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THE ECONOMIC RETURNS TO INSTITUTIONAL INNOVATIONS IN NATIONAL AGRICULTURAL RESEARCH: ON-FARM RESEARCH IN IDIAP PANAMA

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To the Caisan team, for its personal and professional commitment to the Panamenian Farmer.

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This work is not a result of our isolated intelectual efforts; it is rather the outcome of our intense interaction with both, our colleagues in CIMMYT and IDIAP, and our field experiences in on-farm research operations.

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THE ECONOMIC RETURNS TO INSTITUTIONAL INNOVATIONS IN NATIONAL AGRICULTURAL RESEARCH: ON FARM RESEARCH IN IDIAP PANAMA

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I. INTRODUCTION

It has been common practice in modeling technological change to consider institutional development as an exogenous variable. Furthermore, these models have usually hypothesized that causality runs from technological to institutional change (Ruttan, 1978). 1/ The fact that, despite widespread promotion, many new technologies are not used by farmers, has lead to the development of alternative models considering institutional change as endogenous in the model with causality running in both directions (De Janvry, 1978, Ruttan, 1978).

This study deals with the economic evaluation of certain innovative methodologies for agricultural research, aimed to develop appropriate technologies for target farmers in the near term. These methodologies were initially implemented on a trial basis by a recently created national research institute in Panama, and later institutionalized within the research organization on the grounds that they significantly contribute to increase the efficiency of public investment in agricultural research. In the past, agricultural research in Panama was conducted by different organizations including the Agricultural Development Ministry (MIDA), the University of Panama, and various public and private enterprises. In general, it was carried in agricultural experimental stations often under conditions quite different from those faced by farmers.

At the same time, there was a general consensus among policy makers that the existing research structure was generating an insufficient

1/ Following Ruttan "an institutional change occurs when there is a change in (1) the behavior of a particular organization, (2) the relationship between such an organization and its environment, or (3) in the rules that govern behavior and relationships in an organization's environment" (1978, p. 329). In this definition the term organization means a decision unit which exercises control of resources.

amount of appropriate technology to impact effectively the technological structure of the agricultural sector. This deficiency provoked interest in revising traditional research strategies. As a consequence, the Institute of Agricultural Research (IDIAP) was created in 1975 with the main objective of increasing farmers' productivity and income levels with special emphasis on farms of medium and small size.

A guideline of the institution was that of focusing research on specific regions and crops for the development of technologies appropriate to representative farmers in areas defined as high national priorities. Research could thus be concentrated on the most important farmer problems and the scarce resources of IDIAP used to best advantage. Its activities were planned in a sequential pattern to permit methodological adjustments as experience was gained and to provide a framework for the training of a corp of national on-farm researchers.

In 1978, the first such program began in the area of Caisan with the cooperation of CIMMYT and with a former CIMMYT trainee assigned as coordinator of the program. At the same time, the issues which would shape IDIAP's institutional organization were being discussed and Caisan, its first area-specific on-farm research program, was expected to be a source of experience for the development of research procedures for IDIAP.

The Caisan program was planned and carried out strictly within the limits of the human and financial resources normally available to IDIAP. Thus, the cooperation of CIMMYT (development of procedures and in-service training) was designed in such a way as to not exceed normal resource allocation for area-specific programs.

The area of Caisan is located in the northwest side of Panama, involving 10,000 has. of territory and about 300 families. The most important production system is a maize/bean rotation, which lead to consider both maize and beans as target crop for the research program. A complete report of maize results, including surveys and experiments carried between 1978 and 1982 could be seen in Martínez and Arauz

(1983), and will not be covered in detail in this paper.

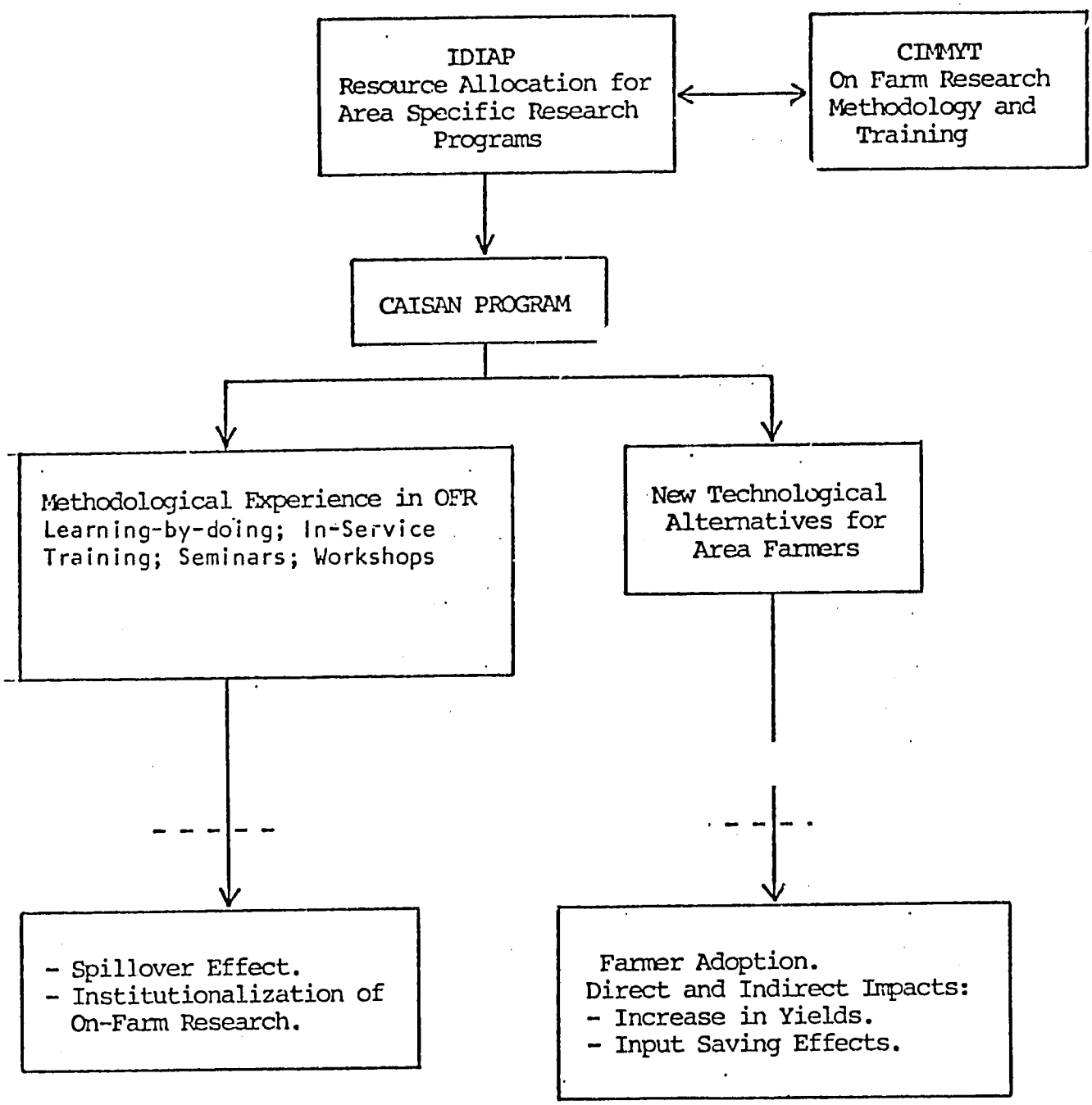
The main objective of the program was to increase in the near term productivity and income of representative area farmers. Also, Caisan represented a first step in a process which built up from on-farm research actions towards an articulated on-farm research program. In this framework, the methodological implications of Caisan experience and their spillover effect in terms of its contribution to institutionalizing on-farm research within IDIAP was an important "output" expected from the program. Accordingly, the progress of the work was closely followed up by directing staff and intensively discussed by researchers and directive staff in national meetings, field days and regional workshops. As a result of these follow up and given the increasing emphasis in area specific on-farm research in IDIAP, the institution decided to conduct an evaluation of the cost efficiency of the on-farm research procedures used in Caisan. Such evaluation was expected to quantify the social rate of return of IDIAP investment required to implement these on-farm research procedures for the case of one of the target crops of Caisan. With this basic goal in mind, an evaluation research was designed and conducted for maize within Caisan program by 1982. [2/] This paper reports on the qualitative and quantitative results of such evaluation.

II. CAISAN: PRODUCTS AND INPUTS

The flow of basic inputs and outputs of Caisan Program is described in Figure 1. Two basic types of "outputs" resulted from the implementation of Caisan. The first one is associated with the contribution of Caisan to the institutionalization of on-farm research within IDIAP. These contributions -methodological and institutional implications- have been obtained through learning-by-doing, in-service

2/ On-farm research methodologies used in Caisan are not crop specific and were equally applied to both target crops (maize and beans). Although results on beans were less documented and sistematized at the time of the evaluation (mid 1982), the impact of the program in beans production has been at least equivalent, if not superior to the one obtained in maize, being research costs at similar level for both crops.

FIGURE 1 THE CAISAN ON FARM RESEARCH PROGRAM. FLOW CHART OF BASIC INPUTS AND OUTPUTS.



training and workshops, all based on Caisan experience. The resulting increase in IDIAP's capabilities to implement on-farm research procedures in other areas of the country can be considered as an addition to the national stock of knowledge and hence as an important positive externality produced by the Program.

The other product is that related to the main objective of increasing, through technology generation, productivity and income of representative area farmers. In this sense, the products are the technological alternatives generated by the program and recommended to farmers. Benefits of these products are valuated through impacts associated with actual farmer adoption of these alternatives. In other words, the farmer is placed as the final judge of this process of technology generation transfer, and accordingly, adoption is taken as necessary condition for associating positive benefits with the technological alternatives involved. At the time of the evaluation four technological alternatives had been generated by the Program. Two of them, chemical weed control and spatial arrangement and density, were of yield increasing nature requiring some additional resources (costs) per hectare for its adoption. The other two, zero-minimum tillage and no use of fertilizers were basically input (costs) saving per hectare without affecting yields.

On the input side of the Program, two types of inputs can be identified. First, CIMMYT contribution, which has been entirely composed of procedures for on-farm research and training in the use of these procedures. These have been one of the most important elements in the recent CIMMYT cooperative work with National Programs. 3/ The second type of inputs corresponds to resources reassigned by IDIAP from the experimental station research to on-farm research in Caisan. 4/ These includes, human resources, source fixed assets (like venicles and a mini

3/ This cooperative work takes place through CIMMYT Regional Programs. See Juan Carlos Martínez (1982).

4/ On-farm research is understood here as a liasson and needed complement between the more traditional station research on one hand and the extension activities on the other.

tractor), the rental of a farmer house in the area, and the different materials (fertilizer, herbicides, insecticides) required for carrying the on-farm experiments.

III. METHODOLOGY

Figure 2 shows the sequence of decisions followed in the evaluation of the Caisan program. In the rest of this section the main methodological problems associated with each stage are briefly described and the particular decision taken regarding the case at hand is justified.

