced alternative determinants of farmers' production response, especially since sample size often limited the ability to control for these factors. The monitoring system at this early stage suggested improvements to its own comprehensiveness, rather than providing a conclusive test of the production-response hypothesis.

The monitoring results showed that association members increased the area they planted to cassava by 17% between 1984 and 1985 and 26% between 1985 and 1986. The ex ante analysis indicated that this increase in area planted would occur principally in farms of over 8 ha with secure access to land. The monitoring results, however, suggested a different pattern. First, there was an unexpected tenancy effect. Farmers with insecure access to land made up a significant portion of the farmers' associations. They were in fact first to respond to the presence of the processing plants (Table 8), with land owners lagging somewhat behind. However, for farmers who were not members of the plant associations, then the effect was as predicted, with owners showing a more consistent response.

Table 8. Percentage Increase in Area Planted to Cassava, by Land Tenancy and Membership in a Farmers' Association

	Member of Farmers' Association		Not a Member of Farmers' Association
Land Tenancy	1984/85	1985/86	1985/86
Rental or share tenancy	36	11	-25
Land owner	12	32	29

Source: Monitoring data.

This was an important result, since it suggested that the social technology (i.e., the farmers' association) could be combined with the processing and production technology to reach the poorest and most insecure portion of the population, results that could not be incorporated into the ex ante analysis. The project design was shifted to further direct benefits to a segment of the population that had been very difficult to target.

Second, the monitoring results suggested that the principal response would come from farms where the cassava area was well below the optimum, as predicted by the ex ante model (Figure 2). The initial response in fact came from farms with apparent excess capacity and where the farmers rented land. There was a significant lag in the response of farmers who were already growing at least 3 ha of cassava. This implied either a longer reaction time on the part of farmers who had already committed significant resources to cassava or constraints on expansion not captured in the model. This observation raised a still deeper question: How can the efficiency of plant operation be evaluated as an organizational constraint limiting the farmer's production response, compared to the case where land or labor resources formed the primary constraint?

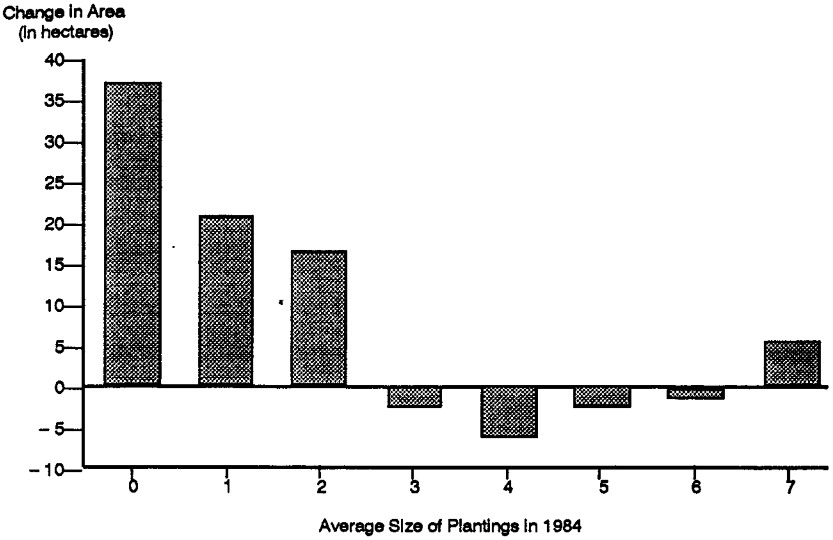


Figure 2. Atlantic Coast, Colombia: Change in area planted to cassava from 1984 to 1985, based on average area planted to cassava in 1984

Demand Assessment

Alternative demand for cassava as a raw material for animal feed was critical to project success since it would stabilize prices in the traditional cassava market, allow integration with the grain (i.e., sorghum) market, and provide significant potential for expanding production. The project did produce the desired price floor (Table 9); however, this did not prevent the market price for fresh cassava from rising in 1985-86 to the point where it acted as a constraint to the supply of raw materials. Moreover, the project appears to be having a stabilizing impact on market prices for fresh food, indicating both the effect of the supply response and the relatively marginal intervention needed to influence prices in the traditional fresh market.

