Economic Analysis of Agronomic Trials for the Formulation of Farmer Recommendations

by

Eric Crawford and Mulumba Kamuanga

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SPECIAL NOTE FOR ISRA-MSU REPRINTS

In 1982 the faculty and staff of the Department of Agricultural Economics at Michigan State University (MSU) began the first phase of a planned 10 to 15 year project to collaborate with the Senegal Agricultural Research Institute (ISRA, Institut Sénégalais de Recherches Agricoles) in the reorganization and reorientation of its research programs. The Senegal Agricultural Research and Planning Project (Contract 685-0223-C-00-1064-00), has been financed by the U.S. Agency for International Development, Dakar, Senegal.

As part of this project MSU managed the Master's degree programs for 21 ISRA scientists at 10 U.S. universities in 10 different fields, including agricultural economics, agricultural engineering, soil science, animal science, rural sociology, biometrics and computer science. Ten MSU researchers, on long-term assignment with ISRA's Department of Production Systems Research (PSR, Département de Recherches sur les Systémes de Production et le Transfert de Technologies en Milieu Rural) or with the Macro-Economic Analysis Bureau (BAME, Bureau d'Analyses Macro-Economiques) have undertaken research in collaboration with ISRA scientists on the distribution of agricultural inputs, cereals marketing, food security, farm-level production strategies and agricultural research and extension. MSU faculty have also advised junior ISRA scientists on research in the areas of animal traction, livestock systems and farmer groups.

Additional MSU faculty members from the Department of Agricultural Economics, Sociology, Animal Science and the College of Veterinary Medicine have served as short-term consultants and professional advisors to several ISRA research programs.

The project has organized several short-term, in-country training programs in farming systems research, agronomic research at the farm-level and field-level livestock research. Special training and assistance has also been provided to expand the use of micro-computers in agricultural research, to improve English language skills, and to establish a documentation and publications program for PSR Department and BAME researchers.

Research publications from this collaborative project have been available only in French. Consequently, their distribution has been limited principally to West Africa.

In order to make relevant information available to a broader international audience, MSU and ISRA agreed in 1986 to publish selected reports as joint ISRA-MSU International Development Paper Reprints. These reports provide data and insights on critical issues in agricultural development which are common throughout Africa and the Third World. Most of the reprints in this series have been professionally edited for clarity; maps, figures and tables have been redrawn according to a standard format. All reprints are available in both French and English. A list of available reprints is provided at the end of this report. Readers interested in topics covered in the reports are encouraged to submit comments directly to the respective authors, or to Dr. R. James Bingen, Associate Director, Senegal Agricultural Research and Planning Project, Department of Agricultural Economics, Michigan State University, East Lansing, MI 48824-1039.

Jacques Faye
Director
Department of Agrarian
Systems and Rural
Economic Research
Senegal Agricultural Research
Institute

R. James Bingen
Associate Director
Senegal Agricultural Research
and Planning Project
Department of Agricultural
Economics
Michigan State University

ECONOMIC ANALYSIS OF AGRONOMIC TRIALS FOR THE FORMULATION OF FARMER RECOMMENDATIONS

By

Eric Crawford and Mulumba Kamuanga*

1988

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ABSTRACT

The recent emphasis on farming systems research has reinforced the role of on-farm agronomic trials. This paper sets forth one method for the economic analysis of on-farm trials (proposed earlier by CIMMYT), whose objective is to evaluate the profitability and feasibility of experimental treatments from the farmer's point of view, as part of the process of formulating farmer recommendations. The paper presents the major steps involved in the analysis; key concepts, evaluation criteria, and data necessary for the analysis; valuation of costs and returns; construction of partial budgets; calculation of the marginal rate of return; and finally, risk and sensitivity analysis. Concepts of opportunity cost and marginal analysis receive special emphasis. The paper illustrates the application of this method to several types of on-farm trials (experiments including various chemical input levels, variety trials, and tests of improved production practices).

ECONOMIC ANALYSIS OF AGRONOMIC TRIALS FOR THE

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ECONOMIC ANALYSIS OF AGRONOMIC TRIALS FOR THE FORMULATION OF FARMER RECOMMENDATIONS*

E. W. Crawford and M. Kamuanga

INTRODUCTION

The reorientation of research programs at ISRA and the recent emphasis on applied research strengthen the role and the importance of on-farm agronomic trials. Farmer-managed trials set up by the production systems research teams, and on-farm trials managed by researchers from commodity-oriented research programs, both share the objective of developing improved technology or production practices.

This paper is intended for use by researchers (plant breeders, agronomists, and economists) and extension workers involved in formulating recommendations for farmers based on common types of trials (experiments including various chemical input levels, variety trials, tests of improved production practices, etc.), and using the technique of marginal analysis. Investments in agricultural equipment are best analyzed with other techniques.

The overall objective of the economic analysis of agronomic trials is to determine the profitability and the feasibility of experimental treatments from the farmer's point of view, so as to contribute to formulating recommendations which he can adopt. The "best" treatment in economic terms is not necessarily the one which offers the greatest physical output. The analysis also makes it possible to identify the optimal combination of elements in the technical package and/or the best level of input application.

Since the objective is to formulate recommendations, we will evaluate profitability from the farmer's point of view (financial return), which involves using existing prices including taxes or subsidies. Thus we are

*This is an English translation of a paper originally written in French.

not concerned here with an analysis at the level of the national economy (economic return), which would instead require using prices prevailing in the international market, free of taxes and subsidies. (This approach is nonetheless entirely valid when the objective is to evaluate economic return.)

The economic analysis or interpretation of on-farm trials can be performed using various methods. In this paper we will present one method which is frequently used, without suggesting that it is perfectly adapted to all situations requiring economic analysis. (For a more detailed presentation of this method, see the CIMMYT manual by Perrin, et al.)

GENERAL METHOD

In summary, the method includes the following stages:

1. Preparation of a partial budget for each treatment. This stage includes, in turn, the following sub-stages:

a. Estimation of the value of production (gross benefit) corresponding to the different treatments incorporated into the trial.

b. Enumeration of the different inputs used and estimation of their value.

c. Calculation of the net benefit for each treatment (equal to the gross benefit less the value of the inputs used, excepting capital).

2. Identification of the "superior" treatments, whose profitability justifies adoption by the farmer.

3. Calculation of the marginal rate of return (MRR) for each "superior" treatment, in other words the ratio (as a percentage) of the additional net benefit to the additional costs resulting from the adoption of increasing levels of inputs. This is in effect a measure of what the farmer gains in terms of net income when he spends progressively higher amounts for production inputs.

4. Identification of the most promising treatment, from among all treatments considered sufficiently profitable, taking into account the means at the disposal of the farmer, as well as any of his objectives not yet factored into the analysis. In theory, this is the treatment which

will be proposed to farmers through the regional development organization, and subjected to further trials and pre-extension tests.

ANALYTICAL CONCEPTS AND CHOICE CRITERIA

There are two key concepts underlying the analysis presented here:

1. **Partial budget approach.** Partial budgets indicate the net gain attributable to switching from current practices to recommended practices. Cost or return items which remain the same are not included in the analysis. The classic structure of the partial budget is as follows:

Additional benefits, which include:

- the additional value of production
- the decrease in costs

Additional costs, which include:

- additional costs
- any decrease in the value of the production (loss)

Net gain = additional benefits - additional costs

For example, the response of rice to different levels of mineral fertilizers could be compared to the traditional practice of manuring rice fields. In this simple case, it is unlikely that there would be any "decrease in costs" or "decrease in the value of the production."

2. **Marginal analysis.** In trials which incorporate several treatments with different levels of inputs (and thus different levels of cost), the increase in cost and in income obtained by moving from one combination to another is studied. This makes it possible to identify the point at which a given increase in production costs no longer yields an equal or greater increase in income. (As stated above, major investments or radical changes in the production system are better analyzed with other methods such as capital budgeting or whole-farm budgeting. Nonetheless, the principle of marginal analysis is fundamental in economics.)

In general, the treatments incorporated into the trial are evaluated with respect to the following criteria:

Profitability. Net returns are compared to the funds invested. The calculated rate of return is compared either to a target rate which is assumed to be acceptable to farmers, or to rates observed in empirical studies on the economic activities of farmers.

Risks. In addition to the profitability of a new technology, attention must be paid to its sensitivity to environmental contingencies. This means taking account of factors such as the stability of the yield, the yield obtained in poor years, etc.