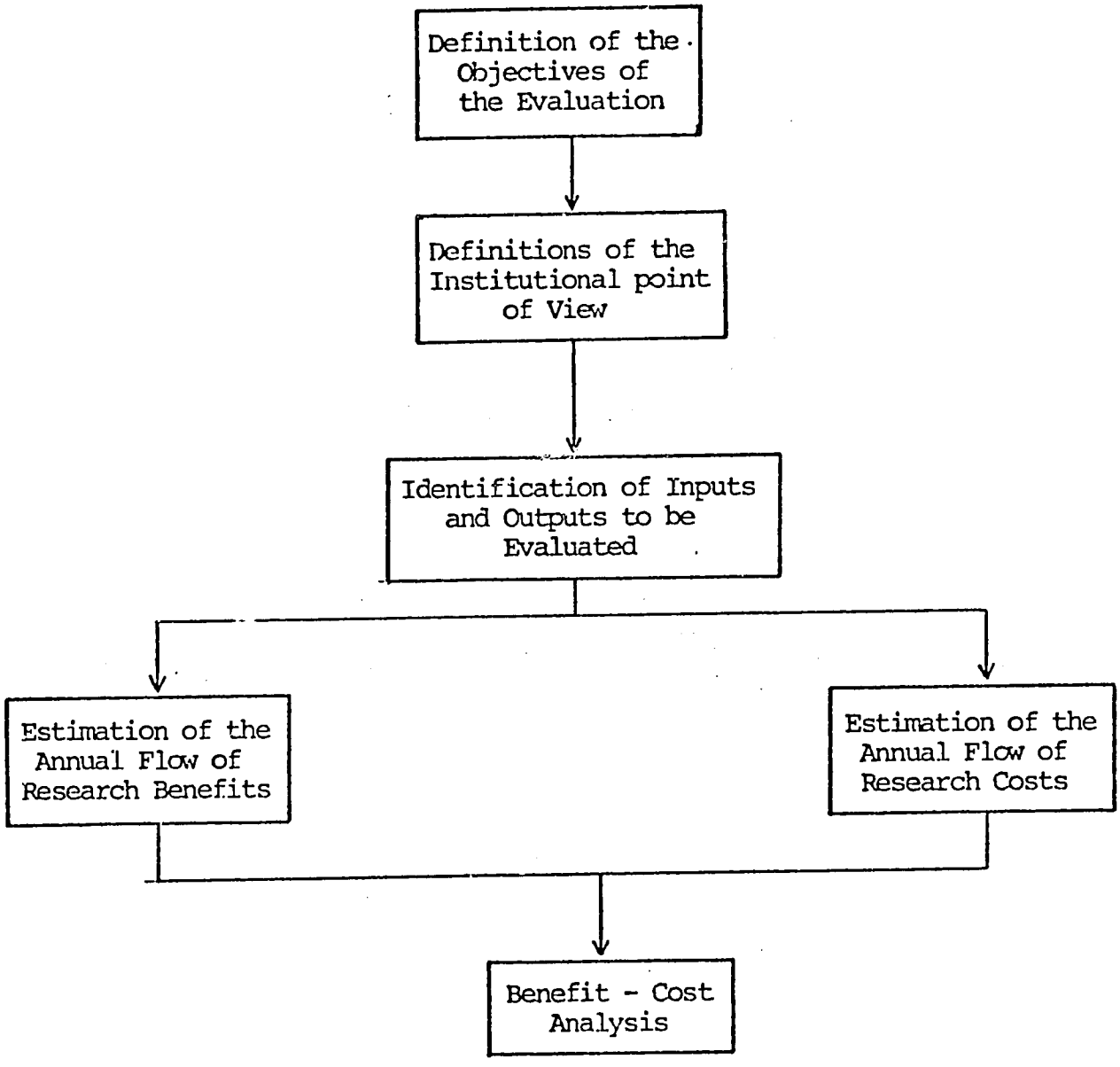
1. Objectives of the Evaluation and the Institutional Point of View.

Given the nature of the Program, its evaluation could be carried out assuming either a national or international perspective. Whether to follow one or the other will basically depend on the objectives of the evaluation.

The objective of the evaluation was the measurement of the cost efficiency of the methodology applied in Caisan. Specifically the national research institution, IDIAP, was interested in knowing the rate of return of the investment required to implement area specific on-farm research programs like Caisan as a needed complement to station research. In this sense the objective of the evaluation can be stated as the estimation of the rate of return to the Panamenian society of the resources invested in implementing the OFR methodology used in Caisan.

Assuming an international perspective will imply that benefit and costs will be traced beyond Panamenian borders. In this particular case, on the benefit side spillover effects and increased methodological experience accruing to other countries via CIMMYT international programs should be considered as a positive externality. On the cost side, CIMMYT resources allocated to this type of activities should also be considered, spreading their cost among the various international programs of similar nature implemented with CIMMYT cooperation. In other words, assuming an

FIGURE 2. STAGES OF THE EVALUATION PROCESS.



international perspective would imply the evaluation, starting from Panama, of the international system operating via CIMMYT in the area of on-farm research. This does not appear consistent with the objectives of the evaluation, and in any case of little, if any usefulness for IDIAP decision makers.

Assuming a national perspective has different implications. Spillover effects would be confined within Panama, while, on the cost side, CIMMYT could be visualized as part of the international environment faced by the country, from which IDIAP, could occasionally, take elements without any cost. This was the case of the contribution of CIMMYT to the program, in terms of OFR methodologies and training, which accrued to IDIAP without cost for the country. In the words of Kislev and Hoffman evaluating wheat improvement in Israel: "From the point of view of the Israeli decision maker who has to decide on the allocation of funds to research in the country, free knowledge is part of the environment in which the local research system is operating. The cost of producing this knowledge abroad should not have any effect on his decision." (1978, p.173). In this case the concept is extended to include not only knowledge captured and used directly by Panama, but as well to include the free training and methodological and professional services which complemented Panamenian resources.

Since this appears to be more consistent with the specific objectives of the evaluation, this was performed with a strict national point of view. Accordingly only resources allocated to the Program by IDIAP were considered.

2. Identification and Characterization of the Products to be evaluated.

Agricultural research may be thought as a production process in which inputs such as previous knowledge, research scientists, laboratories, and libraries are combined to produce certain products.

Definition and characterization of the outputs presents conceptual problems which are, in general, dependant on the correct statement of the

objectives and institutional point of view of the evaluation (Scobie, 1979, Schuh and Tollini, 1979). The decision to perform the evaluation from an strict national point of view, clarifies some of the issues outlined by Scobie and Schuch and Tollini but not all of them. As a result of the research process two types of outputs were identified (see previous section): 1) An addition to the national stock of knowledge through increased capabilities and gain in experiences within IDIAP, and 2) an increase in productivity and income of area farmers through technology generation-adoption.

As recognized in the literature assigning a value to the first type of product would imply an almost unafordable methodological burden in the evaluation. This is so given that the product defined as a gain in the stock of knowledge is intangible, and also due to the fact that there is neither a market nor other feasible mechanism measuring how much society values this kind of product. By considering only the product related to technology generation it is possible to have an indication of the social returns due to the methodological innovation applied in Caisan. This is feasible if the evaluation is performed taking as a starting point the prevailing technological situation (farmer practices) which in turn can be associated with the more traditional station research. 5/ That is, incremental Benefit-Cost analysis applied to a case study (Caisan) would serve as a proxi of the social gains of applying OFR methodologies. As every other case of study generalization should be made with care.

In summary, due to methodological difficulties only technological innovations generated by the program would be entered as products in the evaluation. By comparing the benefits generated by this product with that which would have resulted without the program, a reasonable measure of the rate of return accrued from the OFR strategy followed in Caisan can be achieved. In turn, this rate would be a proxi, assuming replicability of the project by the national institution, of the returns to the second type of product: the increased capability within IDIAP to conduct similar area specific OFR programs in other regions of Panama.

5/ Traditionally the area was covered by the extension service from MIDA.

3. Estimation of the Annual Flow of Research Benefits.

3.1 Direct Impacts

Two main ex-post procedures have been used to evaluate the benefits of agricultural research: the economic surplus (or index number) approach and the production function approach. The choice between both methods rests basically on the quantity and quality of the available data and on the nature of the case at hand. 6/

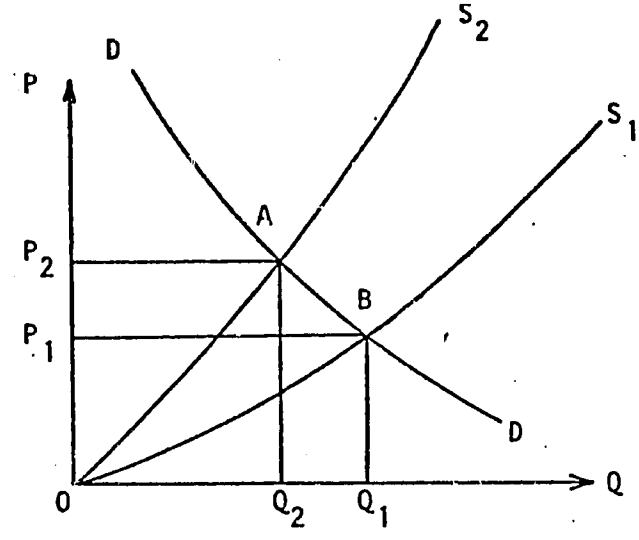
Following Norton and Davis (1981), the production function approach consists essentially in introducing into the production function a variable as proxi for research and extension. Among the studies using this approach at an aggregate level are those of Griliches (1964), Evenson (1967, 1968), Cline (1975), Davis (1976), Kahlon (1977), and Lu, Quance and Li (1978). While Peterson (1960, 1967) and Berdhal (1975) used the approach at the individual product level.

The economic surplus approach, much less data demanding that the previous one, has been widely used to estimate returns to agricultural research in both developed and developing countries. The approach is based on the concept of consumer and producer surplus. An excellent discussion of both concepts can be found in Currie, Murphy and Schmitz (1971), Hertford and Schmitz (1977), and Mishan (1968). A discussion about the surpluses as measures of welfare changes can be found in Boadway (1974). The work of Schultz (1953) and Griliches (1958) are considered as pioneers in using the approach.

Griliches' analysis can be regarded as a special case of a more general scheme presented by Peterson (1967). Figure 3 shows this general case.

6/ There is also a differentiation in terms of marginal and average rates. In the economic surplus approach what is estimated is an average rate of return to the investment in agricultural research,

FIGURE 3 CHANGES IN CONSUMER AND PRODUCER SURPLUS.



The displacement of the supply curve from S_1 to S_2 due to the vanishment of the innovation would reduce social benefits (consumer and producer surplus) by an amount equal to the area OAB which is regarded as the net social benefits due to the innovation. The area OAB is in fact the algebraic sum of the area P_1P_2AB, measuring the change in consumer surplus and the area $[(OBP_1)-(OAP_2)]$, measuring the change in producer surplus.

Among other studies which have used the approach are those of Schmitz and Seckler (1970); Hertford and Schmitz (1977); 7/ and Kislev and Hoffman (1978). In a recent article, Wise (1981) shows that the surplus method can be derived as a specific case of a more general

7/ The authors showed that linear supply and demand functions provide enough accuracy in the calculations without the complications due to the non-linear specifications. In their words: "However differences in the estimates of benefits provided by the more complicated formulations and those presented here are small for usual values of the key parameters. The main reason is that in all formulations the critical determinant of the value of the benefits derived from research is simply K.P.Q. or the percentage change in the value of production attributable to research."

approach measuring benefits. The author also showed the equivalence of both methods: when distributional aspects are introduced, social net benefits can be obtained either as a sum of benefits or as a sum of surpluses.

In order to measure the direct impacts generated by the adoption of the new alternatives, the Wise benefit approach was chosen as the more appropriate. Although the Wise benefit approach and the surplus method have been shown to be equivalent the former was preferred because it adjusts more naturally to the division of the technological alternatives generated by the Program into two groups according to the type of impacts resulting from its adoption.

Before proceeding to the application of the benefit approach, the structure of regional supply and demand curves must be specified. Because maize acreage affected by the program represents a small percentage of total national maize acreage, it was considered that the project would have a negligible impact on the national maize market, hence, its evaluation may proceed at fixed prices. This assumes that the region faces a perfectly elastic demand curve. Furthermore, the existence of a minimum support price fixed at the national level provides further motivation for considering the region as a "price taker", i.e. an increase in regional production due to the Program will not affect the maize price level.