Table 9. Changes in Costs and Prices during Project (1983 to 1987), in 1983 Constant Prices

	1983 Pesos/ton			
	1983/84	1984/85	1985/86	1986/87
Price of fresh roots	4,980	4,870	5,340	5,100
Total processing costs[1]	14,895	14,280	15,719	16,855
Price of dried cassava	17,180	18,220	18,770	20,454
Profit margin	2,285	3,941	3,053	3,653
Conversion rate[2]	2,530	2,380	2,430	2,570

[1] Includes costs of raw materials.

[2] Fresh roots per unit of dried cassava.

Market access, in one sense, was expanded, as is shown in the diversity of outlets utilized and the movement of dried cassava out of the region (Table 10). However, the decline in the use of dried cassava in the Atlantic Coast is indicative of the thin market in that area. Market access in the Coast was conditioned by periodic sorghum imports, both legal (through the ports) and illegal (across the border from Venezuela). Cassava became much more competitive in deficit markets inland. This gave rise more rapidly than expected to a second-generation problem: how to increase the bulk density of the product to reduce transport costs. An growing issue was when to introduce pelleting technology and what should be the organizational strategy for such an introduction. The ex ante studies oversimplified the sorghum market to a significant extent, but there was sufficient scope for adjustments so that price stabilization was in fact achieved at a relatively early stage.

Table 10. Percentage Breakdown in Sales of Dried Cassava by Market and Marketing Year

	Atlantic Coast		Interior			
Year	Cartagena	Barranquilla	Medellin	Bucaramanga	Valle	Total (tons)
1983/84	100.0	—	—	—	—	946
1984/85	37.5	15.8	15.6	3.2	4.9	3,006
1985/86	6.9	27.0	46.5	9.4	10.2	2,980
1986/87	9.5	14.8	67.7	6.7	1.3	3,853

Source: Monitoring data.

Market Simulation

The simulation model added a forecasting component to project planning. The project did start with the development of the dried cassava market, but only in 1987, with the achievement of market consolidation based on dried cassava, was the storage technology for fresh cassava introduced. The model suggested that these should be complementary strategies. In practice, this has been the case so far. The initial focus of the introduction of a storage technology for fresh cassava was Atlantico, a subregion where plants for drying cassava had difficulty competing with the fresh market for the supply of raw materials. These plants ended up processing the roots that were discarded for storage. The farmers' associations also provided the organizational nucleus for the efficient introduce of storage technology at the farm level.

The project recognized that the growth of the capacity to process cassava would determine the size of the project benefits. The predicted stabilization in cassava prices was achieved in a relatively short period; however, indicators of plant efficiency suggested that the plants were operating below capacity because of an insufficient supply of raw materials. Achieving a balance between demand expansion and production response was proving difficult because of a longer lag time than was predicted in the model. Another complicating factor was that the principal production response was coming from renters and the project was driving up the rental price of land.

Moreover, the relatively larger farmers (who farmed between 8 and 20 ha) were not as quick to respond. Their constraint appeared to be access to the rental machinery market, especially since a boom in the local cotton market was monopolizing tractors for large-farm land preparation. In two cases, however, the farmers' associations were so successful in managing dried cassava processing that they were able to purchase their own tractor, through a credit line. Changes in commodity markets were thus inducing changes in factor markets, an issue which was not incorporated in the simulation model, apart from a calculation of the increase in labor use. There has been pressure by farmers for a similar credit line for land purchases, but this has so far been resisted by local credit institutions. Nevertheless, the economic and organizational preconditions for the success of such a credit line are in now place.

The ex ante model demonstrated that there was significant growth potential in an integrated cassava project. The great utility of ex ante impact studies lies in just such a diagnosis. However, the leap from potential to realized increases in cassava production and utilization is still a large one, even with a model as detailed as this one. Such detail is only captured in partial equilibrium approaches, which must often exclude interactions with other output and factor markets. Predetermining which substitution or factor market effects will be significant is difficult and depends heavily on prior knowledge.