Feasibility. It is critically important to know whether the new technology is compatible with the current production system of the farmer. To what degree is the adoption of a technology (even a very profitable technology) limited by the resources available to the farmer, for example the level of funds which can be mobilized for investment, or by lack of liquidity, family labor, land, etc.? It should not be assumed that one can always find a way to overcome the obstacles posed by the farmer's limited resources.

DATA REQUIRED FOR THE ANALYSIS

1. Each trial for which an economic analysis is planned must include a control treatment (zero input level and/or existing farmer practices). Otherwise, it will be impossible to determine the attractiveness of the new technology to the farmer.

2. It is important to know the quantity and price of all inputs whose level varies across treatments, whether they are furnished by the farmer himself from his own supplies, purchased at market prices, or obtained on credit. This category includes inputs such as seed, manure, fertilizers, other chemical products, family or outside labor, as well as the expense of using any agricultural equipment.

3. The quantity and price of everything produced must also be calculated, whatever the eventual use (sale, storage, consumption). Frequently the by-products of plant production (straw, leaves) or animal production (manure) must be taken into account.

4. The same is true of the target rate of return, defined as the minimum rate of return considered necessary for a given technology to be adopted by farmers.

EVALUATION OF COSTS AND RETURNS

Problems in calculating quantities and prices often arise. Several valuation principles come into play:

1. **Product prices**. For products which are generally marketed, we use the sale price at the producer level, in other words the official price or the price charged at the local market, less the costs of transportation and marketing incurred by the farmer. For products intended for home consumption, we use the purchase price, including the cost of transportation and any other expenses involved in bringing the product to the farm.

Using the official producer price is appropriate only when (a) this is the actual price received by the farmer, (b) the purpose is to determine what the official price generates in terms of net income, or (c) no other valid estimate of the true price is available. In practice, in Senegal, official prices will generally be used for peanuts, cotton, and for rice in the SAED zone.[1] For rice in the Casamance region, note that many farmers are currently deficit producers who rarely sell rice; a price based on the paddy rice equivalent of the purchase price of white rice therefore seems appropriate, since in fact locally produced rice is a good substitute for imported rice. For other cereals (corn, millet, sorghum), and for cowpeas and vegetable crops, sale prices observed in local markets are more appropriate than official prices.

It is impossible to specify the appropriate prices in every case. Nonetheless, Appendix 1 gives suggested prices by region and by crop.[2]

2. The same questions arise with respect to valuing the cost of inputs, especially in the case of inputs which are not purchased. It is also important here to apply prices which take into account both the cost of purchase and the cost of transportation between the point of purchase and the place of use, especially for voluminous inputs such as fertilizer

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[1]The official price is used in this particular case because the bulk of the farmer's production is sold through official channels.

[2]Production Systems Research Department or BAME economists in each region should be able to furnish details on the prices to be used.

and manure. (Appendix 1 gives illustrative input costs for use in analyzing trials in Senegal.)

For inputs which are not purchased (seed, manure, and animal traction services), the general principle is to value each input in terms of "opportunity cost," in other words the price which the farmer would have paid if he had purchased the input. This requires a good working knowledge of prices charged in the local markets.

3. **Labor.** Labor often represents a major share of production costs, hence valuation of labor costs is an essential element of the analysis. However, the amount of labor required by a new technique is often difficult to estimate on the basis of agronomic trials, given their small scope and the special requirements of conducting and monitoring trials. Estimation of labor times is especially important when new technology is expected to involve substantial changes (e.g., in weeding time).

It is particularly difficult to estimate the value of family labor. The classic approach is to evaluate its "opportunity cost," in other words "the wage which could be earned in off-farm employment, or the value of the time if spent on another farm enterprise, or the value which the worker places on leisure" (Perrin, et al., p. 8).

In practical terms, this approach is difficult to apply. First of all, it is nearly impossible to determine the value of leisure (which is subjective). Secondly, valuing family labor in terms of the off-farm wage poses three problems (among others): (a) in principle, wages vary according to the task, the season, and the status of the worker, yet data on these variations are rarely available; (b) if few people in a region work outside the farm, it is not logical to treat this as an option available to everyone; and (c) even if off-farm work is potentially available, in general a farmer is willing to work on his farm at a rate of remuneration lower than the wages paid for outside work. All of these factors suggest that often the wages paid for outside labor represent an overestimate of the opportunity cost for family labor. Thus it is common practice to decrease the observed wage rate by a more or less arbitrary factor.

Another solution is to not deduct the opportunity costs of family labor, but instead to calculate net income per family work day rather than net income per hectare. Finally, family labor can be valued in terms of the average return obtained by the farmer across all of his agricultural activities, based on the assumption that if he did not spend time on the particular crop in question, he would spend his time on another agricultural activity (rather than on a non-agricultural activity). This is the approach adopted by the ISRA/Djibélor production systems research team which, based on surveys, has estimated the average return in agriculture at 500 CFA francs per day of work.

The same remarks apply to evaluating the opportunity costs of using family animal traction.

4. The methodology used by CIMMYT includes an **adjustment of the yield** obtained in the trial in order to better represent the yield which the farmer can attain. This yield adjustment reflects the possible lower efficiency of on-farm production practices due to lower quality inputs used by farmers or to less-efficient implementation of the production practices. How to estimate the appropriate yield adjustment factor is not always obvious.

5. Finally, the **target rate of return** is not easy to estimate. We will return to this subject later.

STAGES OF THE ANALYSIS

To illustrate the principal stages, we will use the case of a rice fertilization trial conducted by ISRA/Djibélor researchers. To illustrate sensitivity and risk analyses, we will use a corn fertilization trial conducted by CIMMYT in Mexico.

Construction of the Partial Budget

Our example involves a rainfed rice trial conducted by the ISRA/Djibélor Rice Program at Fadiga in the Kolda region (Mbodj, et al.). We should point out that the yields obtained in this trial are very high for strictly rainfed rice. A split-plot design was used to allow analysis of the main effects of different factors (soil diversity, fertilizers, varieties, and pest control). We limit our attention to the effect of fertilizer on a single variety, in order to show the analytical steps leading to the formulation of recommendations. The levels of NPK fertilization were as follows:

A_0 = no fertilizer, simulating the existing on-farm situation;

A_1 = 25% of the fertilizer dose recommended by researchers, amounting to 50 kg of 8-18-27 and 37.5 kg of urea per hectare;

A_2 = 50% of the recommended dose, amounting to 100 kg of 8-18-27 and 75 kg of urea per hectare;

A_3 = 100% of the recommended dose, amounting to 200 kg of 8-18-27 and 150 kg of urea per hectare.

1. **Calculation of the average yield for each treatment.** The economic analysis is based on the average yield of each treatment across all repetitions. The figures presented in table 1 are the averages for four repetitions per treatment. Only the relevant treatments for a homogenous group of farms ("recommendation domain") are considered, but data for several years or sites can be grouped together.

2. **Calculation of the adjusted yield for each treatment.** The average yield is multiplied by the adjustment factor to arrive at the yield which the farmer can achieve under his own conditions. Normally the farmer does not obtain the same yield as the researcher, even when applying the "identical" treatment, for several reasons, namely:

a. **Management**: in general, the researcher applies the treatment with greater precision and with more appropriate timing than the farmer.

b. **Method of harvest**: the researcher tends to harvest the crop at the time of physiological maturity, whereas the farmer often waits for the crop to dry in the field;[3] thus the average yield must be corrected based on the moisture content at harvest. The quantity harvested by the researcher may also be greater due to better weed control or more careful manual harvesting.

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[3]The case of corn harvested fresh by farmers, or of a corn harvest spread out over time, represents an exception.

TABLE 1

FERTILIZER TRIAL FOR RAINFED RICE (VARIETY 144B/9) AT FADIGA (KOLDA REGION), 1984-1985: PARTIAL BUDGET

Item	Fertilizer Level			
	A_0	A_1	A_2	A_3
Average yield (kg/hectare)	1,517	2,603	2,139	3,555
Adjusted yield (-10%)[a]	1,365	2,343	1,925	3,200
Gross benefit (CFA francs)[b]	146,055	238,010	205,975	298,000
Monetary variable costs (CFA francs)				
Quantity of 8-18-27 (kg)	0	50	100	200
Quantity of urea (kg)	0	37.5	75	150
Unit cost of 8-18-27[c]	120.35	120.35	120.35	120.35
Unit cost of urea[c]	86.52	86.52	86.52	86.52
Monetary cost of fertilizer	0	9,262	18,524	37,048
Other costs	0	0	0	0
Total monetary variable costs	0	9,262	18,524	37,048
Opportunity variable costs (CFA francs)				
Labor (man-days)				
Fertilizer spreading[d]	0	1	1.5	2
Additional harvest labor[e]	0	17	10	31
Average daily wage (CFA francs)[f]	500	500	500	500
Total opportunity costs	0	8,797	5,502	16,570
Total variable costs (CFA francs)	0	18,059	24,026	53,618
Net benefit (CFA francs)	146,055	219,951	181,949	244,382

[a]The adjustment factor represents an estimate of farmer management and possible harvest losses.