In specifying the supply curve elasticity it should be noted that, because of the nature of the on farm research methodology, the short run supply curve should be used in evaluation of the impacts of improved technological components. Although there are no available elasticity estimates, some empirical evidence, (such as the fact that land and farm labor resources remain fully employed despite short term price variations) supports the hypothesis that the short run supply curve is highly inelastic. Furthermore, the fact that maize is a component of an important regional maize/bean crop rotation, the later being an important cash crop in the region, would further sustain this hypothesis. A highly inelastic short run maize supply curve would mean that in the

short run there is not a significant number of farmers leaving or entering the maize production sector. In other words, maize acreage in the region can be considered as fixed.

Summarizing, the postulated regional Supply-Demand structure is one of a perfectly elastic demand curve facing a perfectly inelastic short run supply curve. Within the previous framework, four technological alternatives generated by the Program will be considerated in terms of their direct impact associated with impact farmer adoption. Table 1 describes them in contrast with farmers' practices prevailing in the Recommendation Domain at the initial stage of the Program.

TABLE 1. TECHNOLOGICAL COMPONENTS: FARMER PRACTICES AND ALTERNATIVES GENERATED BY THE PROGRAM.

Technological Component	Farmer Practice	Technological Alternatives	Main Direct Impact Through Adoption (Per Hectare Basis)
Chemical Weed Control	- Application of 1 lt/ha of 2,4-D 30 Days After Planting.	- Application of 1-2 lts/ha of Gramoxone, 20-30 Days After Planting. or - Application of 1-2 kgs/ha of Gesaprim 0-10 Days After Planting.	FIRST GROUP. YIELD INCREASING
Spacing Arrangement and Density	- Irregular Spacing - 40,000 Seeds per ha at Planting	- 50,000 seeds per ha. planted in Rows	
Zero - Minimum Tillage	- Plowing and Harrowing: 3 Passes.	- Manual Chopping of Weeds Followed by 1-2 lt/ha of Gramoxone.	SECOND GROUP INPUT SAVING
Chemical Fertilizers	- Application of 200 lbs of 10-30-10	- No Fertilizer Use	

The four alternatives have been classified in two groups according to the nature of their impact in the production process. The first group includes appropriate chemical weed control and a planting arrangement in rows with increased density, implying a yield increasing effect and a net addition of resources in order to achieve the higher yields. The second

group, includes zero-minimum tillage and no use of fertilizers which are associated with an input saving effect without affecting yields. [8/] This categorization allows separate treatments for each group in measuring the benefits associated with the alternatives involved. In the case of the alternatives within the first group total benefits for each alternative will be:

$B = B_1 - B_2$ being

$B_1 = \Delta R \cdot H \cdot HAS \cdot Pm$

$B_2 = \Delta C \cdot H \cdot HAS$ $\qquad B_1, B_2, \Delta R \geq 0$

Where:

B_1, is the social value of additional maize production generated with the diffusion of the new technological alternative involved.

ΔR, is the yield increase induced by the adoption of the alternative.

H, is the net proportion of maize acreage cultivated with the new technology,

HAS, is the total maize acreage within the recommendation domain, which is assumed to be fixed and estimated in around 1000 hectares.

B_2, is the social value of the additional resources necessary to achieve the increase in production, $(\Delta R \cdot H \cdot HAS)$,

ΔC, is the net addition in variable cost per unit of land necessary to achieve the increase in yields. Recombining previous equation B could be written as:

$B = H\ HAS\ [\Delta R \cdot Pm - \Delta C]$

That is, total benefit generated with each technological alternative will be equal to the total maize acreage cultivated with the alternative times the net benefit per hectare associated with its use.

For the particular case of alternatives in the second group, they do not have any significative yield effect hence $\Delta R = 0$ and consequently $B_1 = 0$. Because they have an input saving effect, decreasing cost per unit of land, $\Delta C < 0$, hence $B_2 < 0$. Consequently, total benefit for each one of these alternatives will be $B = -(-B_2) = B_2$.

8/ For more details see Arauz, Martínez (1983).

3.2 Distributional Impact.

The distributional aspects of the Program can be assessed by considering the four social groups identified by Wise (1982). [9/] Given the nature of the Program these patterns of distributional impact appear to be very simple. Consumer welfare does not change (no production augmenting effect for second group of technologies, no price effect for either group). While benefits of technological development will fully accrue to innovators (adopters) in terms of producer surplus; those who do not adopt the technology remain the same (relevant relative prices are unaffected by the Program). Finally since there is no technological treadmill effect [10/] the number of farmers not adopting the technology and leaving the sector will be negligible.

3.3 Indirect Impacts.

The most important secondary impact of the Program is the effect of zero (minimum) tillage on future soil erosion levels and consequently on the natural fertility of the soil. This impact would be larger for farmers whose maize plots are located on slopes of considerable steepness.

Little information is available about potential yield decrease due to the reduction of soil fertility associated with erosion so quantification of this impact is difficult. In this work no attempt is made to measure it. Consequently, benefits are in this respect, underestimated. [11/]

9/ Consumers, producers who do not adopt the technology and leave the sector, producers who do not adopt the technology and stay in the sector, and producers who adopt the technology.

10/ Cochrane W. (1958) "Farm Prices: Myth and Reality" University of Minnesota Press.

11/ Following tradition in this type of evaluation when an option is encountered the choice is made such that the associated benefits are the lowest.

3.4 The Regional Social Price of Maize

Public policy in Panama with respect to maize production has been directed in the last decade toward the goal of self sufficiency. The main policy instrument used in the attempt to achieve this goal has been the implementation of support prices for this product fixed above the international price. As a consequence domestic production increased from an annual average of 53,800 metric tons during the period 70/71-74/75 to an annual average of 68,600 metric tons during that of 75/76-79/80. Concurrently with this change, importation of maize decreases from an annual average of 19,500 metric tons to 11,400 metric tons during the same periods.

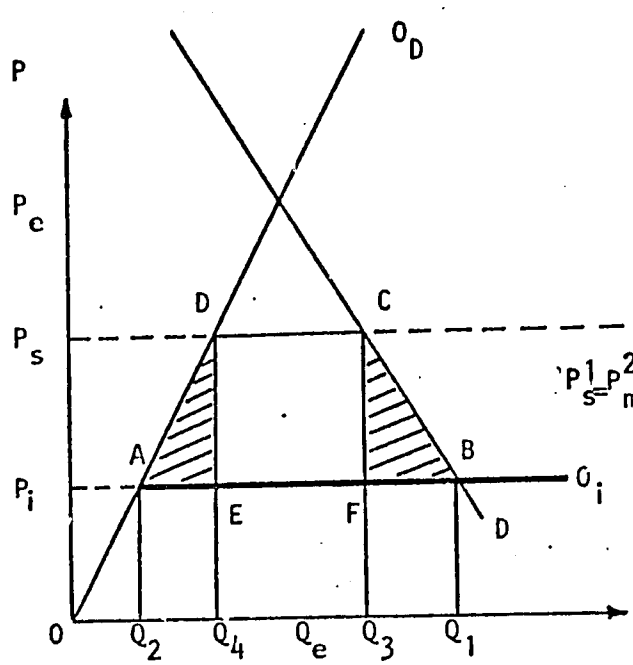
Although there is no direct empirical evidence about the annual balance of the province of Chiriqui, indirect evidence support the hypothesis that Chiriqui is a net exporter of the product [12/]. The situation for Panama and for the region is then depicted in Figures 4 and 5.

In a closed economy and in absence of regulations P_e and Q_e in figure 4 would be the equilibrium price and quantity for maize at the national level. But Panama confronts a perfectly elastic international supply curve given by P_iO_i where P_i is the international price of corn. Then, in absence of regulations, the relevant supply curve becomes OAO_i with OQ_2 domestically produced, OQ_1 domestically consumed and (Q_1-Q_2) imported. Once a support price P_s is established, domestic consumption falls to OQ_3, domestic production increases to OQ_4 and imports decrease

12/ Maize production in Chiriqui is reportedly used as follows: 25.4% is consumed in the farm, 4% is used as seed, 37.1% is used as feed and the remaining 38% is sold out the farm. Given an annual average total production of 11,661 m.t., it results that 4,431 m.t. are annually sold by farms. Chiriqui urban population was, in 1980, of 91,017, considering an estimated consumption of 18.82 kg/person, total urban consumption would be of 1,713 m.t. This would leave a net positive balance of 2,178 m.t. Although there are some small mills in the province, the bulk of Panama's mills are located out of the province, hence the excess production over internal consumption is likely sold out the region for consumption and/or processing.

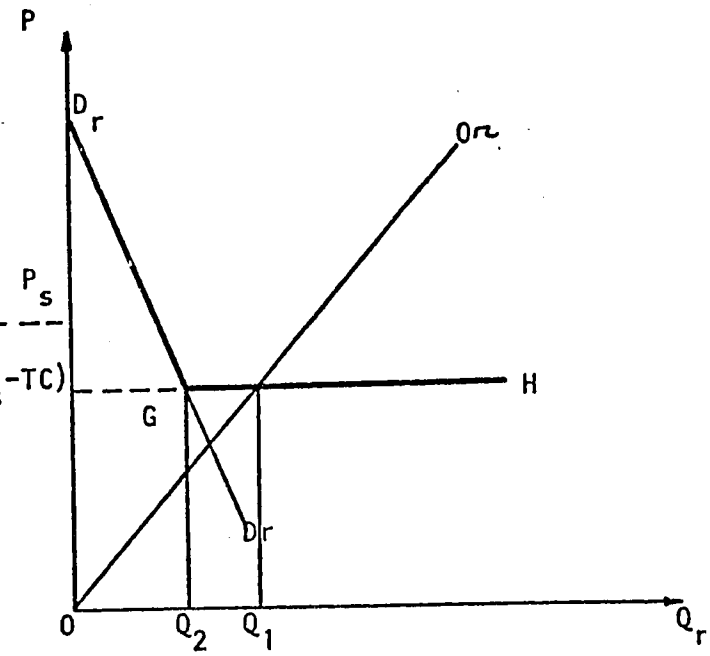
to $\overline{Q_4Q_3}$. The area ADE represents the social loss due to the excess cost of domestic production of the amount Q_4Q_2, and the area CBF is the loss in consumer's surplus due to the reduction in consumption of the amount $\overline{Q_1Q_3}$.

FIGURE 4



National Level

FIGURE 5



Regional Level

In figure 5, O_r and D_r are the regional supply and demand curves respectively. P_s is the support price in Panama City and $P'_s = (P_s - TC)$ is the support price net of transportation costs from the region to Panama City. In this case, OQ_1 is the amount produced by the region, OQ_2 is the amount consumed within the region and $\overline{Q_2Q_1}$ is the amount the region exports.

Given this situation and assuming that the region surplus production is entirely exported to and consumed in Panama City [13/] the social price of extra units of maize produced by the program will be given by the import price of maize (CIF, Panama City) net of transportation costs from

13/ Panama City is the most distant point among those of potential destination for the maize of the region. Hence this assumption implies (via transportation costs reduction) the lowest alternative with respect to pricing the maize.

Caisan to Panama, i.e. $P_m^1 = P_i - TC$. This is so since in absence of distortion in the foreign exchange market this price would reflect the social opportunity cost of extra units of maize without accounting for distortions in the internal market.

Introduction of a support price above the border price increases the social opportunity cost of extra units of maize, hence the society willingness to pay for additional units of maize from Caisan will also increase. In this case the marginal value of extra units of maize from Caisan will be given by the support price net of transportation costs, i.e. $P_m^2 = P_s - TC$.

From a perspective of general equilibrum and welfare considerations, maize pricing should be done under the assumption of non existance of regulations and hence P_m^1 should be used. However, social preferences in terms of food security (through import substitution) are well established and politically legitimized as a sustained policy goal which cannot be ignored neither by IDIAP nor by any institution like IDIAP.