However, the leap between potential and actual interactions goes beyond just defining the structural limits of the model. First, it would be useful to have the probability of success factored into the model, but it is difficult (perhaps impossible) to identify the key variables that define success, much less to attach a probability to them. Moreover, some probability distributions will be conditional to others. Second, institutional support was the key to project implementation, and it is difficult to see how institutional requirements could be forecast, much less the extent to which existing institutions pose a constraint or are amenable to modification. Third, the farmers' associations were probably the key factors in the successful transfer of the technology to this socioeconomic stratum. The associations proved to be the pivotal organizational concept that gave the project flexibility in adapting to unforeseen problems or constraints. Such a role was not predicted, although it was identified early in the project and then utilized in its expansion. All of this points to the fact that technology transfer in developing countries is very much an under-researched area.

Conclusions

The integrated ex ante and ex post evaluation of the generation of cassava technology in the Atlantic Coast Region of Colombia strongly improved the creativity, focus, and goal orientation of the project. It emphasizes that agricultural technology does not necessarily have to be production oriented to improve the overall efficiency of a commodity system. It has helped rebalance the disciplinary composition of the project, define target areas, and refine the bias towards small farmers. The procedure, however, is costly in the use of project analysts. This last section will try to derive some general conclusions on the feasibility of these methods in other circumstances.

A first conclusion should be on the usefulness of the ex ante-ex post evaluation for the R&D planning of CIAT's cassava program. Understanding the supply-demand linkages has helped focus research on utilization. It has also given rise to an extensive, Latin America-wide study on ex ante prospects for cassava demand and on CIAT's potential to link its research to these prospects. In addition, it has proved critical for the development of other integrated cassava projects, which are located in Panama, Ecuador, and Mexico.

The conclusions on organizational aspects and farmer involvement have particular significance. Initially, the cassava program thought that research on processing and production would be sufficient, but now the program is more aware of the need for social technology. This is especially true with respect to the question of scale adaptation in production-market linkages (e.g., from small farmers through associative drying plants to the large-scale animal-feed industry), where appropriate organizational arrangements have proven their worth. The lack of ex ante assessments of organizational arrangements only serves to reinforce the importance of early monitoring in integrated cassava projects.

A second conclusion should be made with respect to the methods applied in the ex ante phase of the analysis. These methods originated mainly in the field of economics. This has provided a number of very valuable conclusions, e.g., on area planted and market stabilization. However, it has failed to predict other important developments. Small farmers appear to be more motivated to join cassava-drying associations because they hope to win more by organizing themselves. In a similar way, the progress of the drying industry was not assessed well because the motivation of government programs to pursue this development had not been judged correctly.

In the project design presented in this paper, forecasting was done by economists alone, and monitoring was done by economists, anthropologists, and organizational scientists. For further refinement of project evaluation and planning methods, it is essential that anthropologists and organizational scientists be included in the traditionally economic domain of forecasting. Such a move would initially make their work more speculative and their conclusions riskier, but later on it would improve applicability and disciplinary strength. The ex ante evaluation is riskier and more difficult than the ex post one, but it also provides a greater challenge and a higher pay-off if correctly applied.

Some remarks should be made with respect to the degree of complexity that can be handled within a technology-generation project. The present paper deals with a relatively small-scale effort, one that is location- and crop-specific. Issues at different levels of the product channel were studied, and although the study is of an applied nature, rather elaborate data manipulation was needed. Still, most of the study's conclusions have had to be drawn within a partial equilibrium framework, one that can be derived from the simulation model and from the problems involved in monitoring production.

More comprehensive analytical methods could be developed, but they might well loose their versatility as a means of forecasting, or their results may become available too late to influence major decisions. A structure that might theoretically be the most advanced solution and one that could still have sufficient applicability, might be one in which the detailed analysis and modeling of a specific commodity system could be linked with an aggregate general equilibrium model and iteratively corrected with new findings.

Ex ante and ex post evaluation should thus try to identify the project components that are most critical for successful technology generation and application. These components should then be the focus of the analysis and would lead to rapid redirection of the planned strategy. The definition of precise hypotheses on technology generation becomes crucial to efficient and flexible resource use. Intimate knowledge of socioeconomic conditions is needed to define these hypotheses, and requires that the analysts involved have the most up-to-date knowledge and experience possible.

With respect to project design, even as simple an effort at generating technology as that described in the present paper (which was for a single crop in a single region) requires complex analysis and integration of numerous components. This tends to suggest that efforts at generating technology should limit their scope. Technology generation that depends on components from many different crops or many different levels in the commodity system might be too complex to be manageable or too diluted to be effective.