[b]Up to a level of 2,000 kg/hectare (the threshold applied to rice), the yield is valued at the paddy rice equivalent of the consumer price (107 CFA francs/kg). It is assumed that up to 2,000 kg serves as a substitute for purchased rice, given the deficit situation of most farmers. Any yield above 2,000 kg/hectare is valued at the official producer price (70 CFA francs/kg in 1984-1985).

[c]The unsubsidized prices which farmers currently pay.

TABLE 1 - (Continued)

[d]Labor times associated with different fertilizer levels are based on empirical data.

[e]For rainfed rice, the average amount of harvest labor is 38 days (Production Systems Team Report, ISRA/Djibélor, 1984). Spencer's survey data suggest that a 40% increase in harvest labor is required by a 65% increase in yield (or 6.15% for a 10% increase in yield).

[f]The daily wage represents average returns per day of agricultural work, estimated from surveys conducted in the Casamance region in 1982-1984. (See Production Systems Team Reports, 1983 and 1984.)

c. **Size of plot:** even taking into account the border effect, yields on small test plots are often higher than yields obtained on larger farm plots.[4] In table 1, the gross output has been reduced by 10%.

3. **Calculation of the farm-gate producer price** (called the "field price" by Perrin, et al.). This price is calculated by subtracting all of the expenses incurred by the farmer for post-harvest processing, transportation, storage, and marketing from the price which he receives at the local market taking into account the period and the form of sale. In the CIMMYT approach, unit harvest costs (per kg) are also deducted.[5] In table 1, rice is valued by using a combination of the paddy rice equivalent of the consumer price (107 CFA francs/kg) applied to the first 2,000 kg of output per hectare and the official producer price (70 CFA francs/kg in 1984-1985) applied to the output above 2,000 kg/hectare. This is based on the reasoning that farmers in this area are currently deficit rice producers, thus the first part of the output would serve as a substitute for purchased rice, while any surplus over and above family food needs (represented by the arbitrary threshold of 2,000 kg/hectare) would be sold at the official price.[6]

4. **Calculation of gross benefit**, which is simply the adjusted yield multiplied by the producer price.

5. **Calculation of net benefit**, which is the gross benefit less the value of all variable costs (both monetary and non-monetary). This

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[4]See Harrington. CIMMYT includes another deduction for losses during storage which could reduce the amount of the product actually available to the farmer. In our opinion, this method is debatable; it is best not to confuse this aspect with the evaluation of the impact of the treatment in terms of production.

[5]They consider it simpler to take these costs into account by adjusting the price of the product, instead of using a "gross" price and grouping these costs with the other variable costs. Whatever method is applied, it is critical to identify all the production and sale costs in order to determine the net benefit.

[6]The principal results of the analysis of this trial remain the same if the official price of 70 CFA francs per kilo (1984-85) is used to value the entire output. In that case, the net benefits are lower, but the rank order of the treatments, the superior treatments, and the preferred treatment do not change. Treatment A_1 would have a marginal rate of return of 279% instead of 409%.

requires (a) listing the categories of variable costs, (b) determining the quantities of inputs utilized in each category, and (c) setting the price (or opportunity cost) associated with each input.

We discussed earlier the principles to be followed in fixing the monetary value of the inputs utilized. For the Fadiga rainfed rice fertilization trial, see the notes to table 1 for details of the method used. Other points to note for this trial include:

a. The only monetary variable cost is fertilizer, since the quantity of improved seed remains the same for all four treatments.

b. There are two types of opportunity cost which must be taken into account: the cost of spreading the fertilizer, which depends on the amount applied per treatment; and the cost of the additional time spent to harvest any significant additional output. As the basis for our estimate of the work time for rainfed rice on farms in the Casamance region, we have used data from the surveys conducted by the ISRA/Djibélor Production Systems Research Team.

c. The daily wage rate used to value family labor is based on the returns to labor in on-farm agricultural activities, as estimated from three years of survey data (1982-1984) collected by the Production Systems Research Team in the Ziguinchor region.

Table 1 shows that the treatment with the highest yield (A_3) also has the highest net benefit. However, this rule does not necessarily hold in all cases. Furthermore, we will see later that the "best" treatment (from an economic point of view) is not necessarily the one which affords the highest net benefit.

Options for Simplified Analysis

If difficulties are encountered in evaluating the cost of labor or other non-purchased inputs (for example, manure or seed provided by the farmer himself), a simple analysis can be conducted in two ways, as follows:

1. First, one can calculate the additional output (AO) needed to cover the cost of purchased inputs. This result is obtained by dividing the monetary costs (MC) for each treatment by the unit price of the product (P):

AO = MC/P. To take into account the cost of the capital involved, a fraction of this capital can also be added, as in the following formula:

AO = (MC + (MC x CC))/P, where CC represents the interest rate (%).

2. For fertilizer trials, the value-cost ratio, a concept often used by the FAO, can be calculated. This ratio represents the additional gross benefit divided by the value of the fertilizer used in a given treatment. It is frequently stated that this ratio must be equal to or greater than 2 for the farmer to agree to apply the fertilizer. (Others say that in the conditions of the Sahel the threshold should instead be 3 or 4.) The weaknesses of this ratio as a basis for evaluating profitability are, first, that costs other than fertilizers are not taken into account, and second, that this ratio is generally calculated on an average, rather than marginal, basis.

Identification of "Dominated" Treatments

In CIMMYT terminology, a treatment is said to be "dominated" when there is at least one option that offers a greater net benefit at an equal or lesser cost. Thus a treatment is "undominated" when no other option exists offering a greater net benefit at an equal or lesser cost. The terms "superior" and "inferior" can be substituted for "undominated" and "dominated." Superior treatments can be identified by means of graphic or numerical analysis.

In figure 1, the three superior treatments are located along the line connecting the points which are highest and farthest to the left. The superior and inferior treatments can also be determined by reading table 2, where they are classified in descending order of net benefit. The dominated treatments have higher variable costs than the treatments which are better in terms of net benefits.

From figure 1 (and table 2 as well), it can be seen that treatment A_2 (50% of the recommended amount, or 100 kg of 8-18-27 plus 75 kg of urea per hectare) is a dominated option. Thus to the left of A_2 there is at least one treatment with a total variable cost which is lower and a net benefit which is higher (A_1). So the choice of preferred treatment is based only on