In other words, what could be considered with a global perspective as a variable (i.e. agricultural policy) should be and has been considered by IDIAP as a parameter, setting the framework within which the institution could display its research policy and institutional strategies. Then when considering how efficiently IDIAP has been doing this in the particular case of Caisan the maize price which should be used is the one provided by P_m^2 as a reflexion of the agricultural policy framework faced by IDIAP. Accordingly, the resulting rate of return will best reflect, in our view, the efficiency of OFR methodologies implemented by IDIAP in Caisan. In any case, the decision was taken to conduct the evaluation under both maize pricing options.

4. Estimation of the Annual Flow of Research Costs.

Definition and characterization of inputs to the research process presents similar problems to those described in the case of the products (Scobie, 1979, Schuh and Tollini, 1979). Among the most common problems

are those arising when a particular resource is used to produce multiple or joint products, the case of serendipity in the process, and the correct specification of the knowledge stock participation in the research process. Because the decision to perform the evaluation from a strict national point of view, resources contributed by CIMMYT are considered as free and do not enter the cost side of the evaluation. With respect to resources contributed by IDIAP, Table 2 shows their composition in terms of basic items. The human resources figures indicate the proportion of men-year used by the program for each of both labor categories, for example during 1979 the program used. 8 men-year of skilled labor and 1.45 men-year of semi-skilled labour. In the case of fixed assets the figures reflect the proportion of the total annual services provided by the asset which is assigned to the program i.e. in 1979, 50 percent of the annual services provided by the rented house is assigned to the Program. Similarly 80 percent of the annual services (hours per annum) provided by a pick-up is used by the Program. Finally, as research materials are project specific, the table listed the amounts of each one of the used in the program. 14/

The economic evaluation of the program requires first that the project be evaluated against the without alternative and that resources used be priced at their respective opportunity cost interpreted as the value of the output the resource would produce in the activity from which the resource is withdrawn.

Application of the with-without criterion requires the identification, as component of the cost side of the evaluation, of only

14/ While identifying research costs an interesting problem came out in the discussion. Part of the cost of on-farm experimentation are shared by the farmers (i.e. land, farmer time). Since OFR fits in the production process, that is, it takes place while the farmer production process takes place, these costs will be usually more than outweighted by the benefits resulting from leaving the products of the experimental plot with the cooperator farmer. While this could still leave some doubts in terms of how it should be tested in an evaluation of OFR, it has, from the perspective of research strategy and management, a positive side associated with the fact that a percentage, even though small, of research costs is paid by those who will be the final recipients of research results.

additional resources necessary to conduct the program. In the case of fertilizers and pesticides they are program specific resources, hence they are enterely charged to the program (see table 2). With respect to fixed assets, the program used existing equipment and in addition a house was rented. In the case of the equipment it was considered that program accomplishment would require an additional time effort because increasing out of station work. As no reliable estimate of this increase existed the total time proportion assigned to the project was taken as a proxi for each piece of equipment used by the project (see table 2). With respect to the house, only fifty percent was regarded as assigned to the program.

TABLE 2: COMPOSITION OF RESOURCES CONTRIBUTED BY IDIAP TO THE PROGRAM.

RESOURCES	YEARS			
	1978	1979	1980	1981
A. Human Resources (Men-year)				
1. Skilled Labour	.40	.8	1.20	1.20
2. Semi-skilled Labour	.20	1.45	1.45	1.45
B. Fixed Assets (Proportion of Total Annual Services)				
1. Rented House	.50	.50	.50	.50
2. Equipment				
Pick-up	.65	.80	.80	.80
Kubota	-	.50	.50	.50
C. Research Materials				
1. Fertilizers				
Formula	-	12qq	12qq	12qq
Urea	-	6qq	6qq	6qq
Superphosfate	-	10qq	10qq	10qq
2. Herbicides				
Gramoxone	-	-	10 Gl.	10 Gl
Gesaprim	-	8 kg	8 kg	8 kg
2-4-D	-	1 Gl.	1 Gl.	1 Gl
Prowl	-	1 Lt.		
3. Insecticides				
Furadan	-	45 kg.	45 kg.	45 kg

All personnel involved in the project was already working for IDIAP. Application of incremental analysis requires again the identification of additional time effort attributable to the program as the component of the program's labor cost. The same criterion adopted for the equipment was used in this case, the total time proportion assigned to the project by each member was taken as a proxi for the additional time effort required by the accomplishment of the program over the traditional station work.

All resources allocated by IDIAP to the program including labor, fixed assets and fertilizers and pesticides are evaluated at 1981 market prices. This implies that market prices for these resources reflect their opportunity costs. A brief justification for this procedure follows for each resource category.

i. Labor- There is a general agreement in the welfare economics literature that skilled labor wages approximately reflect the opportunity cost of this type of labor (Irvin 1978). Since the program only used skilled or semiskilled labor, 1981 wages were used to estimate the labor cost incurred by the Caisan Program.

ii. Fixed Assets - Lack of accurate data availability precludes the estimation of the total costs of using the equipment employed by the project. The only data available was that of gasoline expenses. As the gasoline price in Panama reflects its importation costs it was considered that this price properly represented the opportunity cost of using it. Ignoring other user costs would result in underestimation of the true costs of the program. This is partially corrected by increasing the total annual estimated cost by 10%. In the case of the rented house the annual rent was considered as reflecting its opportunity cost.

iii. Pesticides and Fertilizers - The use of market prices was justified in this case on the grounds that there are no subsidies with respect to these resources. As such, domestic prices have historically followed world price fluctuations.

5. The Benefit/Cost Ratio and the Rate of Return

In order to calculate the benefit cost ratio and the rate of return of the project, the methodology employed by Griliches (1958) -also used by Kislev and Hoffman (1977) among others- was adopted. The benefit/cost ratio is estimated as:

$$(1) \qquad B/C = \frac{(PANB + AFNB - AFMC)}{PARC}$$

Where:
PANB are the past annual net benefits compounded to the base year
AFNB are the annual future net benefits discounted to the base year
AFMC are the annual future maintenance costs discounted to the base year,
and PARC are the past annual research costs compounded to the base year.

Griliches presents the rate of return, r as (1958, p.425):

$$(2) \qquad r = k \times B/C$$

where k is the discount rate used to estimate the B/C ratio. The rate of return r, can be interpreted as the discount rate at which the stock of costs yields an annual flow exactly equal to the annual flow of net benefits, alternatively r may be interpreted as the discount factor at which the annual flow of net benefits should be discounted in order to yield a stock exactly equal to that of costs. In other words, a rate of return of say 1.90 (190 percent) would indicate that each dollar spent in the project would generate a future annual flow of 1.90 dollars of net benefits.

The criterion to judge a given project according to the B/C ratio is that for the project to be acceptable this ratio should be larger or equal to one. Then this last equation says that:

$$r \lesseqgtr k \qquad \text{if} \qquad B/C \lesseqgtr 1$$

That is, if k represents the social rate of time preference between

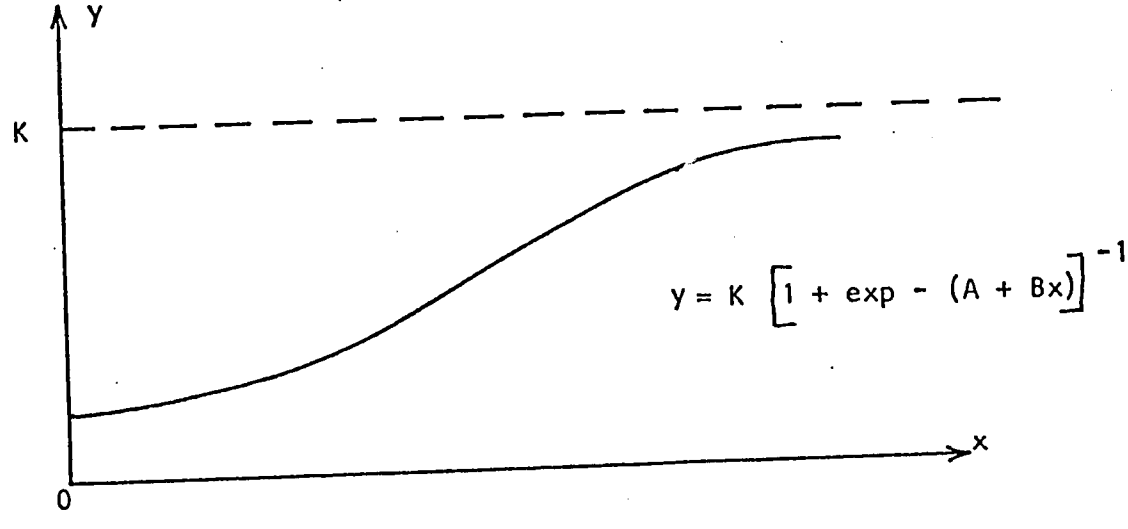
present and future consumption, then equation 2 states that the average rate of return for each dollar invested in the project (r), will be larger equal or smaller than the social rate of preferences if the discounted benefits are larger equal or smaller than the discounted (at the same rate) costs.

6. Estimation of Adoption Patterns. 15/

An important element for measuring the benefits of agricultural research is the estimation of the percentage of farmers (acreage) who have adopted the new technology. The nature of the OFR methodology used in Caisan presumed that appropriate technologies would be available in the near term. This in turn would fulfil a necessary condition for farmers' acceptance and accordongly speed up adoption.

A formulation commonly used to represent the diffusion of new innovations is the logistic growth function or learning curve. The graph of the function and its generic functional form are shown in figure 6.

FIGURE 6: THE LOGISTIC CURVE



15/ This section draws heavily on Martinez (1973).

Adaptation of this function to a context of technology adoption process is straightforward. Let $h_i(t)$ be the maize acreage proportion cultivated with the i-th technological alternative in year t. Then the logistic function representing the difussion time pattern is:

$$h_i(t)=K_i[1+\exp-(A_i+B_it)]^{-1}$$

In this equation K_i represents a constant called by Griliches the "ceiling" of the adjustment function. That is K_i is the maximum expected percentage of adoption of the technology. A_i is a parameter positioning the curve in the time scale, while B_i shows the rate of growth or rate of acceptance of the innovation.

Martínez conceptualizes the diffusion process along the logistic curve as succesive short-run equilibrium points between the supply and demand for the new technology. In this context the value of the ceiling would be interpreted as the long run equilibrium. Quoting Griliches: "While shift on the supply side determines the origin of the development, the rate of development is largely a demand or acceptance variable" (Martínez, 1973, p.81).

The rate of acceptance B, therefore can be interpreted as summarizing the demand conditions for the technology. As such, the estimated value of B could be used as an indicator of the farmers' degree of acceptability of the technology.

If enough data is available the logistic parameters A and B can be estimated, after the model has been previously linearized, by the least square method. If enough observations are not available, Martínez (op. cit. p. 92) presents a method to obtain a crude estimation of the parameters. The method consists in the simultaneous resolution of the following two equation system:

$$h_i(t_1)= K_i\ [1+ \exp-(A + B_it_1)]^{-1}$$

$$h_i(t_2)= K_i\ [1+ \exp-(A + B_it_2)]^{-1}$$

To solve this system in terms of A and B it is necessary to have information about the maximum expected adoption proportion K, and of the adoption proportions in two points in time $h_i(t_1)$ and $h_i(t_2)$. 16/

This has been the procedure followed for estimating the patterns of adoption for each technological alternative generated by the Program. The point $h_i(t_1)$ was based in the initial formal survey implemented at the planning stage of Caisan for assessment of farmer circumstances. The other point $h_i(t_2)$ was $h_i(1982)$; estimated with an especially designed adoption survey carried out in July 1982. The survey methodology used in this case was similar to that used in the assessment of farmer's circumstances (yet with different objectives). That is, an informal survey (done in May 1982) was carried to design a well focused formal questionnaire. This questionnaire was filled out in June 1982 for a random sample of 45 farmers within the recommendation domain of the Program.