One last conclusion is on the character of technology generation in agriculture. Ruttan (1977) has made it clear that technology generation is not an exogenous process. He writes that understanding the needs of farmers and society leads to a specific allocation of research resources. This allocation, in turn, influences the speed of technology generation. The present paper supports these conclusions but would take them even further. Technology generation is not only induced by the allocation of resources for research, but also by market forces. Technology generation reacts to demand pressure as supply does. Absence of demand or obscured demand (by inefficient market channels or rigid quality criteria) reduces the momentum among farmers to search for and test technological alternatives. Market instability reduces the inclination to experiment or even to introduce new technology. Successful technology generation is intrinsically linked with the existence of promising, expandable markets, especially where the concern for small-farm income is dominant. Where traditional markets are stable or deteriorating, market development, although speculative and risky, should have priority over the generation of production technology.

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Appendix 1
Positive and normative procedures used to assess the impact of market risk and their advantages and disadvantages

1. *The positive procedure*

Definitions:

AMR = Area planted at the existing price expectation

AWR = Area planted if the present price had been guaranteed

ADM = Difference between AMR and AWR because of elimination of price variability

$E(P)$ = Expected cassava price

PR = Subjective cassava price variance

YR = Subjective cassava yield variance

COV = Subjective covariance between yields and prices

OTH = Other factors that influence area planted

A simple function to express area planted could be as follows:

$$\begin{aligned} AMR &= a + b*PR + c*YR + d*COV + \\ &\quad [e + f*PR + g*YR + h*COV]*E(P) + i*OTH \end{aligned} \tag{1}$$

This equation assumes that the area planted has a linear dependence on price and other factors. The income variance is divided into a yield variance, a price variance, and a covariance component. The squared covariance component has been left out, following Hazell (1982). The variance components affect the intercept (through the first four terms) as well as the slope (through the terms within brackets).

The function to express area planted at contracted prices would be as follows:

$$AWR = a + c*YR + [e + g*YR]*E(P) + i*OTH \tag{2}$$

Now the price variance term has been eliminated. Since there is no price variance, covariance terms disappear as well.

For each farmer, one point at the original supply curve 1 was known because price expectations and area planted had been asked. Supply curve 2 was estimated by means of the elicitation procedure in which farmers were asked about their planting behavior at guaranteed prices.

Now equation 2 can be subtracted from equation 1. This gives

$$ADM = b*PR + d*COV + [f*PR + h*COV]*E(P) \tag{3}$$

This equation expresses the difference in area planted for an expected price versus a contracted price, which is the impact of price uncertainty on planting decisions. Within a cross-sectional framework, parameters *b* and *d* (that shift the intercept) and *f* and *h* (that shift the slope) can be estimated. Knowledge of these parameters allows estimations of the impact of incomplete price stabilization on planting behavior by solving equation 3 for the observed differences.

2. *The normative procedure*

The normative procedure to estimate the impact of market risk consists of the development of a quadratic programming model:

$$\text{Maximize} \quad E(u) = r'x + \tfrac{1}{2} L\, x'Qx \tag{4}$$

$$\text{subject to:} \quad \begin{array}{ll} Ax & b \\ x, L & O \end{array} \qquad \begin{array}{r} (5) \\ (6) \end{array}$$

where

r = a vector that represents income values of different farm activities

x = the vector that represents the level of these activities

Q = the variance-covariance matrix of the income values

A = the matrix of technical coefficients

b = a vector that describes resource availability

L = a scalar that weighs risk aversion versus expected income maximization

This model was specified for one of the major cassava producing areas of the region.

Production of dried cassava would provide an outlet for cassava that is currently discarded and would allow a floor price in case prices in the fresh cassava market plunge. To calculate the effect on the expected price and on the price variance, the cassava price to be paid by the drying industries was imputed for presently discarded cassava. The drying-industry price was also imputed for those points in the fresh market price probability function where fresh cassava prices are below drying-industry prices. In this way price expectations and variances with and without drying industries were generated.

The effect of incomplete price stabilization can be estimated by running the Quadratic Programming (QP) model for the different combinations of price expectations and variances.