FIGURE 1. NET BENEFIT CURVE

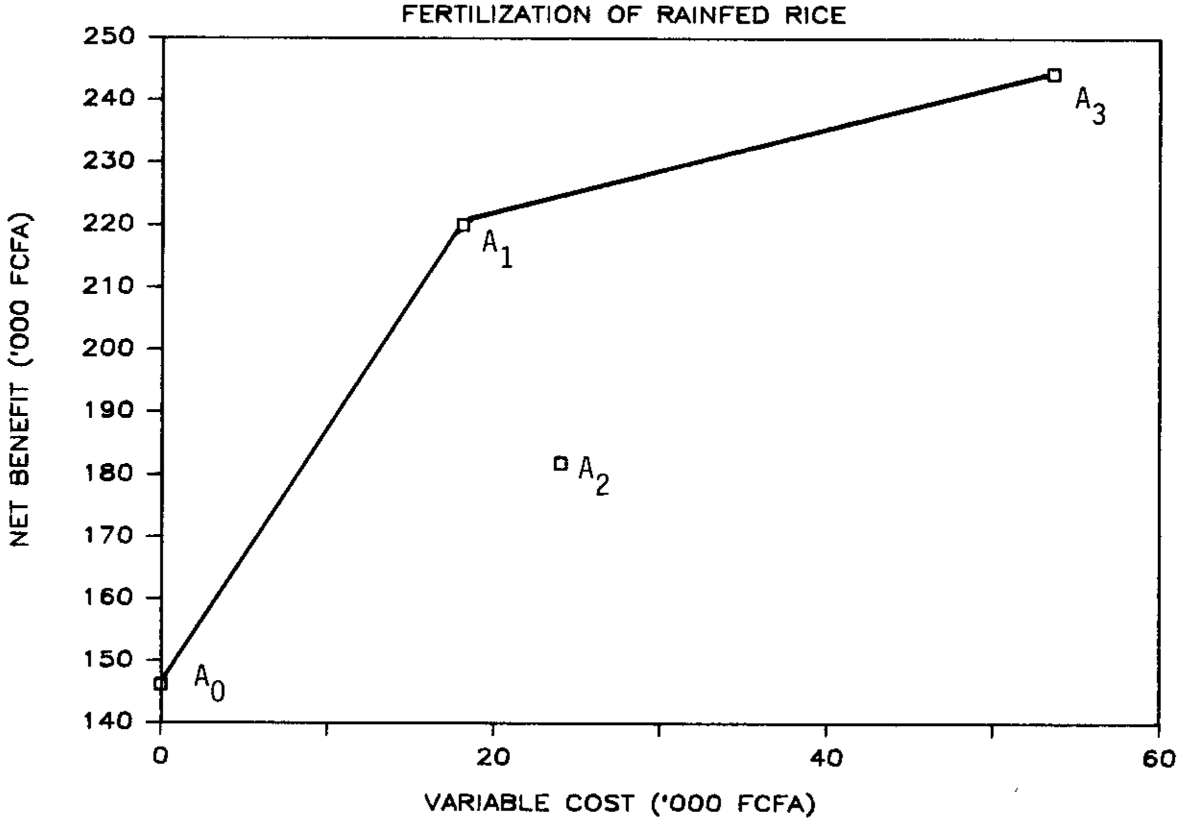

TABLE 2

RAINFED RICE FERTILIZATION TRIAL--IDENTIFICATION OF SUPERIOR TREATMENTS

Treatment	Net Benefit (CFA francs)	Total Variable Costs (CFA francs)	Superior?
A_3	244,382	53,618	Yes
A_1	219,951	18,059	Yes
A_2	181,949	24,026	No
A_0	146,055	0	Yes

treatments A_0 (no fertilizer), A_1 (25% of the recommended amount), and A_3 (100% of the recommended amount).

Analysis of Profitability

Calculation of the Marginal Rate of Return

The marginal rates of return (MRRs) are first calculated for all undominated treatments, then compared with the target rate in order to identify satisfactory treatments. The MRR is calculated as indicated in table 3: the increase in variable costs resulting from moving from one option to another more expensive one is compared to the corresponding increase in net benefit. Thus the MRR is the ratio of marginal net benefit to marginal variable costs, expressed as a percentage.

It can be seen that the MRR is much higher when moving from treatment A_0 to treatment A_1 than when moving from A_1 to A_3. The slope of the net benefit curve reflects the same result (see figure 1, where only the superior treatments are connected).

The advantage of marginal analysis should be noted here. If we calculate the **average** rate of return for treatment A_3 in comparison with treatment A_0, the result obtained is (244,382 - 146,055)/(53,618) = 183%. But this hides the fact that the rate of return on the initial expenditure of 18,059 CFA francs (when applying one-quarter of the recommended amount) is 409%, whereas the rate of return on the additional expenditure of 35,559 CFA francs (when applying the remaining three-quarters) is only 69%. Thus an expenditure which appears attractive based on an average or overall analysis turns out to be considerably less attractive based on a marginal analysis. It should also be noted that it is treatment A_1, rather than the treatment with the highest net benefit (A_3), which provides the highest MRR.

Choosing the Target Rate of Return

What is the appropriate target rate of return? In principle, the farmer, when evaluating a new option for investment (or for the purchase of

TABLE 3

RAINFED RICE FERTILIZATION TRIAL--CALCULATION OF THE MARGINAL RATE OF RETURN

Treatment	Total Variable Costs (CFA)	Marginal Variable Costs (CFA)	Net Benefit (CFA)	Marginal Benefit (CFA)	MRR (%)
A_3	53,618	35,559	244,382	24,431	69
A_1	18,059	18,059	219,951	73,896	409
A_0	0	--	146,055	--	--

inputs), hopes to receive an equal or greater return than the return he would obtain by placing his capital in other investments. Thus the target rate of return could be estimated by referring to the rates observed for the farmer's other activities. Since such data are not always available, an alternative method of estimation is often used, based on the cost of capital (or the interest rate).[7]

In the example given by Perrin, et al. (p. 13), the target rate is calculated as follows: 11% (the actual interest rate on the loan) plus 20% (the risk premium, which we will discuss later), which gives a target rate of 31%. In reality, as an empirical standard, a target rate of 40% is advocated.

In the context of Senegal, 50% would represent the minimum threshold. Indeed, a target rate of 100% would seem more reasonable if we take into account the interest rates paid on money borrowed for purchasing food during the pre-harvest period, which often corresponds to the period when farmers' needs for agricultural inputs are most pronounced.

We noted earlier that the FAO uses a standard which advocates a value-cost ratio of at least 2. This approach fails to take into account other costs such as labor for spreading fertilizers. Since the gross benefit, rather than the net benefit, and the total cost, instead of the marginal cost, are involved, this standard represents an **average** rate of return of 100%.

Choosing the Preferred Treatment

All treatments with MRRs equal to or greater than the target rate are satisfactory. Among the satisfactory treatments, the final choice of the treatment to be recommended will be made by considering a number of factors. Very often the satisfactory treatment with the highest net

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[7]It is important to incorporate the cost of capital, given the very limited availability of this resource. There are two ways to take the cost of capital into account: (1) either the cost of capital is added to the costs of the other factors, then deducted from the gross benefit; or (2) the cost of capital is not applied to the costs of the other factors, but the estimated "gross" rate of return is compared to the opportunity rate of return, represented by the target rate.

benefit will be recommended, except in the case where the financial resources of the farmer do not allow him to make the necessary expenditure. Thus, for a target rate of 50%, our illustrative trial would lead to the choice of treatment A_3 on the basis of net benefit. In practical terms, however, A_3 would be eliminated because purchasing the amounts of fertilizer required would call for more cash income than is available to most farmers. Thus the risk factor (which will be discussed below) is significant enough that it must be taken into account here.

If, on the other hand, a target rate of 100% (which appears most appropriate in the Senegalese context) is adopted, then only treatment A_1 is satisfactory and worth recommending. (In general, for technical reasons it is not correct to make the choice based solely on the highest MRR, although by coincidence this would lead to choosing treatment A_1 in this particular case.)

Risk Analyses

Up to this point, the risk factor has not been considered explicitly, apart from including the "risk premium" in the target rate of return. However, it is important to consider not only the expected profit level but also its variability over time and space. This is a key factor, especially for farmers unwilling or unable to incur deficits.

Risk analysis can be done with several simple calculations, as follows:

1. The standard deviation of the net benefit for each treatment, calculated for all repetitions.

2. The "variability index," defined as the standard deviation of net benefit divided by the average net benefit, expressed as a percentage.

3. Identification of the minimum net benefit, which reflects the performance of the treatment under poor conditions.

4. To take into account the occurrence of unfavorable situations, we can also calculate the average of the net benefits of the weakest treatments by focusing on the bottom quarter (25%) of all the treatments.

The results of these calculations for the example of a corn fertilization trial in Mexico are presented in table 4. (See Appendix 2 and

TABLE 4

RISK ANALYSIS FOR THE CORN FERTILIZATION TRIAL

Treatment (kg N,P)	Average Net Benefit	Standard Deviation	Variability Index[a]	Minimum Net Benefit	Average of Two Lowest Net Benefits
			(Pesos)		
0,0	1,991	1,345	67.5	360	725
50,0	2,376	1,302	54.8	666	972
100,0	2,619	1,150	43.9	873	923
150,0	2,312	1,084	46.9	671	689
0,25	1,899	1,309	68.9	411	744
50,25	2,792	890	31.9	1,622	1,712
100,25	2,806	1,137	40.5	1,091	1,375
150,25	2,802	1,465	52.3	970	1,029
0,50	1,576	1,532	97.2	512	598
50,50	2,698	866	32.1	1,309	1,728
100,50	2,864	1,072	37.4	1,552	1,570
150,50	2,846	1,114	39.2	1,458	1,476

Source: Based on Perrin, et al. Number of observations = 8 per treatment.

[a]Variability index = (standard deviation/average NB) x 100.

