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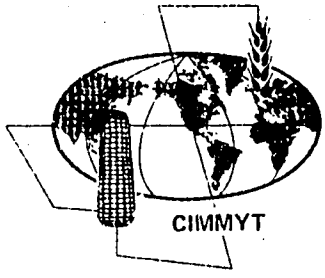
# ECONOMICS PROGRAM

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ISN-32234

# EXERCISES IN THE ECONOMIC ANALYSIS OF AGRONOMIC DATA*

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1982 Working Paper

* A workbook to accompany Perrin et al, 1976. "From Agronomic Data to Farmer Recommendations".

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## Introduction

The following set of exercises were initially developed for the benefit of in-service production agronomy trainees at CIMMYT headquarters in Mexico. They augment and complement materials found in the CIMMYT Economics Manual (Perrin et al, 1976) for instructing these trainees in the use of partial budgets.We believe this set of complementary exercises will help them to confidently conduct their own economic analyses.

The exercises present the elements of partial budgets in a step-by-step manner. Before each exercise, an explanation of the underlying concepts is given. They begin with elementary concepts and end with analytical complications that researchers must face in practice. Consequently, the exercises are best used in the sequence in which they are presented.

The concept of the recommendation domain pervades all of the exercises and is therefore best explained in this introduction. A recommendation domain is a group of farmers with similar practices and circumstances, for whom a unique recommendation will be roughly appropriate. Delineation of domains in a target area is nothing more than the stratification of farmers into a few roughly homogeneous groups. The use of domains stems from the practical recognition that (1) it is not feasible to make individual recommendations for each farmer, and (2) a global, general recommendation for a whole study area will probable not be appropriate for many of the farmers in the area.

The concept of the recommendation domain is made operational in economic analysis by means of analysis of pooled data. Given that a single recommendation is to be formulated for a given domain, the results of all experiments planted in the domain, and for the domain, should be included in the analysis. Pooling should be undertaken across years as well as across sites, within one domain. The specific techniques for analysis of pooled data are presented in the exercises.

This set of exercises uses, for the most part, data from experiments on maize. The concepts and procedures can easily be applied to experiments on other crops.

Thanks are due to many people for their help in developing these exercises. I would like to express special gratitude to Derek Byerlee, CIMMYT economist; Federico Kocher, A.F.E. Palmer and Alejandro Violic, CIMMYT agronomists; and the in-service production agronomy trainees with whom it has been such a pleasure to work.

## SECTION 1) FIELD PRICE OF THE PRODUCT

A key concept in the CIMMYT Economics Manual is that of the field price of the product, eg. maize or wheat. It is defined as "the value to the farmer of an additional unit of production in the field, prior to harvest ....." (Perrin et al, 1976, p 7).

The field price of the product is calculated by subtracting from the sales price of the product (where the farmer sells it, when he sells it and in the form in which he sells it) those costs which are roughly proportional to yield. These frequently include such costs as harvesting, shelling, transport from field to point of sale, and farmers' storage costs. (When the farmer does not sell, an opportunity field price should be used, equal to the money price incurred to acquire an additional unit of the product for consumption.)

The "field price" concept is used for three purposes: 1) To insure that the costs mentioned above are included in the analysis. (These costs are frequently overlooked by researchers but must nonetheless be faced by farmers.) 2) To simplify the succeeding steps in partial budgeting. (Once these costs are handled via the field price, they do not have to be individually estimated for each treatment.) 3) To exclude harvest and post-harvest costs from marginal analysis, because the farmer's capital invested in these activities will be recuperated almost immediately.

## Exercise No. 1 - Field Price of Maize

Calculate the field price of maize for the following cases:

a) The farmer sells his maize in his house to a trader for $5.50/kg. He also has the following costs: harvesting = $0.40/kg; shelling = $0.60/kg; transport from field to house = $0.20/kg.

Field price of maize = $ _____ /kg.

b) The farmer sells his maize in his house to an intermediary for L15/quintal, abbreviated "qq" (1 qq = 100 lbs. = 45 kg.). He must also pay the following costs: maize harvest = L 1.20/qq; shelling = L 1.40/qq; transportation from field to house = L 2.50/"carga" (1 carga = 4 qq = 400 lbs. = 180 kg.).

Field price of maize = L _____ /kg.

## SECTION 2) GROSS FIELD BENEFITS

Gross field benefits are defined as "Net yield times field price for all products from the crop. In general, this may include money benefits or opportunity benefits, or both." (Perrin, et al, p 7). Gross field benefits are estimated for each treatment to be evaluated.

"Field price" was defined in section (1). "Net yield" is defined as "The measured yield per hectare in the field, minus harvest losses and storage losses where appropriate." (Perrin, et al, p 6).

The concept of "net yield" stems from the recognition that farmers often do not receive the same yield as researchers, even when they apply the "same" treatment. This has several causes:

1) Management: Researchers can often be more precise and timely than farmers in applying a given treatment, e.g. plant spacing, timing of planting, fertilization, and weed control, etc.

2) Harvest date: Researchers often harvest fields at "physiological maturity" whereas farmers tend to let their crop dry in the field. Even when the yields of both researchers and farmers are adjusted to a constant moisture (eg. 14%). the researchers' yield is higher -- because of fewer yield losses to insects, birds, rats, ear rots, or shattering.

3) Form of harvest: At times, mechanized harvest by farmers leads to heavy field loss if the crop has lodged or if the rows were planted unevenly. In these cases, a careful manual harvest by researchers will lead to yield levels that farmers cannot obtain.