Finally, the value of the adoption ceiling was estimated based on the knowledge and experience of regional technicians with the acceptability of the alternatives offered, their potential impact in net income and the relative degree of difficulty in their management. For

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16/ Once the values of K, $h(t_1)$ and $h(t_2)$ are known, the system is reduced to a two equation-two unknown system which admit a unique solution. System (3) can be rewriten as:

$$A + B\,t_1 = C_1$$

$$A + B\,t_2 = C_2$$

where

$$C_1 = \ln\,[h(t_1)/K-h(t_1)]$$

and

$$C_2 = \ln\,[h(t_2)/K-h(t_2)]$$

The values of A and B which solve the system are calculated as:

$$A = \frac{C_1 t_2 - C_2 t_1}{t_2 - t_1} \quad \text{and} \quad B = \frac{C_2 - C_1}{t_2 - t_1}$$

example, the change from irregular planting to planting in rows is seen by farmers as more "complicated" than the change in the type of weed control. Furthermore, zero and minimum tillage requires the replacement of usually contracted mechanical tillage by hand chopping plus application of herbicides, activities which are usually performed with own farm labor force.

In order to identify farmers who adopted the new technology, definition of a set of relevant adoption criteria (discriminant variables) for each new technological alternative is necessary. Once these criteria are defined farmers are classified as full adopters if the technology they are actually using agrees with all these criteria. Similarly, partial adopters are those farmers whose current practices only match some but not all of these criteria.

Partial adoption may occur if because of lack of information and/or financial or market restrictions the farmer adopts only part of the new technology. This case should not be confused with that of farmers who decide to "test" the new technology. In this case he usually adopts the new technology in full but applies it to only a fraction of his parcel. In this way the farmer is able to compare for himself the "advantages" of the new technology against those of the conventional one.

Table 3 describes the adoption criteria defined for each of the four technological alternatives.

7. The Economic Returns to the Methodological Innovation.

As it was stated earlier, one of the objectives of the evaluation is the estimation of the returns accrued to the application of the on-farm methodology into the research process. In order to do so it is necessary that the program be evaluated against the alternative i.e. against traditional station research, hence an adoption pattern for the traditional approach needs to be assumed.

TABLE 3 DISCRIMINANT VARIABLES AND ACCEPTANCE CRITERIA FOR EACH TECHNOLOGICAL ALTERNATIVE.

TECHNOLOGICAL ALTERNATIVE	DISCRIMINANT VARIABLES	ACCEPTANCE CRITERIA
T.A.1: Chemical Weed Control.	1. Chemical Weed Control	1. If the farmer uses chemical weed control
	2. Type of Product	2. If the control is accomplished with Gesaprim or Gramoxone.
	3. Application Time	3. i) Gesaprim: 0-15 days after planting. ii) Gramoxone: 0-35 days after planting.
	4. Doses	4. i) Gesaprim 1-3kg/ha ii) Gramoxone: 1-3 lt/ha.
T.A.2: Spacing arrangement and density.	1. Planting Arrangement	1. If planting is accomplished in rows.
	2. Density	2. 45,000-60,000 plants/ha.
T.A.3: Zero Tillage.	1. Tillage system	1. If the farmer does not use a mechanical tillage.
	2. Application of herbicides	2. If the farmer applies herbicides prior to planting.
T.A.4: Fertilization	1. Application of fertilizers	1. If the farmer does not apply fertilizers.

Following tradition, a pessimistic assumption which can be made about this pattern, is that station research would be able to identify exactly the same research opportunities than those identified by OFR. This assumes that the only advantage of applying the new research methodology is accounted by an extension effect. 17/ In other words, the only difference between both research strategies is given by a time lag in the process of discovery and dissemination of the same technological components. 18/

Once this assumption is adopted the benefits to be estimated are a function of the differential rates of adoption under both alternatives. Following Lu (1981) several alternatives may be considered: these are illustrated in Figure 7.

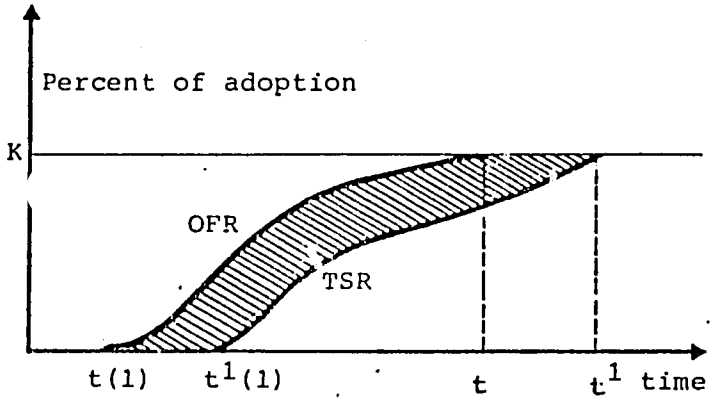
In order to estimate the incremental benefits due to the application of the on-farm methodology in Caisan the shadow area under both curves needs to be estimated. The problem is that the adoption curve under the station research stragegy (TSR in the figures) is an hypothetical one and cannot be estimated directly. Hence it was decided to estimate upper and lower bounds of benefit-cost ratios and rates of returns to the program by assuming different cut off points of the benefit flow of the program. Figure 8 illustrates the approximation method used for the case of a change in the adoption lag.

17/ The process of technological innovation can be decompossed into two highly interrelated and complementary effects: a research effect dealing with the creation of new technology and an extension effect dealing with the dissemination of this technology. (Lu, 1981).

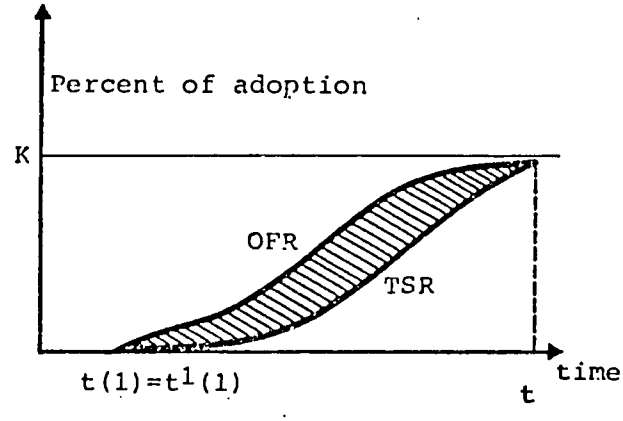
18/ In case of complex farming systems, ignoring bioeconomic interactions lead to situations in which promising research opportunities remain uncovered. OFR methodology implies the ex-ante assessment of most promising research opportunities minimizing therefore the probability of missing an important one. Hence the assumption of ignoring the research effect in OFR will certainly underestimate its contribution within the research process.

FIGURE 7 ALTERNATIVE EFFECTS OF OFR OVER TSR

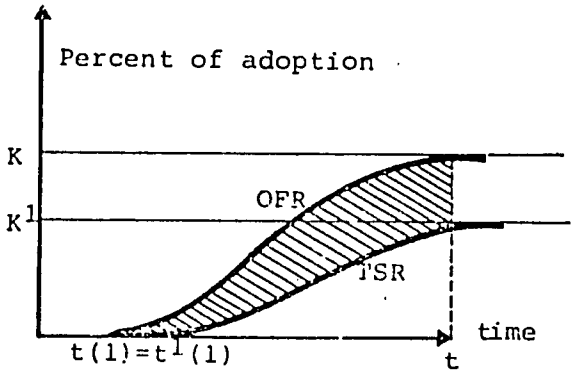
i. The only change is in the year of introduction of the new technological components



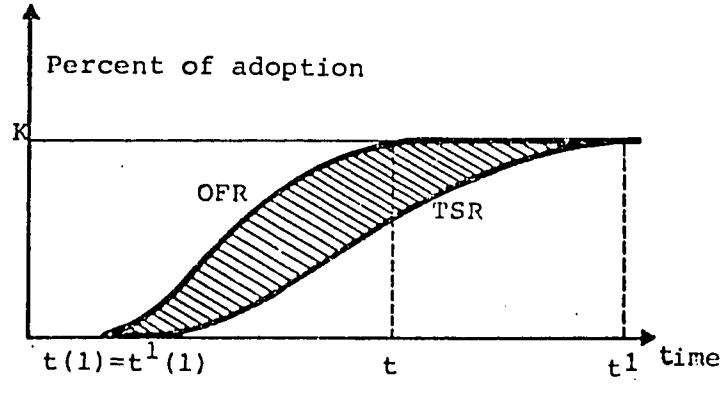
ii. The only change is in the rate of adoption of the new technological components.



iii. The only change is in the adoption ceiling K of the new technological components.



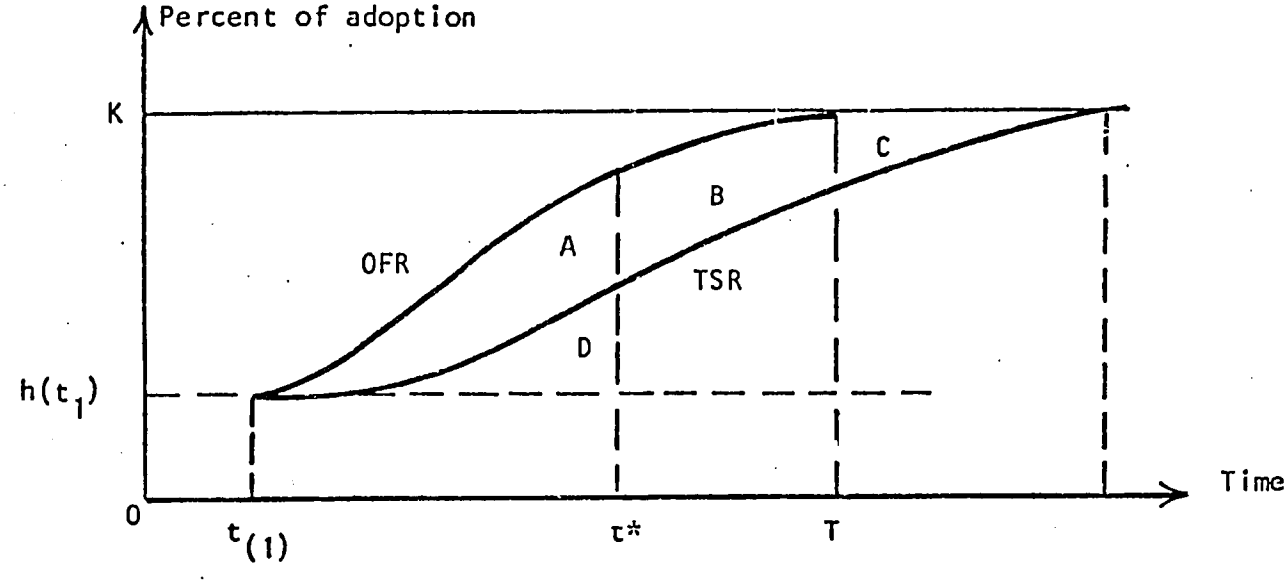
iv. The only change is in the adoption lag of the new technological components.



OFR= Adoption pattern of new technological components under OFR.

TSR= Adoption pattern of new technological component under traditional station research.