3 for the partial budget and the calculation of the MRRs corresponding to this trial. Based on these figures, the treatment (50,25) is preferred.) The risk analysis does not lead us to modify our choice of treatment (50,25) since, in comparison with treatment (50,0), the standard deviation is low (890 as opposed to 1,302), the variability index is not as high (32 as opposed to 55), and the "worst" net benefits are higher (1,712 as opposed to 972).

It would also be useful to know the probability of occurrence of the minimum net benefit case, and even more useful to know the probability distribution of possible returns. The latter would make it possible to estimate more precisely the expected average net benefit. This would require experimental data over a series of years, unless we were in a position to predict yields based on rainfall by means of a quantitative model.

Sensitivity Analyses

The analyses presented above are based on both empirical data and estimated parameters. It is important to ask how different the results would be if the values of certain parameters were modified. Would the choice of preferred treatment be different, for example, if the producer price or the variable costs were altered?

For the example of the Mexican corn trial, let us first consider the case where the price of corn varies by 20% with respect to the initial price of $1,000/metric ton (see table 5). At a price of $1,200/metric ton, the question is whether treatment (100,50) will now turn out to be preferable to treatment (50,25), given that the new price increases the MRR of treatment (100,50) to 49%. We see that the MRR in moving from (50,25) to (100,50) is 34%. This falls below the target rate, but if another price increase were anticipated, treatment (100,50) would deserve consideration. At a price of $800/metric ton, treatments (50,0) and (50,25) yield satisfactory MRRs. Treatment (50,25) is more appropriate; it has a higher net benefit, and its average rate of return (compared with (0,0)) is 71%.

TABLE 5

SENSITIVITY ANALYSES, CORN FERTILIZATION TRIAL

Treatment (kg N,P)	Net Benefit ($)[a]	Variable Costs ($)	Marginal Net Benefit ($)	Marginal Variable Costs ($)	Marginal Rate of Return (%)
Case No. 1:	**Price of corn = $1200/metric ton**				
100,50	3,724	1,400	122	250	49
100,25	3,602	1,150	114 (236)	450 (700)	25 (34)[b]
50,25	3,488	700	542	250	217
50,0	2,946	450	558	450	124
0,0	2,388	0	--	--	--
Case No. 2:	**Price of corn = $800/metric ton**				
50,25	2,092	700	278	250	111
100,25	2,018	1,150	(dominated)		
100,50	2,016	1,400	(dominated)		
50,0	1,814	450	222	450	49
0,0	1,592	0	--	--	--
Case No. 3:	**Cost of labor = $50/day**				
100,50	2,770	1,500	30	750	4
50,25	2,740	750	410	250	164
100,25	2,710	1,250	(dominated)		
50,0	2,330	500	340	500	68
0,0	1,990	0	--	--	--
Case No. 4:	**Price of fertilizer increased by 100%**				
50,25	2,140	1,350	150	1,350	11
0,0	1,990	0	--	--	--
(other treatments dominated)					

Source: Based on Perrin, et al.

[a]$ = Pesos.

[b]The figures in parentheses refer to the difference between treatment (50,25) and treatment (100,50).

Now let us assume that the opportunity cost of labor is $50/day instead of $25/day. The results summarized in table 5 show that treatment (50,25) still remains preferable.

Finally, if the cost of fertilizer increases by 100%, the only treatments remaining "superior" are (50,25) and (0,0). However, treatment (50,25), with an MRR of 11%, is no longer acceptable.

In one variant of sensitivity analysis, the break-even price or cost is calculated, in other words the threshold (in terms of price or cost) below which the treatment becomes unacceptable. As an example, for treatment (50,25) an increase of about 90% in the cost of fertilizer could be tolerated without falling below the target rate of 40%.

Final Choice of Preferred Treatment

The following stages of analysis have now been accomplished: we first evaluated the profitability of all treatments in terms of net benefit and marginal rate of return. Comparing these MRRs to the target rate makes it possible to select the satisfactory treatments, taking into account the cost of capital and the risk factor. Next we examined the variability of returns for each treatment, as well as its performance under poor conditions. This allows us to favor treatments which are stable and resistant to climatic contingencies. Finally we reviewed the treatments again based on the results of the sensitivity analyses, where the objective was to evaluate the performance of satisfactory treatments under different price and cost conditions.

Returning to the corn fertilization trial, it turned out that treatment (50,25) remained the best treatment no matter which criteria were applied. Obviously, other trials could give less clear results. In such a case, it would be up to the members of the research team to select the preferred treatment based on the results of these analyses as well as their knowledge of farmer conditions in the zone being studied. Sometimes the correct decision will be to conduct additional trials before issuing definitive recommendations. In that case, the economic analysis will have helped by providing better guidelines for future trials.

EXAMPLES OF ANALYSES OF OTHER TYPES OF TRIALS

Analysis of Varietal Selection Trials

The analysis of varietal selection trials is easiest when the level of inputs utilized does not vary according to variety. In such cases, for the economic analysis it is sufficient to compare the different varieties in terms of gross income or value of production. It is also possible in certain cases to calculate for each variety the return per day of the growing cycle, if the potential exists for increasing the value of the time so gained (double cropping, for example, or the possibility of selling earlier at a favorable price). It is generally important to evaluate other aspects of the performance of the different varieties, such as the quality of the seed, culinary and taste characteristics, the quantity of straw, etc., but this is not part of the economic analysis *per se*.

If the level of inputs is not the same for all varieties, a marginal analysis is appropriate. This situation can arise when the design includes a local variety with the level of inputs typically used by farmers, compared with improved varieties for which a higher level of inputs is provided.

By way of example, let us examine the case of a lowland rice trial conducted in Affignam by the ISRA/Djibélor Rice Program. The varieties compared (IRAT 112, IRAT 133, IKP, DJ 12-519, and Barafita (a local variety developed many years ago)) are recommended based on varietal yield tests. The three levels of fertilization are those defined earlier, namely A_0 (no fertilizer), A_1 (25% of the recommended amount), A_2 (50% of the recommended amount), and A_3 (100% of the recommended amount).

The purpose of the analysis is to identify desirable options (variety + fertilizer level) based on the marginal rates of return for each option and on the financial investment required. This type of trial is normally conducted over several years in order to take interannual variations into account. Thus the exercise presented below is of purely illustrative value.

Construction of the Partial Budget

The Barafita variety with no fertilizer represents our reference situation. This is a local variety (itself probably descended from an introduced variety) whose erect posture is greatly appreciated by farmers for lowland rice cultivation. It is also a variety which responds well to fertilizers.

The partial budget presented in table 6 was set up according to the same procedures followed for table 1. We assume that farmers use their own seed in the case of Barafita, but the seed is valued at the same price as selected seed, given its high opportunity value for consumption as well as planting. The recommended density of 100 kg per hectare is used for all varieties.

The net benefits range from 77,458 CFA francs for Barafita (A_0) to 270,692 CFA francs for DJ 12-519 (A_3). This last combination also provides the highest average yield (4,369 kg per hectare).

Eliminating Dominated Options

In table 7, the net benefits for each option are ranked in decreasing order. As recommended by Perrin, et al., we then eliminate options which produce a net benefit below the reference situation, in this case Barafita A_0. However, in this particular case, it turns out that the reference situation itself produces the lowest net benefit.

The next step is to identify the dominated options. Once the dominated options (indicated by the letter D in table 7) have been rejected, the marginal net benefit is calculated for the superior options, of which there are 8. These same options are connected by the curve in figure 2.