4) Storage losses: If the farmer stores his harvest for home consumption or for later sale, and thereby incurs insect or rat damage, his effective production is less than that predicted by researchers on the basis of experimental data. (Note: storage losses should not be

counted if they were already included in the "storage cost" used to calculate field price.)

5) Plot Size: Even when researchers are careful to use harvesting techniques that reduce border effects, yields estimated from small plots tend to be higher than yields taken from an entire field.

## Exercise No. 2 - Gross Field Benefits

Calculate gross field benefits for the following nitrogen by density (N x D) treatments. It is estimated that researchers obtain higher yields than farmers (for the same levels of N and density) due to management (10%) and harvest date (10%). Farmers sell their maize immediately after harvest.

The farmer receives $6.00/kg for his shelled maize. Transport cost from the field to place of sale = $0.40/kg., shelling cost = $0.30/Kg., and harvest cost = $1.10/kg.

| VARIABLE | TREATMENT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N0[1/] D25 | N0 D50 | N0 D75 | N50 D25 | N50 D50 | N50 D75 | N100 D25 | N100 D50 | N100 D75 |
| Average yield (kg/ha) | 1360 | 1040 | 940 | 1070 | 1180 | 1200 | 1180 | 860 | 910 |
| Adjusted Yield (Kg/ha) | | | | | | | | | |
| Gross Field Benefit ($/ha) | | | | | | | | | |

1/ N0 = 0 Kg/ha N, etc.
D25 = 25,000 plants/ha, etc.

## SECTION 3) ADJUSTING FOR "LOST SITES"

Researchers at times discard experimental data (or do not even harvest the experiment) when yields are extraordinarily low due to such natural factors as drought, frost or flooding. Insofar as these natural factors must also be faced by farmers, these cases of "Zero Response" should be accounted for. If the data on these lost sites are available, yields per treatment from "lost sites" should be included when averaging to obtain average treatment means for yield, for the recommendation domain under study (see Introduction). If the data from lost sites are not available, suitable uniform low yields per treatment should be estimated and used. Often an estimate of "zero yield" for all treatments is most accurate. It should be noted that any minor errors in estimating the uniformly low yield for treatments in a "lost site" are much less serious than the errors introduced by ignoring the problem.

## Exercise No. 3 - Adjusting for Lost Sites

Calculate gross field benefits for the following weed control treatments. It is considered that researchers obtain higher yields than farmers (for the same weed control practice) due to an earlier harvest date (10%) and a more painstaking manual harvest (5%). The farmer receives B1.80/kg for his shelled maize. Harvest cost = B0.30/kg; this includes shelling. The government pays transport cost from the field to location of sale. Farmers sell their maize immediately after harvest.

The results of three experiments are available, all of which were planted for the same recommendation domain. A fourth experiment for the same domain was abandoned due to drought - it was not harvested. No response to improved weed control is expected under drought conditions, so a uniform yield of 500 kg/ha was estimated for all treatments.

| Variable | TREATMENT | | | |
|---|---|---|---|---|
| | Manual Control | Gesaprim | Prowl | 2,4-D |
| Yield-Experiment 1 (kg/ha) | 2500 | 2800 | 3100 | 2600 |
| Yield-Experiment 2 (kg/ha) | 2000 | 2500 | 2600 | 2200 |
| Yield-Experiment 3 (kg/ha) | 2700 | 3500 | 3700 | 2900 |
| Yield-Experiment 4 (Kg/ha) | | (Not harvested - drought) | | |

Average yield (kg/ha)
Adjusted yield (kg/ha)
Gross Field Benefits (B/ha)

Field price of maize = B_____/ kg..

## SECTION 4) INCLUDING THE VALUE OF BYPRODUCTS

Frequently, maize or wheat grain is not the only product with economic value that comes from maize or wheat fields. Leaves, tassels, stover and straw may all have value to the farmer. (When a market for these byproducts exists, it is usually easy to calculate a sales price, from which a field price may be estimated by subtracting costs that are proportional to yield. (See section 1). Gross field benefits for byproducts should be added to gross field benefits for grain in order to obtain total gross field benefits.

## Exercise No 4 - Value of Byproducts

Calculate total gross field benefits for the following experiment on the response of wheat to levels of N. Farmers sell their wheat immediately after harvest for $4.00/kg. Harvesting and threshing cost $0.30/kg., and transport to place of sale costs $0.20/kg. Wheat straw is baled and sold as animal feed for $5.50 per 18 Kg. bale. The purchaser of the straw, not the farmer, pays transport cost. The farmer does pay, however, the cost of baling of $0.60 per bale.

It is estimated that researchers obtain higher wheat and straw yields than farmers even with the same N levels, due to management precision (10%) and earlier harvest that leads to fewer losses to shattering (5% for wheat only). No experimental sites were lost.

| Variable | TREATMENT | | | |
|---|---|---|---|---|
| | N0[1/] | N50 | N100 | N150 |
| Grain yield (Kg/ha) | 1500 | 2100 | 2400 | 2500 |
| Straw yield (Kg/ha) | 1800 | 2520 | 2880 | 3000 |

Adjusted grain yield (Kg/ha)
Adjusted straw yield (Kg/ha)

Gross field benefits-wheat ($/ha)
Gross field benefits-straw ($/ha)

Total gross field benefits ($/ha)

Field price of wheat = $ _____
Field price of straw = $ _____

[1/] N0 = 0 Kg/ha N, etc.

## SECTION 5) NET BENEFITS

Net benefits are defined by Perrin et al as "total gross field benefits minus total variable costs" (p.9). "Gross field benefits" were discussed in section (2). "Total variable costs" are defined as "the sum of field costs for all inputs which are affected by the choice... Variable costs can consist of either money costs or opportunity costs or both" (p. 9). That is, costs can reflect either a cash payment by the farmer (monetary cost) or the value of a farmer owned resource (opportunity cost).