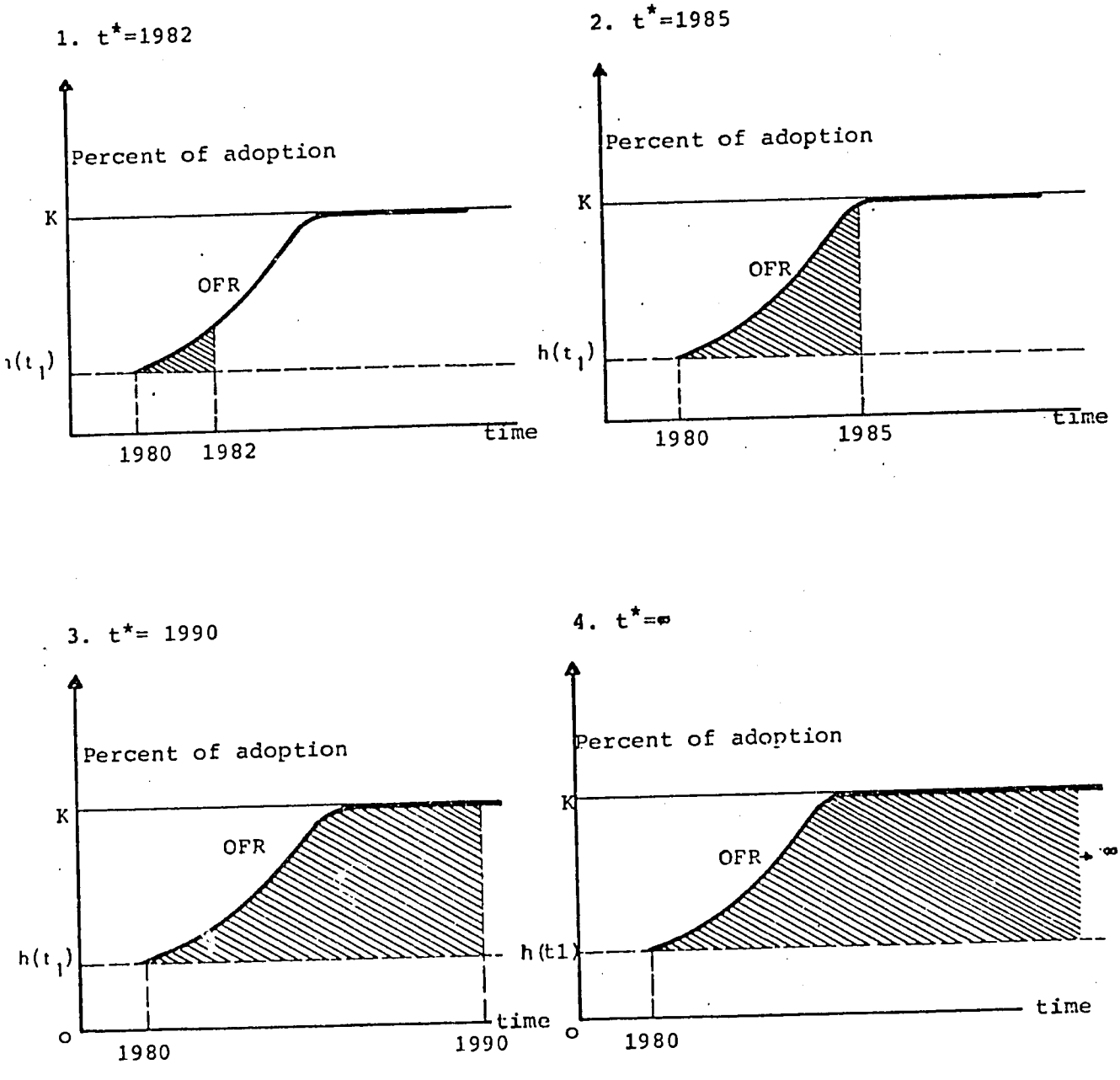
FIGURE 8 ESTIMATION OF BENEFITS ATRIBUTABLE TO OFR OVER TSR.



Given the estimated OFR curve, and the hypothetical TSR curve then a cut off point t^* should be chosen such that the true unknown area ABC would be approximated by the area AD. In order to do not overestimate benefits the area D should be smaller than B and C. By changing the cut off point t^* it is possible to simulate different effects and positions of the TSR curve, leading to upper and lower bounds in the benefits side and hence in the rate of return of the program. The four cut off points simulated in the evaluation are illustrated in figure 9.

The most likely changes between both methodologies (considering only extension effects) would be a combined change in the year of introduction and in the adoption lag of the new technological components. Hence, the cut off point of 1982 would provide a very unlikely lower bound of the benefits and returns to the OFR methodology applied in Caisan, while the case of t^*=1985 would provide a fairly pessimistic estimate of benefits and returns to the program.

FIGURE 9 ALTERNATIVE HYPOTHESES FOR ESTIMATING THE CONTRIBUTION OF OFR METHODOLOGY IN CAISAN



A more realistic estimate of the benefits and returns to the OFR methodologies would be given by the cut off point of 1990, in which case some research effects would be also incorporated. Finally, the case of $t^* = \infty$, illustrates the upper bound in benefits and returns to the program. As a matter of fact this case is equivalent to remove the assumption that traditional station research would have been able to identify and effectively work with the same research opportunities identified by the OFR program in Caisan.

It should be stressed here that the simulation of benefits and returns performed in this work does not imply that there are not benefits to the society after a certain date. Social benefits due to technological innovation are, once adopted, permanent.

IV. RESULTS

1. Adoption Patterns.

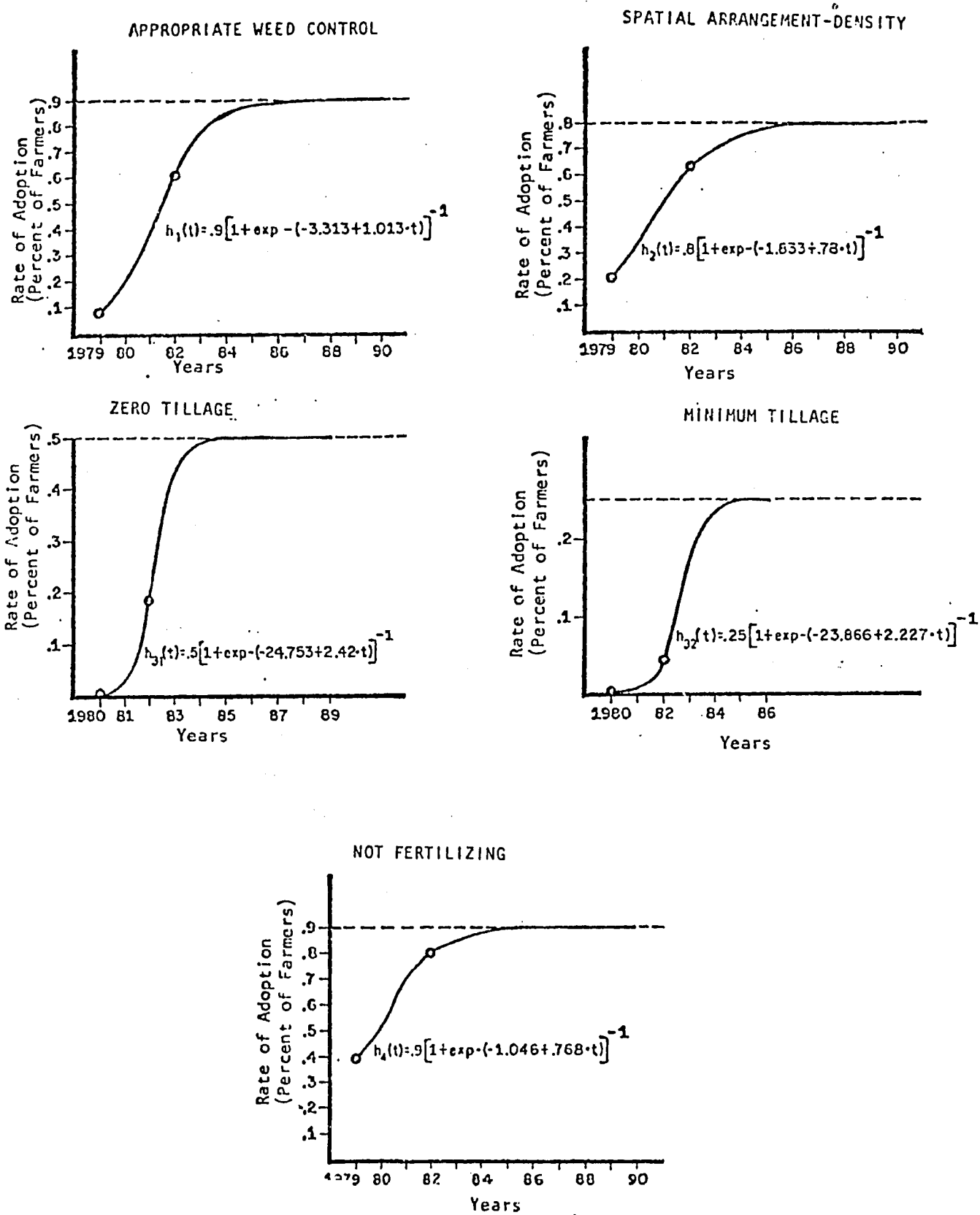
The initial step in the implementation of the evaluation methodology described in previous section was given by the adoption surveys conducted in 1982. The application of the adoption criteria resulted in the percentage of maize acreage cultivated with each alternative. The same procedure was carried for farmer practices from the 1978 survey. Table 4 presents the resulting percentages, as well as the estimates of maximum adoption points (K_i). In turn, these values lead to the estimation of logistic adoption functions whose parameters A_i and B_i are also included in Table 4. The shape of each logistic functions as well as their location in the time scale are shown in Figure 10.

TABLE 4 ESTIMATED ADOPTION PARAMETERS

Alternatives	t_1	$h_i(t_1)$	$h_i(1982)$	K_i	A_i	B_i
1.Chemical weed control	1979	.082	.609	.90	3.3	1.0
2.Seeding arrangement and density	1979	.207	.62[illegible]	.80	1.8	1.8
3.1.Zero tillage	1980	0	.188	.50	24.8	2.4
3.2.Minimum tillage	1980	0	.042	.25	23.9	2.2
4.No use of fertilizers	1979	.388	.795	.90	1.0	1.0

FIGURE 10

ADOPTION PATTERNS FOR THE RECOMMENDED TECHNOLOGICAL ALTERNATIVES



The values obtained for h_i (1982) indicate a high percentage of adoption for the alternatives after only few years of the Program operation. This confirms the hypothesis that technologies where appropriate to farmer circumstances prevailing in the recommendation domain. Also, the speed at which adoption took place, reflected by the value of the parameter B_i, is telling us not only that the alternatives generated where agroeconomically viable for representative farmers, but also that they likely represented a solution for an important production problem faced by farmers and correctly identified as a research opportunity at the planning stage of the Program. 19/ This, as it stands, is an important result of the evaluation. It is still to be seen in the rest of this section whether or not they have been reached efficiently.

In order to proceed towards the estimation of benefits we need to consider the values of h_i (t_i). The starting point for the diffusion due to the Program is placed in different years according to the time of release of the alternative. In this sense, it was considered that there was not diffusion, hence no adoption due to the Program, of any technological alternative until 1980. We are then interested in clarifying the meaning of the positive values for $h_i(t_i)$ and what role have they play in the quantification of benefits.

The relatively high values for not use of fertilizer (38.8%) and planting arrangement and density (20.7%) could be understood by the fact that in the first case, some farmers were not having access to credit and consequently not using fertilizer in spite of prevailing recommendations, while the second one was also related to credit programs but in a different sense, it correspond to farmers which had accepted the fully mecanized services of PROMECA, included in the credit package, and consequently had conventional mechanized land preparation and planting, in which case obviously arrangement and also density were decided by PROMECA which had the same calibration of the planters for all the services provided. Note that as the Program evolved, conventional

19/ The research hypothesis formulated at the planning stage could be seen in Martínez and Arauz (1983) chapter 4.

mecanized tillage and planting decreased as a result of the release of the zero-minimum tillage alternative.