3. *Advantages and disadvantages of market risk assessment procedures*

The QP model provides an understanding of how farm organizations could change because of improved cassava market perspectives. It indicates how supplies of other products change and evaluates technological changes in cassava production by including alternative production technologies in the activities matrix. The elicitation approach has the advantage that it does not involve an estimation of the degree of risk aversion.

A problem encountered with both methods is that they are not sufficiently region specific. The elicitation analysis needs cross-sectional data for to estimate supply curves. It uses the variability in the data to calculate an overall supply curve, but it cannot use this again to estimate supply curve differences per subregion. Data collection for the QP model is time-consuming and costly and could not be justified for the different subregions.

Appendix 2

The procedure used to estimate dried cassava demand

Dried cassava is comparable or slightly superior to sorghum with respect to caloric content, but it is quite inferior in protein content. A rough guideline would be that one ton of dried cassava plus 0.2 tons of soya would replace 1.2 tons of sorghum. This results in the following price equation:

$$PCCS = 1.2*PSOR - 0.2*PSOY \qquad (7)$$

where

$PCCS$ = Price at which dried cassava competes with sorghum

$PSOR$ = Price of sorghum per ton

$PSOY$ = Price of soya per ton

Nevertheless QP models calculate a shadow price for cassava of around 80% of the price of sorghum in chicken feed but close to 90% in pig feed. The willingness to pay for cassava depends on the diets produced by the manufacturer and their protein content. Cassava would first enter those diets where its shadow price relative to sorghum is highest.

This implies that an ordinary demand curve for dried cassava can be estimated. A questionnaire was sent to the animal-feed industry to estimate demand at three different price levels. This produced the slope for a dried-cassava demand curve. Since dried-cassava demand is also determined by its relative price with respect to sorghum, the slope coefficient was related to the difference between the real price of dried cassava and the price at which cassava would be competitive with sorghum, as determined in equation 7. The final demand equation for dried cassava had the following structure:

$$QCAS = a - b*(PCAS - PCCS) \qquad (8)$$

Where:

$QCAS$ = Demand for dried cassava

$PCAS$ = Price of dried cassava per ton

$PCCS$ = Price per ton at which dried cassava competes with sorghum

Appendix 3
A brief description of the simulation model used to forecast cassava development in the Atlantic Coast Region

The model consists of six components (for more detailed information, see Janssen 1986: 198-223).

The first component is the consumption component. Equations for fresh cassava demand are developed for different urbanization strata, an equation for dried cassava demand is included and some secondary demand components are distinguished. Shift factors are included in the fresh cassava demand functions to simulate successful introduction of storage technology. Dried cassava demand is modeled as described above. Demand equations are linear.

The second component is about cassava production. Distributed lag functions are estimated for area planted, as well as for yield. Production is then defined as yield times area. Area and yield functions are shifted upwards for that part of the region where drying plants have stabilized market perspectives. Yields are random in nature.

The third component examines marketing and processing. Marketing margins for different urban strata are determined on the basis of farm-gate prices. Shift factors are included to express the potential margin reduction if technology for the successful storage of fresh cassava is introduced. The costs of processing and marketing dried cassava are modeled.

The fourth component examines the development of the drying industry. This is made endogenous with respect to existing drying capacity, market prices for fresh cassava, potential prices for dried cassava, and profits realized from drying. This component feeds directly back to the production component by defining the part of the region where drying plants have been built and market perspectives have stabilized.

The fifth component defines equilibrium conditions for the cassava system in the region.

The sixth component calculates potential project benefits. Four types of benefits are distinguished: foreign exchange saved by consuming dried cassava instead of sorghum; employment in the cassava sector, in urban as well as rural areas; the discounted 10-year producer surplus per farm size group; the discounted 10-year consumer surplus for various types of rural and urban consumers and for the drying industry. By means of the project's benefit parameters, the planned cassava development can be evaluated with respect to the overall objectives of agricultural policy.

The model can be written as 45 condensed equations but involves the balancing of some 90 behavioral relations per year of simulation. The model was written in Fortran. To facilitate its use, a panel was designed to set the values of the most important parameters. Since the model has a stochastic nature, 25 runs were made for each modeled situation.