Net benefits should not be confused with "profits". Recall that only costs that vary over treatments need be included in the net benefit calculation, i.e. Costs that do not vary need not be taken into account. It should be noted, however, that the inclusion of costs that do not vary over treatments will not make the economic analysis incorrect. In fact, the rate of return to investment capital (the measure of profitability used here) will not change at all if non-varying costs are included.

There is one cost that should not be included in "costs that vary over treatments". This is the "cost of investment capital", of which interest is usually a major element. This is because rates of return to capital are compared with this "cost of capital" when a recommendation is formulated (see sections (9) and (10)).

In the exercise that follows, data is given from three insect control experiments. All experiments were planted with the same recommendation domain in mind. So the calculation of an average yield for each treatment is the first step in the analysis which leads sequentially to the calculation of net yields, gross field benefits, total costs that vary, and net benefits.

## Exercise No. 5 - Net Benefits

Calculate the net benefits for each treatment, using the average maize yields for several insect control experiments. Yields for each treatment can be averaged over experiments because all experiments were located in a single recommendation domain. No experiments were abandoned.

| VARIABLE | TREATMENT | | | |
|---|---|---|---|---|
| | NO CONTROL | BIRLANE 1 X | BIRLANE[1/] 2 X | BIRLANE[2/] + FURADAN |
| Yield (kg/ha) Experiment 1 | 3000 | 2900 | 3100 | 3600 |
| Yield (kg/ha) Experiment 2 | 2400 | 2500 | 2700 | 3000 |
| Yield (kg/ha) Experiment 3 | 2750 | 2505 | 2950 | 3100 |
| Average Yield (kg/ha) | | | | |
| Adjusted Yield (kg/ha) | | | | |
| Gross Benefits (L/ha) | | | | |
| Birlane (kg/ha) | 0 | 8 | 16 | 8 |
| Furadan (kg/ha) | 0 | 0 | 0 | 4 |
| Insecticide Cost (L/ha) | | | | |
| Application Cost (L/ha) | | | | |
| Total Costs that Vary (L/ha) | | | | |
| Net Benefits (L/ha) | | | | |

1/ Birlane two times, 8 kg/ha each application.

2/ Birlane and Furadan are not applied together. Furadan is placed in the hole at planting but Birlane is used in a foliar application.

Cont'n. Exercise No. 5

Here are the data needed to complete the calculation:

| | | |
|---|---|---|
| Sales price of maize | = | L 14.50/qq |
| Harvesting cost | = | L 1.50/qq |
| Shelling cost | = | L 1.00/qq |
| Transport - field to sales point | = | L 1.60/qq |
| Wage in Market | = | L 6.00/day |
| Price of Birlane | = | L 1.70/kg |
| Price of Furadan | = | L 4.30/kg |
| Application cost: | | |
| Birlane | = | 1 man-day/application |
| Furadan | = | 0.5 man-day/application |
| Yield adjustment | = | 20% |
| 1 qq | = | 45 kg |

## SECTION 6) FIELD PRICE OF BULKY PURCHASED INPUTS

The calculation of total costs that vary and net benefits is at times complicated by transport charges for bulky purchased inputs, eg. fertilizer and seed. This can have a large impact on treatment costs where transport costs are high. For example, consider the following calculation of the field price of N:

| | | |
|---|---|---|
| | $ 5.00/kg | price of urea in store |
| + | | |
| | 3.50/kg | transport to field |
| | $ 8.50/kg | price of urea in the field |

$$\$ \frac{8.50}{.46} = \$ 18.48 =$$ price of N in the field, in the form of urea (46% N)

To find the cost of N for a given N dose, one only has to multiply this field price by the dose (eg. $ 18.48/kg x 100 kg/ha = $ 1848/ha).

## Exercise No. 6 - Field Price of Fertilizer

Calculate the field price of N and P, and the cost of the N P dose, for each treatment in the following N P experiment.

### TREATMENTS

| | N0P0 1/ | N0P40 | N50P0 | N50P40 | N100P0 | N100P40 |
|---|---|---|---|---|---|---|
| N Cost ($/ha) | | | | | | |
| P Cost ($/ha) | | | | | | |
| Fertilizer Cost ($/ha) | | | | | | |

1/ Numbers refer to kg/ha of N and P element

Data:

| | |
|---|---|
| ammonium nitrate (33.5% N) | $ 4.80/kg |
| triple super phosphate (46% P) | $ 7.50/kg |
| transport of fertilizer | $ 3.00/kg |

N field price = $ _____ /kg N

P field price = $ _____ /kg P

## SECTION 7) DOMINANCE ANALYSIS AND THE NET BENEFIT CURVE

The calculation of net benefits for each treatment is only an intermediate step in the economic analysis of agronomic data. That is, the treatment with the highest net benefit does not always make the best recommendation. Such factors as capital scarcity and risk aversion have yet to be included in the analysis.

Net benefits and "costs that vary" are used to calculate "marginal rates of return to investment capital" as one moves from a less expensive to a more expensive treatment (sections (8) and (10)). This "marginal analysis", however, can be made more efficient by an intermediate step -- "dominance analysis" -- in which clearly unprofitable treatments are discarded. (See Perrin et al, p 18).

A "dominated" treatment has lower net benefits and higher costs that vary, than some other treatment in the experiment. Dominated treatments need not be considered further in the analysis.