Choosing the Alternatives to Recommend to Farmers

IRAT 112 (A_0) represents the superior option with the minimum investment. However, its net benefit is not very different from the net benefit of Barafita A_0 (table 7), for which the farmer is not required to

TABLE 6

PARTIAL BUDGET FOR VARIETY X FERTILIZATION TRIAL ON LOWLAND RICE IN AFFIGNAN (LOWER CASAMANCE)

	IRAT 112				IRAT 133				DJ 12-519				Barafita				IKP			
Item / Fertilizer Levels	A_0	A_1	A_2	A_3	A_0	A_1	A_2	A_3	A_0	A_1	A_2	A_3	A_0	A_1	A_2	A_3	A_0	A_1	A_2	A_3
Average yield (kg/ha)	918	1,092	1,759	2,644	890	1,226	1,641	2,803	1,368	2,245	3,211	4,369	882	1,630	2,782	3,960	1,840	2,914	3,841	4,116
Adjusted yield (-10%)[a]	826	983	1,583	2,380	801	1,103	1,477	2,523	1,231	2,021	2,890	3,932	794	1,467	2,504	3,564	1,656	2,623	3,457	3,704
Gross Value of Production (107 CFA francs/kg)	88,382	105,181	169,381	240,600	85,707	118,021	158,039	250,610	131,717	215,470	276,300	349,240	84,958	156,969	249,280	323,480	177,192	257,610	315,990	333,280
Monetary Variable Costs																				
Quantity of 8-18-27 (kg)	0	50	100	200	0	50	100	200	0	50	100	200	0	50	100	200	0	50	100	200
Quantity of urea (kg)	0	37.5	75	150	0	37.5	75	150	0	37.5	75	150	0	37.5	75	150	0	37.5	75	150
Unit cost of 8-18-27 (CFA francs)	102.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35	120.35
Unit cost of urea (CFA francs)	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52	86.52
Total fertilizer cost (CFA francs)	0	9,262	18,524	37,048	0	9,262	18,524	37,048	0	9,262	18,524	37,048	0	9,262	18,524	37,048	0	9,262	18,524	37,048
Improved seed (100 kg/ha @ 75 CFA/kg)	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	0	0	0	0	7,500	7,500	7,500	7,500
Total monetary variable costs (CFA francs)	7,500	16,762	26,024	44,548	7,500	16,762	26,024	44,548	7,500	16,762	26,024	44,548	0	9,262	18,524	37,048	7,500	16,762	26,024	44,548
Opportunity Costs																				
Fertilizer spreading (man-days)[b]	0	1	1.5	2	0	1	1.5	2	0	1	1.5	2	0	1	1.5	2	0	1	1.5	2
Additional harvest labor (man-days)[c]	0	0	16	33	0	6	14	36	9	26	44	66	0	14	36	58	18	38	56	61
Daily wage (CFA francs)[d]	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Own seed													7,500	7,500	7,500	7,500				
Total opportunity costs	0	500	8,750	17,500	0	3,000	7,750	19,000	4,500	13,500	22,250	34,000	7,500	15,000	26,250	37,500	9,000	19,500	28,750	31,500
Total variable costs (CFA francs)	7,500	17,262	34,774	62,048	7,500	19,762	33,774	63,548	12,000	30,262	48,274	78,548	7,500	24,262	44,774	74,548	16,500	36,262	54,774	76,048
Net Benefit (CFA francs)	80,882	87,919	134,607	178,552	78,207	98,259	124,265	187,062	119,717	185,208	228,026	270,692	77,458	132,707	204,506	248,932	160,692	221,348	261,216	257,232

[a] Adjusted for possible losses at harvest and due to farmer management.

[b] Increasing the amount of fertilizer requires more application time. The estimates are based on empirical data.

[c] The additional harvest labor time is a function of the increased yield. Based on empirical data, harvest labor increases by 40% for a 65% increase in rice yield (Spencer). The reference situation is based on using the local variety (Barafita) with no fertilizer, in which case the average harvest labor time is 28 man-days, estimated on the basis of Production Systems Team data (see 1983-84 Report).

[d] The agricultural work day in Casamance is valued at 500 CFA francs on average.

TABLE 7

MARGINAL ANALYSIS OF NET BENEFITS: LOWLAND RICE VARIETY X FERTILIZATION TRIAL

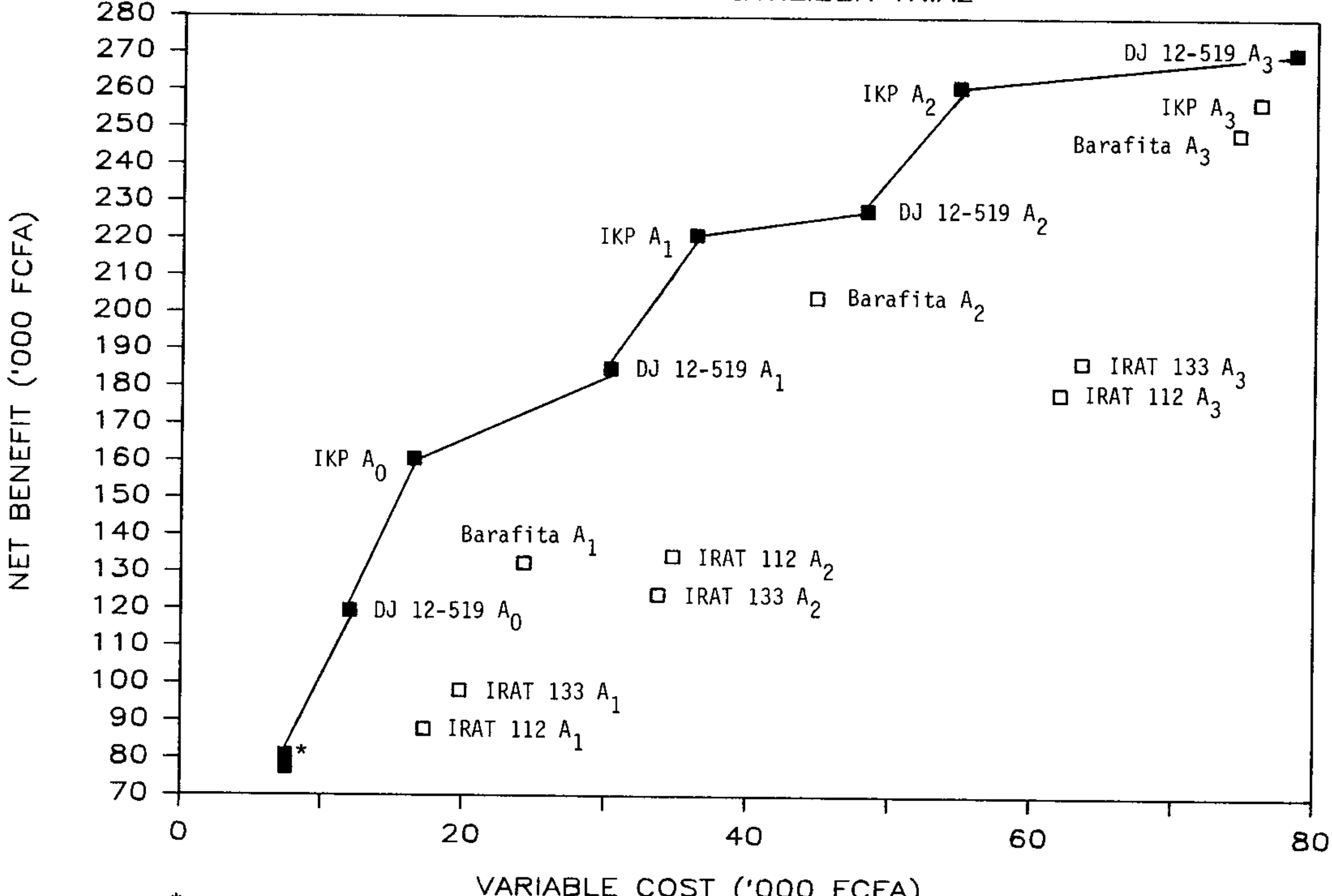
Net Benefit (CFA francs)	Variety	Fertilizer Level[a]	Total Variable Cost (CFA francs)	Dominated Option (D)	Marginal Cost (CFA francs)[b]	Marginal Net Benefit (CFA francs)[b]	Marginal Rate of Return (%)
270,692	DJ 12-519	A_3	78,548		23,774	9,476	40
261,216	IKP	A_2	54,774		6,500	33,190	511
257,232	IKP	A_3	76,048	D			
248,932	Barafita	A_3	74,548	D			
228,026	DJ 12-519	A_2	48,274		12,012	6,678	56
221,348	IKP	A_1	36,262		6,000	36,140	602
204,506	Barafita	A_2	44,774	D			
187,062	IRAT 133	A_3	63,548	D			
185,208	DJ 12-519	A_1	30,262		13,762	24,516	178
178,552	IRAT 112	A_3	62,048	D			
160,692	IKP	A_0	16,500		4,500	40,975	911
134,607	IRAT 112	A_2	34,774	D			
132,707	Barafita	A_1	24,262	D			
124,265	IRAT 133	A_2	33,774	D			
119,717	DJ 12-519	A_0	12,000		4,500	38,835	863
98,259	IRAT 133	A_1	19,762	D			
87,919	IRAT 112	A_1	17,262	D			
80,882	IRAT 112	A_0	7,500		0	3,424	--
78,207	IRAT 133	A_0	7,500	D			
77,458	Barafita	A_0	7,500	D			

[a] A_0 = no fertilizer; A_1, A_2, and A_3 = 25%, 50%, and 100%, respectively, of the recommended amount.