The remaining positive value for $h_i(t_1)$ is a small percentage (8%) in chemical weed control, corresponding to a non sistematic trial and error process followed by farmers searching for better chemical weed control alternatives. This value reflects the magnitude of the weeds problem identified as a promising research opportunity by the Program. 20/ Finally, the values of $h(t_1)$ for zero and minimum tillage were zero, as there were no farmers using at t_1 these alternatives. In any case, in order to obtain the net annual adoption level due to the Program, whenever a positive value for $h_i(t_1)$ was found it was discounted from the adoption level reached in each year.

In other words, this net proportion was estimated along the time scale of the logistic adoption function as $H_i(t_j) = h_i(t_j) - h_i(t_1)$ Table 5 shows the annual values of $H_i(t_i)$ for each alternative. Zero values for 1979 reflect the reasonable assumption already established that no adoption due to the Program took place during this year.

TABLE 5 NET PROPORTION OF MAIZE CULTIVATED WITH EACH TECHNOLOGICAL ALTERNATIVE.

Year (j)	ALTERNATIVE 1 $H_1(t_j)$	2 $H_2(t_i)$	3.1 $H_{3.1}(t_j)$	3.2 $H_{3.2}(t_i)$	4 $H_4(t_i)$
1979	0	0	0	0	0
1980	.113	.039	0	0	.170
1981	.307	.292	.024	.005	.313
1982	.527	.420	.129	.042	.407
1983	.685	.503	.433	.163	.460
1984	.727	.549	.493	.236	.487
1985	.800	.572	.500	.249	.500
1986	.811	.583	.500	.250	.507
1987	.815	.589	.500	.250	.510
1988	.818	.591	.500	.250	.511
1989	.818	.593	.500	.250	.511
1990	.818	.593	.500	.250	.511
After 1990	.818	.593	.500	.250	0

20/ For more details see Martínez and Arauz (1983) chapter 4.

The ceiling (maximum adoption) is approximately achieved for every alternative around 1985. The ceiling is continued to perpetuity for all but fertilization. In this case it is assumed that due to natural process fertilizer application would start to have significant responses starting in 1990, hence adoption of this alternative was assumed to produce benefits only until 1990. 21/

2. Estimation of the Annual Flow of Net Benefits

Net benefits per hectare are estimated for each alternative subtracting from the change in gross benefits the change in those costs that vary. (ΔC) Gross benefits are, in turn, calculated as the product of the increase in yields due to the alternative (ΔR_i), times the social price of maize, (Pm).

This section is organized as follows: yield increases are estimated in part 2.1; part 2.2 deals with the estimation of net benefits per hectare, and the annual flow of net benefits for each technological alternative and for the entire program are calculated in part 2.3.

2.1 Estimation of the Technology Induced Yield Increase

Although Hertford (1977) stressed some years ago that the most important component in measuring the benefits from agricultural research is the production shift parameter K (the parameter measures the relative change in production $\Delta Q/Q$ due to the adoption of the new technology), Dalrymple (1981) pointed out the existence of an imbalance between the relatively sophisticated methodology developed to measure the area under the supply-demand curves and the poor data base upon which the method is used.

21/ The Program currently includes fertilizer level trials in continuous plots to analyze what will happen in the medium run to the natural fertility of the land as result of adoption by farmers of improved (more intensive) production practices in weed control and spacial arrangement and density.

Traditionally two sources of data have been used to measure the relative change in yields: data gathered at experimental level and data from aggregate average farm yields.

While data from aggregate average farm yields has the advantage of being readily accessible; in most developing countries it is a very unreliable estimate of yields at farm level. On the other hand, two reasons are commonly quoted for the existence of an upward bias in the yield gathered at experimental station level when used as farm level yields estimators. The first one given by the fact that the level of non-experimental variables is kept at what is considered an "optimum" one, and the second one given by the existence of marked differentials in managerial factors.

In this work a third source of data is used to estimate the relative increase in yields at farm level: data gathered in on-farm trials. In this case yield data is free of the first source of bias because the level of non-experimental variables are kept at farmer level. Hence, yield increases reflect more accurately increases due to the change in experimental variables and cannot be partially attributed to the interaction with high intensity use of other inputs. Furthermore experimental yields were adjusted not only to account for agroclimatic and pest related risk factors but also for managerial factors.

In this sense, data used in this work reflects in the most accurate possible way yield gains at farmer level due to the adoption of the technological innovations. It is believed that if this source of data is available (results of OFR experimentation), it should be preferred over alternatives when estimating the gain in yields due to technological innovation.

Estimation of the yield increase induced by the adoption of technological alternatives belonging to the first group was carried out using the experimental results from all the three cycles of the project. The first two years of experimentation were considered as normal, while during 1981 yields were adversely affected by an epidemic attack of

Helminthosporium sp. Since epidemic attack of Helminthosporium sp. in the region is estimated to have a very low frequency of approximately one in twenty years, a weighted average of both periods using these frequencies as weights was estimated.

Another adverse factor which should be taking into account is that of lodging. Results from the 1978 survey indicate a high frequency of occurrence with partial crop losses. As there is no information about the magnitude of partial damage, this effect was incorporated into the yields calculation by assuming a total loss impact and a smaller occurrence frequency of once every ten years. Adjusted yields are shown in Table 6, where D_o and H_o represent the farmer's practice for seed density and herbicides application respectively where D_1 and H_1 represent the recommended levels in each case.

TABLE 6 YIELDS ADJUSTED BY RISKS FACTORS

	H_o	H_1	Average
D_o	2.901	3.893	3.40
D_1	3.682	4.841	4.26
Average	3.29	4.37	

Source: Caisan On-Farm Trials 1979/81.

These numbers indicate a yield increase due to chemical weed control of 1.08 ton/ha, while seed arrangement and density raises yields by .86 ton/ha. 22/ These impacts should be weighted by a "yield adjustment coefficient" which account for differences between farmers and experimental managerial conditions. In the case of Caisan this coefficient was estimated by Arauz and Martinez (1982) to be 10%, hence the final increase in yields to be used in the evaluation are:

22/ Although a positive interaction effect was identified in some of the trials, this impact was ignored in the evaluation.

$$\Delta R_1 = .972 \text{ ton/ha}$$

and

$$\Delta R_2 = .774 \text{ ton/ha}$$

for alternative 1 and 2 respectively.

2.2 Net Benefits per Unit of Land.

Calculation of the net benefits per unit of land generated by each technological alternative is accomplished by the method of partial budgeting (Perrin et al 1976). Tables 10, 11, 12, 13, and 14 in the appendix 1, provide details of performing this operation, a summary of the results under the two pricing alternative is given in Table 7.

TABLE 7 NET BENEFITS PER UNIT OF LAND (DOLLARS/HA, 1981) 1/

Social Pricing	TA 1: Chemical weed control	TA 2: Spacing arrangement and density	TA 3.1: Zero tillage	TA 3.2: Minimum tillage	TA 4: Fertilization
1. Without Regulation	141.14	104.66	18.75	12.75	39.74
2. With Regulation	191.29	145.22	18.75	12.75	39.74

1/ Taken 1981 prices the estimated social prices were:

P^1_m = without regulation = \$149.50/metric ton., and

P^2_m = with regulation = \$201.09/metric ton.

2.3 The Annual Flow of Net Benefits.

Once net benefits per unit of land and the total net acreage cultivated with each alternative are estimated, calculation of the annual flow of net benefits proceeds by multiplying both numbers for each alternative. The annual flow for the entire program is procured by adding up the individual flows over the alternatives.

Tables 14-a, 14-b, in the appendix, present these flows for both

social pricing alternatives. The benefits flows shown in these tables correspond to those generated under the upper bound assumption of perpetual flows. Alternative ones are estimated by choosing appropriate cut-off years.

3. The Annual Flow of Research Costs

Annual research costs elapsed from mid 1978 (last 5 months) to 1982. It was assumed that after 1982 there would be a perpetual flow of maintenance costs in order to keep yield constant against an adverse nature (Griliches, 1958). A pessimistic annual estimation of these costs amounted to 40% of the 1982 cost level. Table 8 shows the estimated annual flow of research costs of the program.

TABLE 8 ANNUAL FLOW OF RESEARCH COSTS (IN DOLLARS)

	1978	1979	1980	1981	1982	After 1982
Annual Research Costs	3,000	14,300	17,800	17,800	17,800	7,200

4. Benefit - Cost Ratio and the Rate of Return.

To estimate the Benefit-Cost ratio (B/C) and the rate of return (r), 1982 was chosen as base year. A discount factor of 15%, the same used by A.I.D. in the evaluation of Panamenian agricultural projects of similar length, was employed to carried out the flows to the base year.

The benefits cost ratio and the rate of return were estimated for the four assumed cut off points of the flow of net benefits under both pricing alternatives. The results of the calculations are summarized in Table 9.

TABLE 9. BENEFIT-COST RATIOS AND RATES OF RETURN [1/]

	CUT-OFF POINTS			
Pricing options	t^*=1982	t^*=1985	t^*=1990	t^*=00
Social prices without regulation	3.11 (47%)	7.86 (118%)	12.93 (194%)	16.36 (245%)
Social prices with regulation	4.05 (61%)	10.30 (155%)	16.99 (255%)	21.69 (325%)

[1/] Values within parenthesis are rates of return, without parenthesis benefit-cost ratios.

In all cases, the rates of return substantially exceed the social cost of investment capital. The level of the rates of return will depend upon the assumption adopted about the true position of the tradition station research curve (see section 3.7), ranging for the first pricing option from the very unlikely 47% in the case of a cut off point of 1982 to 245% in the case of a cut off point at infinite.

In the authors criterion the case of t^*=1982 can be disregarded as very unrealistic. Not only it ignores by assumption any "research effect" in the implementation of the on-farm research methodology, but also, it attributes an almost negligible "extension effect" which appears to be inconsistent with the fact that in the past, actions of traditional research and extension have not resulted in significant changes in technological production patterns in the area, while as shown in the adoption patterns, important technological changes have taken place soon after the OFR starts rendering its first results.

A more realistic lower bound would be that of t^*=1985, while the upper bound would be given by $t^*=\infty$. The first case would still represent a purely "extension effect" as the only advantage of on-farm research over traditional station research strategy. On the other hand, the upper bound would represent a removal of the restrictive assumption that

traditional station would have generated in due time the same technological alternatives as the OFR program. In other words, this cutt off point stress the research effect of OFR by actually assuming that the alternatives generated in Caisan would not have been available should the OFR had not been in operation. The cut off point of $t^*=1990$, represents a middle point. It compromises between stressing the "extension effect" in some components like the case of fertilizers and planting arrangement and density where relatively high $h(t_1)$ values were found, and stressing the "research effect" in others like herbicides and zero-minimum tillage in which case the survey shows zero or near zero $h(t_1)$ values.

Summarizing, the rate of return due to the methodological innovation in Caisan ranges between 118% and 245% with a most likely value of 194% in the case of social prices without regulations and between 155% and 325% with 255% as most likely value when regulations are taken into account.

The most likely values of 194% and 255% are revealing that each dollar invested up to the base year in implementing the on-farm research methodology in Caisan, render a flow of social net benefits of 1.94 and 2.55 dollars per year depending on the pricing option.

V. CONCLUSIONS

In the last five years considerable progress has been acomplished by National Research Programs in the testing and developing of operational methodologies for on-farm research, as well as in terms of the amount of resources allocated to this type of activities. As this process evolves, methodological and technical problems are resolved and new ones start taking their place, among them that of the institutionalization of on-farm research within national research structures.

The starting point for this institutionalization process has been the experience arising from the ongoing area specific on-farm research programs. These have usually been managed in the initial stage of this process by ad-hoc technical groups from within the research structure.