Dominance analysis can be seen graphically in the "net benefit curve". The net benefit curve "shows the relation between the variable costs ... and the net benefits ..." (see Perrin et al, p 16, for an example). To construct a net benefit curve, each treatment is plotted on a graph, the vertical axis representing net benefits and the horizontal axis representing costs that vary. The net benefit curve is formed by connecting these points with a solid line having a positive or upward slope.

That is, beginning with the point that corresponds to the least expensive treatment, a line is drawn to a point that represents the next most expensive treatment -- but only an upward sloping line is allowed. Undominated treatments will be on the net benefit curve but dominated treatments will be below the net benefit curve.

## EXERCISE NO.7 - DOMINANCE ANALYSIS AND THE NET BENEFIT CURVE

Based on five N by density experiments, all from one recommendation domain, the following data were obtained. Perform a dominance analysis and draw the net benefit curve.

| TREATMENT | NET BENEFIT ($/HA) | TOTAL COST THAT VARIES ($/HA) |
|---|---|---|
| N0 D0 | 3670 | 670 |
| N0 D1 | 4963 | 830 |
| N0 D2 | 5870 | 990 |
| N1 D0 | 3984 | 1373 |
| N1 D1 | 4877 | 1533 |
| N1 D2 | 4717 | 1693 |
| N2 D0 | 3174 | 2074 |
| N2 D1 | 4758 | 2234 |
| N2 D2 | 4075 | 2444 |

## SECTION 8) THE MARGINAL RATE OF RETURN

After dominated treatments have been discarded, marginal analysis can begin. The purpose of marginal analysis "is to reveal just how the net benefits from an investment increase as the amount invested increases." (Perrin *et al*, p 17).

Marginal analysis is based on the "marginal rate of return", which is defined as the increment in net benefits divided by the increment in costs that vary, as one moves from one treatment to the next more expensive treatment. This is usually expressed as a percentage.

$$MRR = \frac{\text{increment NB}}{\text{increment TCV}} \times 100$$

The marginal rate of return can be fruitfully interpreted as the percent return on investment capital, after that capital has been repaid. For example, if a farmer receives a MRR of 50% on an investment of $100, then that $ 100 investment has not only been recovered but a further return of $ 50 has also been earned.

It should be stressed that the MRR does <u>not</u> measure the returns corresponding to a single treatment, but rather to the returns that correspond to a <u>change</u> from a less expensive to a more expensive treatment. It follows from this that the slope of the net benefit curve is a measure of the MRR: the flatter the net benefit curve (small increment in net benefits compared to the increment in costs that vary), the lower the MRR.

This section only deals with the <u>calculation</u> of the MRR. The use of the MRR in the formulation of farmer recommendations must be left to a later section (10) because the topic of the cost of investment capital must first be addressed.

## EXERCISE NO. 8 - MARGINAL RATE OF RETURN

Based on the following data you should obtain, for recommendation domain one, marginal rates of return and the net benefit curve.

| RECOMMENDATION DOMAIN | EXPERIMENT NO. | TREATMENT[1/] N0 | N50 | N100 | N150 |
|---|---|---|---|---|---|
| 1 | 1 | 1000 | 1850 | 2200 | 2250 |
| 1 | 2 | 900 | 1860 | 2100 | 2400 |
| 2 | 3 | 1900 | 2400 | 2500 | 2600 |
| 1 | 4 | 1300 | 2200 | 2400 | 2500 |
| 2 | 5 | 2000 | 2600 | 2600 | 2700 |
| 1 | 6 | 1100 | 2100 | 2400 | 2500 |
| 1 | 7 | 1400 | 2050 | 2600 | 2600 |
| 2 | 8 | 1700 | 2200 | 2100 | 2200 |
| 2 | 9 | (abandoned - drought) | | | |

Data:

| | | |
|---|---|---|
| Yield adjustment | = | 15% |
| Maize sales price | = | $ 6.50/kg |
| Shelling cost | = | $ 0.50/kg |
| Harvest cost | = | $ 1.00/kg |
| Transport cost (maize) | = | $ 0.75/kg |
| Wage | = | $ 150/day |
| Urea (46% N) | = | $ 4.00/kg |
| Transport (urea) | = | $ 0.30/kg |

Fertilizer application:
2 man-days/ha

1/ Numbers refer to kg/ha N

## SECTION 9) COST OF INVESTMENT CAPITAL

Consider a farmer who invests $100 in fertilizer. If the increased value of production (due to fertilizer use) were exactly $100, the farmer would undoubtedly be sorry he bought the fertilizer. In order to willingly invest, he would require that both the $ 100 be repaid and that a "minimum rate of return" be earned. If his minimum required rate of return were 50%, he would have to expect a return of $150 ($ 100 + 50%) before investing. Any investment expected to earn a rate of return lower than this minimum would be rejected; likewise, any investment expected to earn a rate of return higher than this minimum would be accepted (risk aside for the moment). The problem lies in estimating this "minimum required rate of return".

In a few areas, the minimum rate of return required to induce investment can be estimated directly. In one area, for example, a common rule of thumb for farmers was "2 to 1"; i.e. an expected return of $ 2 was required by farmers for each $ 1 invested. This is equivalent to a minimum rate of return of 100% ($ 1 + 100% = $ 2).

Usually, however, no such rule of thumb exists and the minimum rate of return must be inferred from an estimate of the cost of borrowed capital. (This is usually easier to estimate than the opportunity cost of the farmer's own capital.)