[b] The marginal value for a given treatment is the additional cost (benefit) which results from moving to this treatment from the undominated treatment with the next lowest net benefit on the list. Accordingly, the values for treatment DJ 12-519 (A_0) are calculated in relation to the values for IRAT 112 (A_0).

FIGURE 2. NET BENEFIT CURVE

RICE VARIETY X FERTILIZER TRIAL



*IRAT 112 A_0, IRAT 133 A_0, and Barafita A_0.

A_0 = no fertilizer; A_1, A_2, and A_3 = 25%, 50%, and 100% of the recommended dose.

purchase seed. If the farmer wishes to change varieties without incurring the expense of purchasing fertilizers, he is faced with two possibilities with very high and quite similar MRRs: DJ 12-519 (A_0) and IKP (A_0). These two options are attractive when the farmer prefers either DJ 12-519 or IKP to Barafita and is capable of paying for the selected seed (a constraint which can be overcome).

The remaining choices depend on the financial resources of farmers. Those who are able to purchase fertilizer and to apply up to 25% or 50% of the recommended amount (A_1 or A_2) can choose between DJ 12-519 (A_1) and IKP (A_1 and A_2). The latter has a very high MRR (511%). The information we have on the financial resources of farmers in the Lower Casamance suggests that level A_3 will be beyond the reach of many. In any event, combinations using this fertilizer level are dominated or have a very low MRR.

In summary, the choice comes down to the Barafita variety--which is preferred for its erect posture--and IRAT 112 with no fertilizer. Fertilizer levels A_1 and A_2 for varieties DJ 12-519 and IKP make it possible to realize a very high net benefit, but the feasibility of these options depends on the financial resources of farmers. We should point out that using the official price to value rice yields would not change these results.

Analysis of Trials on Alternative Cropping Techniques

The partial budget approach is also useful in analyzing trials which compare alternatives to existing production practices. To illustrate, we can use the example of a trial comparing the effects of plowing flat versus plowing in ridges for corn cultivation. Plowing flat is currently recommended by the PIDAC project in the Lower Casamance for all upland crops and for direct-seeded rice. On-farm trials and tests conducted by the Djibélor Production Systems Research Team show that, for upper rice fields and for corn, the traditional practice of plowing in ridges is quicker than plowing flat. For a given yield, it also makes it possible to control weeds more effectively (see Production Systems Team Report, Djibélor, 1984-85).

Due to the extreme variation in labor times at different sites, the 1984 test was conducted with three farmers in a single village (Boulandor) in order to evaluate the respective merit of these two practices and the appeal of plowing flat. The test includes three treatments:

T_1 -- existing techniques: plowing in ridges with the UCF plow, manual sowing and weeding.

T_2 -- plowing flat (UCF plow) with manual sowing and weeding, in order to evaluate the effect of plowing flat alone.

T_3 -- plowing flat (UCF plow), manual sowing and mechanical weeding/earthing-up during the fourth week after seeding.

The results are presented in table 8 in the form of a partial budget. There is no significant difference in labor time for the two types of animal traction plowing. Accordingly, the net benefits are substantially the same. Plowing flat is beneficial only when followed by mechanical weeding (T_3), which reduces the time spent on weeding to one-fifth of the time required for manual weeding. In fact, T_3 dominates the two other treatments, due to its higher net benefit and lower variable costs. The productivity of labor, in terms of output per day of work spent on plowing and weeding, is close to five times higher than for the two other methods.

Analysis of Trials on Complete Production Packages

A package of production practices is a discrete factor which cannot vary in continuous fashion like chemical inputs. As a result, one might assume that marginal analysis would be less applicable in this case. Nonetheless, given that the analysis is carried out in terms of monetary value, in principle there is an infinite number of intermediate cost levels associated with alternative combinations of practices. Thus we can utilize the approach presented earlier to evaluate the additional net benefit obtained in relation to the additional costs stemming from the application of increasingly expensive production practices.

As an example we will use a trial conducted in Mexico which tested complete production packages for corn (Harrington, 1982). The treatments used are as follows:

TABLE 8

TRIAL ON ALTERNATIVE PLOWING AND WEEDING METHODS FOR CORN IN LOWER CASAMANCE, 1984-85

Item	Treatment[a]		
	T_1	T_2	T_3
Yield (kg/hectare)[b]	1,690	1,732	1,597
Gross value of production (CFA francs)[c]	118,300	121,240	111,790
Monetary variable costs (CFA francs)[d]	--	--	--
Opportunity variable costs[e]			
Plowing time (man-days)	5	5	6
Weeding time (man-days)	28	30	5
Total man-days	33	35	11
Total value (CFA francs)	16,500	17,500	6,500[f]
Net benefit per hectare (CFA francs)	101,800	103,740	105,290
Yield/work-day ratio (kg/man-days)	51.2	49.5	145.2

Source: Production Systems Team Report, 1984-85, ISRA/Production Systems Department.

[a]T_1 = plowing in ridges; manual sowing and weeding.
T_2 = plowing flat; manual sowing and weeding.
T_3 = plowing flat; manual sowing; mechanical weeding.

[b]The yields are not significantly different at the 5% level.

[c]Valued at 70 CFA francs/kg.

[d]The monetary variable costs per hectare (80 kg of seed, 100 kg of urea + 100 kg of 8-18-27) are identical for all three treatments.

[e]Harvest labor time does not vary significantly among the three treatments.

[f]Including the opportunity cost (1000 CFA francs/hectare) of the use of the farmer's own equipment.

1) Local seed
   Density = 12 kg of seed per hectare
   No fertilizer
   No insecticide
   Traditional soil preparation and weed control
2) Same treatment as (1) except with improved seed
3) Local seed
   Density = 12 kg of seed per hectare
   No fertilizer
   No insecticide
   No land preparation plus herbicide
4) Same treatment as (3) except with improved seed
5) Local seed
   Density = 20 kg of seed per hectare
   50 kg of N per hectare
   Birlane applied once
   No land preparation plus herbicide
6) Same treatment as (5) except with improved seed

Table 9 presents the partial budget for the six treatments. The superior treatments are T_1, T_3, and T_5 (see table 10). The marginal analysis shows a marginal rate of return of 422% for T_3 and 4% for T_5. Thus treatment T_3 would be chosen.

NOTE ON STATISTICAL SIGNIFICANCE

As a general rule, economic analyses are done for trials where the difference in impact of various treatments is considered to be statistically significant. However, it can happen that no treatment produces a significant effect, or that only one factor produces a significant impact. In this situation, the approach to be followed is not totally obvious, but a few comments are worth mentioning:

1. First of all, the power of statistical tests is low (particularly for trials conducted on farms). For a trial where the different treatments are not considered significant, the researcher should nonetheless examine the results carefully. If he observes results which appear interesting, it

TABLE 9

PARTIAL BUDGET--FIELD TEST OF COMPLETE PRODUCTION PACKAGES FOR CORN IN MEXICO

	Treatment					
Item	1	2	3	4	5	6
Average yield (kg/hectare)	1,125	1,115	1,475	1,475	1,963	1,975
Adjusted yield (kg/hectare)	900	892	1,180	1,180	1,570	1,580
Gross benefit (pesos/hectare)	3,690	3,657	4,838	4,838	6,437	6,478
Variable costs (pesos/hectare)						
Local seed	84	0	84	0	140	0
Improved seed	0	300	0	300	0	500
Additional planting	0	0	0	0	150	150
Traditional soil prep. and weed control	2,200	2,200	0	0	0	0
Gramaxone (herbicide)	0	0	750	750	750	750
Gesaprim (herbicide)	0	0	720	720	720	720
Rental of sprayer	0	0	50	50	50	50
Herbicide application and water collecting	0	0	900	900	900	900
Insecticide	0	0	0	0	384	384
Insecticide application	0	0	0	0	150	150
N	0	0	0	0	500	500
Application of N	0	0	0	0	300	300
Total variable costs	2,284	2,500	2,504	2,720	4,044	4,404
Net benefit (pesos/hectare)	1,406	1,157	2,334	2,118	2,393	2,074

Source: Harrington, L. Exercises in the Economic Analysis of Agronomic Data. Mexico: CIMMYT, 1982.