From CIMMYT's perspective, the process builds from basic methodological ideas, to on-farm research experiences, to the institutionalization of these activities within the national program. In other words, it goes in a bottom up approach, from on-farm research actions to an articulated on-farm research program.

IDIAP and Caisan illustrate this process. The institutional strategy of IDIAP provided the framework for the development of Caisan. The progress of the program and the methodological experiences arising from it were closely followed by the national directing staff and intensively discussed by researchers and directing staff in national meetings, field days, and regional workshops.

This in turn has lead to a reinforcement of the initial orientation of IDIAP towards area-specific on-farm research. Also, in the methodological dimension, it provided concrete experiences, not only in terms of what to do in on-farm research (surveys, experiments, etc.) but, more important, how to do it, i.e., the informal survey leading to a well-focused formal questionnaire, the prescreening of best-bet technological components based on the assessment of farmer circumstances, the management of experimental and nonexperimental variables within the trials, etc.

The present economic evaluation represents a contribution to this process of institutionalization of on-farm research with some methodological implications in terms of evaluation research; [23/] which in this case has been adjusted to the particular requirements and institutional circumstances of IDIAP.

An impact evaluation in the more traditional sense (for example impact on yields, impacts on production) could represent a necessary, yet not sufficient condition for additional support of this activities on the part of policy makers. Among other things, meeting sufficient condition

23/ No work of similar nature evaluating on-farm research was found in the review of the literature on economic evaluation of agricultural research.

for increasing support also requires dealing with the more controversial issues of the cost efficiency of this methodological innovation in agricultural research. This would be normally considered before the process could be advanced toward the more complex stages of institutionalizing on-farm research within the present national structures. The evaluation has been carried incorporating both elements, impact and cost efficiency, which are sinthetisized in the social rate of return for the IDIAP investment required to implement the Caisan methodology.

In terms of economic evaluation methodology, section III showed how the interaction between the "state of the arts" and the particular requirements coming from the nature of on-farm research activities, resulted in certain key decision for the evaluation methodology to be implemented. Farmer adoption, and consequently actual impact in production, was required for associating any positive benefits to the research process. The same information generated in the on-farm research process was used in the evaluation. This included the initial planning survey of 1978, and the trial results from three production cycles adjusted by risk factors prevailing in the area. In addition to this, an adoption survey specially designed to fit the objectives of the evaluation, was implemented in 1982. With all this, the amount and quality of the information used in the evaluation appear to be superior to that used in evaluations of similar nature. [24/] In this sense, it is believed that the information coming from appropriately conducted on-farm experiments will close Dalrymple's gap between sophisticated evaluation theory and poor data base (see section IV, 2.1).

Meaningful conclusions came out as a result of the evaluation conducted. The level of adoption of the technological alternatives gave indication of the degree in which they fitted circumstances of

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24/ For example, the pioneer work of Griliches (1958), in a more ambitious evaluation (hybrid corn in U.S.), assumes that yield increase associated with the use of hybrids is of 15% over preinnovation yields. The equivalent information in the case of Caisan is based in three cycles of on-farm trials, which incorporates farmer practices as a base for the analysis.

representative farmers from Caisan. On the other hand, the speed at which adoption took place indicated not only that the technologies developed were agroeconomically viable for representative farmers, but also that they represented a solution to an important problem faced by those farmers. This priority had been correctly identified in assessing research opportunities in the planning stage of the program.

In other words, the results in terms of adoption speaks out of the usefulness of the OFR methodology for reaching representative farmers with appropriate technologies in the near term. In assessing "how useful", the evaluation was required to enter into more quantitative aspects dealing with the specific contribution of the methodological innovation represented by OFR against the "without alternative"; that is, what would have happened with purely traditional station research. This way of approaching the evaluation is consistent with the conceptual role attached to OFR as a needed complement of traditional station research.

Quantitative aspects of evaluating methodological innovations were covered by considering three alternative assumptions about the relative importance of the research effect of OFR over that of TSR.

The first assumption puts a zero weight to this effect attributing an extension effect as the only advantage of OFR over TSR. This provides a lower bound for the economic returns to national investment on methodological innovations. The assumption is represented by considering that the flow of net benefits attributed to the programs last only to 1985.

In the other extreme of the scale the upper bound of the returns is obtained by strongly weight the research effect attributable to OFR: technological alternatives engendered by the Program would not have been generated otherwise. In this case the flow of net benefits are extended to perpetuity.

Finally an intermediate case is considered by differentially weighting the research effect by technological components. This provides

a measure of economic returns which appear as the more likely to occur.

In addition, two pricing scenarios for maize were considered. The first one, consistent with a perspective of general equilibrium and welfare considerations, assumed the existence of non regulations; the other, more consistent with the specific objectives of this particular evaluation, takes price policy as a parameter faced by IDIAP. In this scenario, price policy is part of the framework (set of parameters) within which the institution should display its research policy and institutional strategies.

Results indicated that disregarding what pricing scenario is adopted the lowest social benefits generated with the OFR methodology have been comfortably above research costs. This lowest bound for the rate of return ranges between 118% and 155% depending on the pricing scenario adopted, 25/ while in the case of the upper bound the rate fluctuates between 245 and 325 percent.

Finally, when the most likely case of a net flow lasting to 1990 is considered, the rate of return ranges between 194 and 255 percent.

These results reafirm the perception, based on this and other experiences, 26/ that the OFR methodologies used in Caisan are cost efficient in reaching target farmers with appropriate technologies in the near term.

Consistently with preceeding results, IDIAP area-specific on-farm research activities, have gone through considerable expansion since 1978 when the Caisan program begun with only two national researchers. At

25/ As a reassurance the benefit-cost ratio and rate of return for a benefit flow lasting only to 1982 (the base year of the evaluation) was calculated. The rate of return ranges in this case between 47% and 61% depending on the pricing scenario. This indicated that even after only less than four years of the beginning of the program, social benefits basically accruing to farmers, outweighted research costs.

26/ For example see Moscardi, E. (1983).

present these activities include five priority areas in agriculture, involving the work of 24 national researchers, and three priority areas in livestock with 21 researchers. As this expansion takes place, a set of issues related to the institutionalization of on-farm research becomes a matter of primary concern of IDIAP. [27] As the central management moves to cope with these issues, the institution comes closer to realizing its full potential for the benefit of Panamenian farmers and the society as a whole.

[27] See Martínez, Juan Carlos and Arauz, José Román (1983), section V.

APPENDIX 1

TABLE 10 T.A. 1. CHEMICAL WEED CONTROL. NET BENEFITS PER UNIT OF LAND.

	Social price without regulation Pm^1	Social price with regulation Pm^2
A. Gross Benefits por ha. (ΔR x Pm)	$ 145.31/ha	$ 195.46/ha
B. Net Change in Variable Costs (ΔC)	4.17/ha	4.17/ha
b.1 Value of Additional Resources		
i. 2.0 kg Gesaprim x $8.13/kg	16.26/ha	16.26/ha
ii. 1.0 lt Gramoxone x $5.5/lt	5.50/ha	5.50/ha
Weighted average 1/	6.75/ha	6.75/ha
b.2 Value of Replaced Inputs		
i. 1 lt. 2-4-D x $2.58/lt.	2.58/ha	2.58/ha
C. Cost of Capital (15% - 8 Months)	.42/ha	.42/ha
D. Net Benefits per ha	140.72/ha	190.87/ha

1/ The average was weighted by the acreage proportion controlled with each product (weight for Gesaprim = .1166; weight for Gramoxone =.8834)

TABLE 11 T.A. 2. SPACING ARRANGEMENT AND DENSITY

	Social price without regulation Pm^1	Social price with regulation Pm^2
A. Gross Benefits per ha (ΔR x Pm)	$115.71/ha	$156.27/ha
B. Net Change in Variable Costs (ΔC)	11.05/ha	11.05
b.1. Value of Additional Resources		
i. 3 kg/ha of maize seed x $0.35/kg	1.05/ha	1.05/ha
ii. 2 days/ha of labor x $5.00/day	10.00/ha	10.00/ha
b.2. Value of Replaced Inputs.	-	-
C. Cost of Capital (15% - 8 months)	1.11/ha	1.11/ha
D. Net Benefits per ha. (A-B)	103.55/ha	144.11/ha

TABLE 12 T.A.'s 3.1, 3.2: ZERO TILLAGE AND MINIMUM TILLAGE 1/

	Zero Tillage	Minimum Tillage
A. Gross Benefits por ha. (ΔR x Pm)	–	–
B. Net Change in Variable Costs (ΔC)	$ 18.75/ha	$12.75/ha
b.1 Value of Additional Resources		
i. Two men days/ha x $5.00/day (hand chopping)	10.00/ha	-
ii. 1.5 lt Gramoxone x $5.5/lt	8.25/ha	8.25/ha
iii. Two men days/ha x $5.00/day (application of Herbicide)	10.00/ha	10.00/ha
iv. User cost of back pack sprayer	1.00/ha	1.00/ha
b.2 Value of Replaced Inputs		
i. 3 machine hours/ha x $16.00/hour	48.00/ha	-
ii. 2 machine hours/ha x$16.00/hour	-	32.00
C. Cost of Capital (15% - 8 Months)	1.88/ha	1.28/ha
D. Net Benefits per ha (A-B)	20.63/ha	14.03/ha

1/ Since technological alternatives 3.1, 3.2 and 4.0 are purely input saving technologies without affecting yields the distinction between alternative pricing of maize becomes irrelevant and is omitted from the tables.

TABLE 13 TA.4 FERTILIZATION

A. Gross Benefits per ha (ΔR x Pm)	-	-
B. Net Change in Variable Costs (ΔC)	$39.74/ha	
b.1. Value of Additional Resources	-	
b.2. Value of Replaced Inputs.		
i. 2qq/ha of mixed fertilizer x $17.37/qq	34.74/ha	
ii. 1 man day/ha x $5.00/day (application)	5.00/ha	
C. Cost of Capital (15% - 8 months)	3.97/ha	
D. Net Benefits per ha. (A-B)	43.71/ha	

TABLE 14 FLOW OF NET BENEFITS GENERATED BY THE PROGRAM.

a) Social Prices without Regulation

Technological years / Alternatives	1 Chemical Weed Control	2 Spatial Arrangement and Density	3 Zero-Minimum tillage	4 Fertilization	Total Caisan Project
1980	15,901	4,038	0	7,431	27,370
81	43,201	30,237	565	13,681	87,864
82	74,159	43,491	3,250	17,790	138,690
83	96,393	52,086	11,220	20,107	179,806
84	102,303	56,849	12,457	21,287	192,896
85	112,576	59,231	13,482	21,285	207,144
86	114,124	60,370	13,808	22,161	210,413
87	114,687	60,991	13,822	22,292	211,792
88	115,109	61,198	13,822	22,336	212,465
89	115,109	61,405	13,822	22,336	212,672
90	115,109	61,405	13,822	22,336	210,672
After 1990	115,109	61,405	13,822	0	190,336

b) Social Prices with Regulation

Technological years / Alternatives	1 Chemical weed Control	2 Spatial Arrangement and density Siembra	3 Zero-Minimum tillage	4 Fertilization	5 Total Caisan Project
1980	21,568	5,620	0	7,431	34,619
81	58,597	42,080	565	13,681	114,923
82	100,588	60,526	3,250	17,790	182,154
83	130,746	72,487	11,220	20,107	234,560
84	138,762	79,116	12,457	21,287	251,622
85	152,696	82,431	13,482	21,855	270,464
86	154,796	84,016	13,808	22,161	274,161
87	155,559	84,881	13,822	22,292	276,554
88	156,132	85,169	13,822	22,336	277,459
89	156,132	85,457	13,822	22,336	277,747
90	156,132	85,457	13,822	22,336	277,747
After 1990	156,132	85,457	13,822	0	255,411

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