Suppose, for example, that a farmer borrows $ 1000 for 8 months, at an 18% annual interest rate, and that he pays a $ 30 service charge and $ 70 in personal expenses in order to obtain the loan. His cost of capital is estimated as follows:

| | |
|---|---|
| $ 1000 x .18 = $ 180 | annual interest |
| $ 180 x $\frac{8}{12}$ = $ 120 | interest for loan period |
| $ 120 + $ 30 + $ 70 = 220 | loan costs |
| $ 220/$1000 = 22% | cost of borrowed capital for 8 months |

The minimum rate of return that is requested to induce investment will usually be above this "cost of borrowed capital". Perrin et al suggest adding 20 percentage points ("risk premium") onto the cost of borrowed capital to estimate the minimum required rate of return. They further suggest that a 40% minimum rate of return "rule of thumb" is roughly appropriate for many areas.

In Perrin et al, "cost of capital" and "minimum rate of return" are used interchangeably. In the following exercises, references will only be made to "cost of capital".

## Exercise No. 9 - Cost of Capital

a) A farmer borrows $3000 for eight months, at an annual interest rate of 20%. Besides interest, he must pay a service charge of $60 and he has $140 in personal expenses related to obtaining the loan. He also has to pay a crop insurance premium of $90. What is his cost of borrowed capital? What is his cost of capital (minimum rate of return) when a 20% "risk premium" is added?

b) A farmer borrows $2000 from the village money-lender. He does not have to pay any service charge, insurance premium or personal expenses. But the money-lender charges him 10% per month interest. What is his cost of borrowed capital if the loan runs for seven months? What is his cost of capital (minimum rate of return) including a 20% "risk premium"?

## SECTION 10) RECOMMENDATIONS AND THE MARGINAL RATE OF RETURN

In the previous exercises, emphasis was placed on calculation and estimation of field price, gross field benefits, net benefits, cost of capital, etc. Now these calculations and estimations must be interpreted in order to formulate a farmer recommendation.

Researchers have used several incorrect criteria for the formulation of recommendations: highest yield, highest net benefit, or highest marginal rate of return. All of the above are likely to give incorrect and misleading results. The correct way to interpret partial budget calculations is a bit more complicated, involving a series of comparisons between marginal rates of return and the cost of capital.

Consider a net benefit curve, in which undominated treatments are joined. Beginning with the least expensive treatment (lowest TCV), calculate the marginal rate of return that is earned when moving to the next treatment on the net benefit curve. If this marginal rate or return is greater than the cost of capital, the change (or investment) is accepted as profitable (risk aside). Each succeeding change is evaluated in the same way. In summary, researchers are asked to consider each increment in cost separately; they should keep increasing costs until the marginal rate of return approaches (but does not fall below) the cost of capital. (See Perrin et al, Chapter 4, for further information.)

## Exercise No. 10 - Recommendations and the MRR

Based on the following data, conduct dominance analysis and marginal analysis (MRR). What should be recommended if the cost of capital is 30%? If the cost of capital is 60%? Draw the net benefit curve.

a) N x P Experiment

| TREATMENT | | NET BENEFIT ($/HA) | COSTS THAT VARY ($/HA) |
|---|---|---|---|
| N0 | P0 | 500 | 0 |
| N0 | P40 | 480 | 91 |
| N50 | P0 | 610 | 99 |
| N50 | P40 | 520 | 178 |
| N100 | P0 | 650 | 186 |
| N100 | P40 | 580 | 265 |
| N150 | P0 | 420 | 273 |
| N150 | P40 | 350 | 352 |

b) Insect Control Experiment

| TREATMENT | NET BENEFIT ($/HA) | COSTS THAT VARY ($/HA) |
|---|---|---|
| Without control | 450 | 0 |
| Birlane 1 X | 475 | 30 |
| Birlane 2 X | 480 | 45 |
| Birlane + Furadan | 460 | 42 |

c) Verification Trial

| | TREATMENT | NET BENEFIT ($/HA) | COSTS THAT VARY ($/HA) |
|---|---|---|---|
| 1) | Farmer practice | 350 | 50 |
| 2) | (1) + new variety | 320 | 58 |
| 3) | (1) + chemical weed control | 380 | 35 |
| 4) | (2) + chemical weed control | 375 | 43 |
| 5) | (3) + fertilizer | 450 | 135 |
| 6) | (4) + fertilizer | 440 | 143 |

## SECTION 11) PARTIAL BUDGETS AND FIXED COSTS

In section (5) it was asserted that the results of economic analysis using partial budgets would be identical whether or not "fixed costs" (costs that do not vary due to treatments) were included in the analysis. Many researchers find this difficult to believe -- that so many costs can be safely ignored in economic analysis.

The following exercise demonstrates that marginal rates of return to investment capital do not change when fixed costs are excluded from economic analysis using partial budgets.

## Exercise No. 11 - Partial Budgets and Fixed Costs

To demonstrate the value of partial budgets, perform dominance analysis and marginal analysis on the following two data sets. Data set 1 includes only those costs that vary due to treatment changes. Data set 2 also includes some fixed costs. Yields and gross benefits are identical for both data sets.