TABLE 10

MARGINAL ANALYSIS--FIELD TEST OF COMPLETE PRODUCTION PACKAGES FOR CORN IN MEXICO

Treatment	Net Benefit	Total Variable Costs	Superior?	Marginal Net Benefit	Marginal Variable Costs	Marginal Rate of Return
			(Pesos)			
5	2,393	4,044	Yes	59[a]	1,540[a]	4%
3	2,334	2,504	Yes	928[b]	222[b]	422%
4	2,118	2,720	No			
6	2,074	4,404	No			
1	1,406	2,284	Yes	--	--	--
2	1,157	2,500	No			

Source: Harrington, L. Exercises in the Economic Analysis of Agronomic Data. Mexico: CIMMYT, 1982.

[a]Additional value in comparison with treatment 3.

[b]Additional value in comparison with treatment 1.

would be worth repeating the trial. The results could conceivably be of sufficient interest to producers that they would test the treatment themselves under their own conditions, so long as the risks involved are not too high. (See Perrin, et al.; Smail, et al.)

2. If no statistically significant difference has been demonstrated among the treatments, the preferred treatment in an economic sense is the treatment with the lowest cost. For example, a new cropping technique could reduce production costs without affecting yield. If all other factors are equal, this technique should be of interest to producers.

3. If, in a trial involving multiple factors, only one factor is statistically significant, the economic analysis could be conducted using the average values for this factor obtained by grouping the results for the other factors. For example, for a trial where the design includes three levels of mineral fertilizer and three different varieties, if it is found that the yield does not vary significantly according to variety, the average yield could be calculated for each fertilizer level by grouping the results for all varieties.

4. Finally, as stated earlier, if the results of the trial are not conclusive, the proper approach is to program other trials in order to confirm the impact of the treatments, before formulating definitive recommendations.

COMPUTER-AIDED ANALYSIS

The analyses discussed in this paper can of course be performed manually. However, using a computer can facilitate the work if there are many trials to be processed or many sensitivity analyses to be conducted. For data processing by computer, two options are currently available to ISRA:

1. The MSTAT software package includes the ECON subroutine which can be used to perform all of the analyses presented in this paper. ECON can accept the data file created by using the MSTAT software for other statistical analyses. MSTAT can be used on the IBM PC or the Apple II (in CP/M) and is available to all ISRA researchers. The manual for using MSTAT

includes a section which explains how to use ECON and shows the tables that can be produced.

2. The LOTUS 1-2-3 program, an "electronic worksheet" with the capability of manipulating data bases and producing graphics, allows the user to create his own framework or "template" for economic analysis. In theory, it is possible to develop a general template applicable to any type of trial, but in practice it is better to create a specific template for each type of trial. In contrast, many types of trial can be processed with MSTAT/ECON without modifying the program framework. Plans have been made for installing LOTUS 1-2-3 in the various ISRA centers that are to be equipped with IBM PC-XT's. An illustrative example of how LOTUS 1-2-3 can be used for the economic analysis of agronomic trials is available from the authors (Production Systems Department, ISRA).

CONCLUSIONS

In this paper we have presented some simple methods of economic analysis which can be applied to trials set up to formulate recommendations intended for a target group of farmers. We would like to emphasize three important aspects: the role of economic analysis in the process leading up to the formulation of recommendations, the critical importance of identifying and valuing costs and benefits, and the notion of the opportunity cost of resources.

For the various types of trial examined in this paper, economic analysis comes into play as soon as the statistical analysis of the experimental results has been completed. The objective is then to identify the best treatment from the farmer's point of view. But economic analysis can also contribute to formulating or reorienting the design of trials, based on the results of surveys on the performance and the constraints of production systems, or else as a follow-up to the interpretation of earlier experimental data. The objective then is to reorient the design so as to achieve a better understanding of the costs and the risks as perceived by the farmer.

We have presented certain principles and methods for valuing costs and benefits. However, it is clear that the trials presented in this paper only partially illustrate the application of these techniques. It is nonetheless appropriate to emphasize the importance of carefully determining the various relevant costs for the decision-maker, whoever he might be.

In some of the examples cited, the notion of opportunity cost assumes a crucial importance. Opportunity cost is a concept used to value resources in terms of their best alternative use. The idea of opportunity cost does not, however, imply that farmers subjectively value all of the resources at their disposal in monetary terms.

APPENDIX 1

SELECTED PRODUCT PRICES AND INPUT COSTS FOR THE ECONOMIC ANALYSIS OF AGRONOMIC TRIALS IN SENEGAL

Item	Official Price[a]	Local Price		
		Casamance[b]	Sine-Saloum[c]	Fleuve[d]
		(CFA francs per kilo)		
Products				
Millet	70	113	65-80	
White sorghum	70	117	70-80	
Paddy rice	85	85		86
Peanuts (unshelled)	90	160		
Peanuts (shelled)		207	150-200	
Corn grain	70	234	70-85	
Green corn		400		
Cowpeas (dry)	110	233	100-200	
Cotton[e]	100/90/55			
Tomatoes		220		40-65
Industrial tomatoes				23
Inputs				
NPK: 8-18-27		120[f]		
NPK: 0-15-20	60-72	70-72	63-64	67
NPK: 18-46-0				
Urea		87[f]		65
Ronstar		4000/liter		
Hired labor		400-600/day (800/day in the city)[g]		
Improved seed[h]				
Millet/sorghum	90			
Corn	90			
Paddy rice	105			
Cowpeas	150			
Peanuts	105			

[a]Le Soleil of April 5, 1985, for official product prices (1985-86).

[b]Production Systems Team, ISRA/Djibélor. Average figures for the city of Ziguinchor, September 1985-February 1986.

[c]ISRA/Bureau of Macro-Economic Analyses, 1986.

[d]Production Systems Team, ISRA/St. Louis.

[e]The three levels correspond to different product grades.

[f]Price for 1985.

[g]In general, 400 for women and 600 for men.

[h]Le Soleil of November 8, 1985.

APPENDIX 2

CORN FERTILIZATION TRIAL IN MEXICO: PARTIAL BUDGET

Item		Treatments: Amount of Fertilizer (kg/hectare)											
	N:	0	50	100	150	0	50	100	150	0	50	100	150
	P_2O_5:	0	0	0	0	25	25	25	25	50	50	50	50
1)	Average yield (t/ha)	2.21	3.14	3.91	4.01	2.44	3.88	4.40	4.84	2.36	4.05	4.74	5.16
2)	Adjusted yield	1.99	2.83	3.52	3.61	2.20	3.49	3.96	4.36	2.12	3.64	4.27	4.64
3)	Gross benefit (PS/ha @ 1,000 PS/t)	1,990	2,830	3,520	3,610	2,200	3,490	3,960	4,360	2,120	3,640	4,270	4,640
4)	Nitrogen (8 PS/kg N)	0	400	800	1,200	0	400	800	1,200	0	400	800	1,200
5)	Phosphate (10 PS/kg P_2O_5)	0	0	0	0	250	250	250	250	500	500	500	500
6)	Monetary variable costs (PS/ha, 4+5)	0	0	0	0	250	650	1,050	1,450	500	900	1,300	1,700
7)	Number of applications	0	1	2	2	1	1	2	2	1	1	2	2
8)	Cost per application (2 man-days @ 25 PS)	50	50	50	50	50	50	50	50	50	50	50	50
9)	Opportunity cost (PS/ha, 7+8)	0	50	100	100	50	50	100	100	50	50	100	100
10)	Total variable costs (PS/ha, 6+9)	0	450	900	1,300	300	700	1,150	1,550	550	950	1,400	1,800
11)	Net benefit (3-10)	1,990	2,380	2,620	2,310	1,900	2,790	2,810	2,810	1,570	2,690	2,870	2,840

Source: Perrin, et al., 1976.

[a]PS = Pesos.

APPENDIX 3

CORN FERTILIZATION TRIAL IN MEXICO: MARGINAL ANALYSIS OF UNDOMINATED TREATMENTS

Treatment						
N (kg/ha)	P_2O_5 (kg/ha)	Net Benefit (PS/ha)[a]	Variable Cost (PS/ha)	Marginal Net Benefit (PS/ha)	Marginal Variable Cost (PS/ha)	Marginal Rate of Return (%)
100	50	2,870	1,400	60	250	24
100	25	2,810	1,150	20	450	4
50	25	2,790	700	410	250	164
50	0	2,380	450	390	450	87
0	0	1,990	0	--	--	--

Source: Perrin, et al., 1976.

[a]PS = Pesos.

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