### DATA SET 1 N x P EXPERIMENT

| VARIABLE | TREATMENT | | | |
|---|---|---|---|---|
| | N0 P0 | N0P40 | N50P0 | N50P40 |
| Yields (kg/ha) | 2000 | 2100 | 2500 | 2600 |
| Adjusted yield[1/] (kg/ha) | | | | |
| Gross Benefits[2/] ($/ha) | | | | |
| Cost of N[3/] ($/ha) | 0 | 0 | 350 | 350 |
| Cost of P[3/] ($/ha) | 0 | 300 | 0 | 300 |
| Application cost ($/ha) | 0 | 150 | 150 | 150 |
| Total - TVC ($/ha) | | | | |
| Net Benefits ($/ha) | | | | |

1/ 20% adjustment

2/ Field price of maize = $ 3.50/kg

3/ Transport cost already included

Cont'd. Exercise No. 11

## DATA SET 2 - N x P EXPERIMENT

| VARIABLE | TREATMENT | | | |
|---|---|---|---|---|
| | N0 P0 | N0P40 | N50P0 | N50P40 |
| Yields (kg/ha) | 2000 | 2100 | 2500 | 2600 |
| Adjusted Yield[1/] (kg/ha) | | | | |
| Gross Benefits[2/] ($/ha) | | | | |
| Tillage Cost ($/ha) | 1200 | 1200 | 1200 | 1200 |
| Planting Cost ($/ha) | 400 | 400 | 400 | 400 |
| Cost of Seed ($/ha) | 75 | 75 | 75 | 75 |
| Weeding Cost ($/ha) | 1600 | 1600 | 1600 | 1600 |
| Cost of N[3/] ($/ha) | 0 | 0 | 350 | 350 |
| Cost of P[3/] ($/ha) | 0 | 300 | 0 | 300 |
| Application Cost ($/ha) | 0 | 150 | 150 | 150 |
| Total - TVC ($/ha) | | | | |
| Net Benefits ($/ha) | | | | |

1/ 20% adjustment

2/ Field Price of Maize = $ 3.50/kg

3/ Transport cost already included

## SECTION 12) ECONOMIC ANALYSIS OF VERIFICATION TRIALS

As improved production practices are developed through on-farm research, a need arises to measure the consistency with which those improved practices prove to be economically superior to the current farmer practice. This measurement is performed via "verification trials" in which the farmer practice is compared with the improved practice in many locations, within a recommendation domain. The economic analysis of verification trials is crucial, profitability and risk being the major criteria for comparison. Put bluntly, if economic analysis of verifications is not performed, it is probably not worth while to plant them.

Verification trials present special problems for economic analysis. It is usual to find many factors changing simultaneously, as one moves from one treatment to another. Specification of "costs that vary" must be conducted very carefully to insure that all costs that vary are included.

As with other experiments, economic analysis of verification trials is best performed on the average yields (over many experiments) for each treatment, within a given recommendation domain.

## Exercise No. 12 - Verifications

Perform an economic analysis of the following set of verification trials for recommendation domain two. Include marginal analysis and the net benefit curve. What is the proper recommendation for RD 2?

| RECOMMENDATION DOMAIN | EXPERIMENT NUMBER | TREATMENT YIELDS (KG/HA) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 1 | 1200 | 1150 | 1500 | 1510 | 2000 | 2000 |
| 2 | 2 | 900 | 910 | 1100 | 1000 | 1500 | 1400 |
| 2 | 3 | 700 | 500 | 900 | 700 | 1100 | 1100 |
| 1 | 4 | 1500 | 1550 | 2100 | 2150 | 2460 | 2600 |
| 2 | 5 | 1500 | 1700 | 2100 | 2300 | 2700 | 2800 |
| 2 | 6 | 1400 | 1350 | 1800 | 1900 | 2550 | 2600 |

TREATMENTS:

1) Criollo Seed
   Density = (12 kg/ha seed)
   No fertilizer
   No insecticide
   Conventional tillage and weed control

2) Same as (1) but with improved seed

3) Criollo Seed
   Density = (12 kg/ha seed)
   No fertilizer
   No insecticide
   Zero tillage with chemical weed control

Cont'd. Exercise No. 12

4) Same as (3) but with improved seed

5) Criollo Seed
Density = (20 kg/ha seed)
50 kg/ha N
Birlane applied once
Zero tillage with chemical weed control

6) Same as (5) but with improved seed

DATA:

| | | | |
|---|---|---|---|
| - | Yield adjustment | = | 20% |
| - | Farm Gate Price of Maize | = | $ 6.50/kg |
| - | Harvesting Cost | = | $ 1.50/kg |
| - | Shelling Cost | = | $ 0.30/kg |
| - | Transport Cost (field to location of maize sale) | = | $ 0.60/kg |
| - | Transport Cost (store to field) | = | $ 0.40/kg |
| - | Criollo Seed | = | $ 7.00/kg |
| - | Improved Seed | = | $ 25.00/kg |
| - | Increased Planting Cost (due to density increase) | = | 1 man-day/ha |
| - | Increased Harvesting Cost (due density increase) | = | 0 |
| - | Conventional Tillage Cost | = | $ 1400/ha |
| - | Conventional Weed Control Cost | = | $ 800/ha |
| - | Zero Tillage Uses: | | |
| | 2.5 lt/ha Gramoxone at | = | $ 300/lt |
| | 3.0 kg/ha Gesaprim 50 at | = | $ 240/kg |
| - | Sprayer Rental | = | $ 50/ha |
| - | Herbicide application takes | | 4 man-days |

Cont'd. Exercise No. 12

| | | | |
|---|---|---|---|
| - | Hauling water for herbicide application takes | | 2 man-days |
| - | Wage | = | $ 150/day |
| - | Birlane treatment uses 12 kg/ha Birlane at | = | $ 32/kg |
| - | Urea (at store) costs | = | $ 4.20/kg |
| - | N application takes | | 2 man-days/ha |
| - | Cost of capital | = | 55% |
| - | Birlane application takes | | 1 man-day/ha |

## SECTION 13) MINIMUM RETURNS ANALYSIS

Farmers normally wish to earn more income -- but will often insist that this increased income be accompanied by a reasonably low level of risk. Perrin et al note that "farmers want to avoid the possibility of occasional high losses as they seek higher average net benefits" (p 20). These "occasional high losses" can be attributed to yield variability and price variability.

"Minimum returns analysis" is used to look at the effects of yield variability on net benefits, especially the effects of "disaster". This analysis merely entails the examination of the net benefits for each treatment for the worst cases.

Consider a set of ten identical experiments conducted in one recommendation domain. Marginal analysis leads to the selection of one of the treatments as a farmer recommendation. However, researchers should compare the net benefits earned with this treatment in the two or three worst cases (roughly 20% of the total number of experiments) with the net benefits earned by alternative treatments in these worst cases. If the recommended treatment demonstrates "worst-case" net benefits that are much lower than those of some reasonable alternative, researchers may wish to re-consider their recommendation.

For minimum returns analysis to be valid, all experiments of a given kind that are planted in a given domain (except those lost to researcher mismanagement) should be included in the analysis. Specifically, those experiments that are due to natural causes (flooding, drought, etc.) that farmers must face must be included in minimum returns analysis. Otherwise, the riskiness of selected treatments will be under-estimated.

Minimum returns analysis is especially important for experiments with high cost treatments in areas of substantial yield variability.

## Exercise No. 13 - Minimum Returns Analysis

Conduct a minimum returns analysis and a marginal analysis on the following data. If cost of capital = 40%, what is the recommendation if we do not consider risk? Might this recommendation be re-considered due to yield variability? Why?

Net Benefits by Site, Nitrogen Experiments in RD= 1

| SITE | TREATMENT | | | |
|---|---|---|---|---|
| | N0 | N50 | N100 | N150 |
| | - - - - - - - - - | | ($/HA) | - - - - - - - - - - |
| 1 | 2000 | 3000 | 1200 | - 1000 |
| 2 | 5000 | 7500 | 10000 | 10500 |
| 3 | 3000 | 6500 | 8000 | 8100 |
| 4 | 4000 | 5000 | 2000 | 3000 |
| 5 | 4500 | 7000 | 9000 | 10000 |
| 6 | 2500 | 4000 | 1000 | - 500 |
| 7 | 5000 | 8000 | 11640 | 13700 |
| 8 | 6000 | 7000 | 9000 | 9000 |
| Average net benefits | 4000 | 6000 | 6480 | 6600 |
| TCV | 0 | 1000 | 2000 | 3000 |

## SECTION 14) SENSITIVITY ANALYSIS

As noted in the previous section, farmers face two primary sources of risk: yield variability and price variability. The effects of yield variability are examined through minimum returns analysis. The effects of price variability are examined through "sensitivity analysis".

At times, researchers have difficulty estimating some input or product prices. In these cases, the researcher can examine the stability of his recommendation by conducting the economic analysis twice: once using a high (but likely) price and once using a low (but likely) price. Similarly, researchers can study the effect of input subsidies or recommendations by constructing budgets with and without the subsidy.

A stable recommendation (one that does not change given likely price variability) can be extended with much more confidence than an unstable one. If a recommendation is not stable, farmers must be given more information on needed adjustments in technology as prices change.

## Exercise No. 14 - Sensitivity Analysis

Perform, with the following data, marginal analysis of the tillage and weed control experiments for recommendation domain No. 1. First, use the subsidized price, then use the non-subsidized price for herbicides. Which is the correct recommendation for the farmers at present, given subsidies? Which would be the effect on recommendations if the herbicide subsidy were removed (ignore the possible effect on the maize price)?

| RECOMMENDATION DOMAIN | EXPERIMENT NUMBER | YIELDS BY TREATMENTS (KG/HA) FARMERS PRACTICE | ZERO TILLAGE 1 | ZERO TILLAGE 2 |
|---|---|---|---|---|
| 1 | 1 | 2000 | 1900 | 2400 |
| 1 | 2 | 1800 | 2100 | 2200 |
| 2 | 3 | 1200 | 1400 | 1500 |
| 2 | 4 | 1000 | 1300 | 1700 |
| 1 | 5 | 2200 | 2300 | 2600 |

DATA:

| | | |
|---|---|---|
| Cost of capital | = | 40% |
| Yield adjustment | = | 20% |
| Maize field price | = | $ 5.00/kg |
| Farmer practice cost | = | $ 2000/ha |
| Machete chopping, zero till 1 and 2 | = | 4 man-days/ha |
| Herbicide application | = | 2 man-days/ha |
| Hauling water for herbicide applic. | = | 2 man-days/ha |
| Wage | = | $ 120/day |

Cont'n Exercise No. 14

| | | |
|---|---|---|
| Gramoxone (subsidized price) | = | $ 250/lt |
| Gramoxone (non-subsidized price) | = | $ 360/lt |
| Gesaprim 50 (subsidized price) | = | $ 200/kg |
| Gesaprim 50 (non-subsidized price) | = | $ 340/kg |
| Sprayer rental | = | $ 50/ha |
| Farmer practice | = | Land preparation with animal traction, one weeding with hoe |
| Zero tillage 1 | = | Machete chopping followed by 1.0 lt/ha of Gramoxone and 2.0 kg/ha of Gesaprim 50 |
| Zero tillage 2 | = | Machete chopping followed by 2.5 lt/ha of Gramoxone and 3.0 kg/ha of Gesaprim 50 |

## SECTION 15) COMBINING STATISTICAL AND ECONOMIC ANALYSIS: 2 FACTORIAL EXPERIMENTS

The $2^4$ experiment has become increasingly popular in on-farm agronomic experimentation, in part due to the efforts of CIMMYT's maize training program. This experiment is used to examine main effects and interactions for four different factors, each of which is set at two levels. If the two levels for each factor are respectively set at the farmer's level and at a high, non-limiting level, the experiment is useful in identifying those factors that limit crop yield. If the levels are respectively set at the farmer's level and at a higher level that appears to be possible for target farmers, the experiment can also serve as a basis for formulating recommendations for farmers.

However, the very characteristic that makes this experiment useful -- the simultaneous testing of multiple factors -- creates complications in the economic analysis of results. The major complication is that not all treatments in a given experiment are necessarily included in the partial budget used in economic analysis. Sometimes data from individual treatments are used in analysis; at other times averages for main effects are used, depending on the results of statistical analysis.

In the partial budgeting, increased "costs that vary" are compared with increased "net benefits" to calculate a "marginal rate of return". Clearly, the analysis assumes that net benefits and gross benefits are calculated on the basis of yield changes that really exist, and that are really due to treatment effects, i.e., not due to random variation. If yield changes do not exist (or are not due to treatment effects), then the procedures for partial budgets do not entirely apply. In the absence of yield changes (and hence, in the absence of change in gross benefits) preference is normally given to the least-cost treatment.[1/]

---

[1/] This follows classical statistics in guarding against accepting a difference that does not exist. At times, however, it may be less costly to do the reverse: guard against rejecting a difference that does exist.

Whether or not yield changes really exist is determined by statistical analysis. Perrin et al, (p.4) however note two cautions.

"Most statistical tests are geared to the 0.05 or 0.01 levels of significance. But farmers may be willing to accept evidence that is much less persuasive than this. For instance if variety A yields 3 tons in an experiment, while variety B yields 4 tons, farmers may be quite happy to choose variety B even though this difference is statistically significant at, say only the 0.10 level.

Furthermore, it is quite possible that two treatment means are not significantly different at any of five trial sites, but the treatment means are different at the 0.01 level of significance when the data are pooled. Because of these considerations, we suggest that both statistical and economic analysis be conducted. If only one experiment is available, little can be said of the desirability of the treatment for farmers in the area, unless the results are overwhelming. When several experiments are available (from different sites or year or both), a statistical analysis of the pooled data should be conducted. The analysis of variance should include treatments, sites, and site-by-treatment interaction as sources of variation".

The above two points refer to ways in which the search for "significance" may be facilitated. Nonetheless, research programs frequently find themselves forced to analyze one or few experiments, to focus future experimental work and/or make preliminary farmer recommendations. Such is the case when research is begun in a new study area. In these cases, "significance" may be elusive for some factors. Even in those cases where researchers have access to several cycles of data, not even pooled analysis will lead to "significant" differences between treatment means if none exist in the universe under study.

Researchers must be ready, then, to deal with situations in which

some factors demonstrate "significant" differences between treatment means while other factors do not. This possibility creates special complications in such multiple-factor experiments as $2^4$ factorials.

In the procedures and examples used by Perrin et al, experimental treatments are analyzed one by one. In the case of the $2^4$ factorials, each of the sixteen treatments included in a given experiment would be analyzed: net benefits calculated, dominated treatments excluded, etc. This treatment by treatment analysis of $2^4$ factorials is complex due to the large number of treatments included in the budgets, and can be misleading due to the relative difficulty of combining statistical and economic results.

An alternative to a treatment by treatment approach to economic analysis is to pool data, using yield averages for main effects. Further disaggreagation would only be needed in the presence of significant interactions. Thus, instead of a single budget with 16 treatments, there may be several budgets, each with two or possibly four treatments. The exact form of the budgets, however, depends on the results of statistical analysis.

15.1) Case I - No Significance

At times, statistical analysis indicates that there is no significant difference in yields for either main factors or interactions. As noted, the required level of significance is up to the researcher and may range from the .01 level (large cost increase with a marginal rate of return just above the cost of capital) to the .20 level (small cost change with an excellent MRR). In this case, there is no need to use partial budget analysis because yields (and therefore gross benefits) are the same for all treatments. A comparison of costs is all that is needed to select a recommendation: the least-cost treatment. This may be performed on a factor by factor basis.

15.2) Case II - Some Main Effects Significant - No Significant Interactions

Normally, some of the factors in a $2^4$ experiment will demonstrate significant yield differences between the selected levels. This is especially the case when the selected factors are serious limitations to increased production by representative farmers, when the two levels for each factor are set "far apart", and when the experiment is reasonably precise.

When some main effects are significant -- but there are no significant interactions -- it is possible to conduct economic analysis by means of separate budgets for each significant factor. (Factors without significant yield differences between the two chosen levels are treated as in section 15.1 -- the least-cost level is chosen for each such factor.)

15.3) Case III - Some Main Effects and Some Interactions Significant

When some main effects and some interactions are significant, the factor-by-factor approach discussed in Section 15.2 is no longer valid. Nonetheless, it is not necessary to return to the long, complicated treatment-by-treatment approach. A middle ground does exist, in which budgets are constructed for significant main factors and factors with which a significant interaction exists. (In the same experiment if a main factor is not significant and does not interact with other factors, choose the least-cost treatment. If a main factor is significant but does not interact with other factors, construct a budget with two treatments).

The $2^4$ factorial experiment has become more popular in on-farm agronomic research, but the economic analysis of these experiments is somewhat complicated. The purpose of this section was to describe a method of economic analysis that focuses on factors, not on individual treatments, and that uses the result of statistical analysis to help plan economic analysis.

## Exercise No. 15 Combining Economic and Statistical Analysis - $2^4$ Factorials

Using the following data analyze the $2^4$ experiment in the simplest way using the statistical analysis to plan the economic analysis. For simplicity, use the .05 level of significance ($F > 4.60$).

### STATISTICAL ANALYSIS

| SOURCE OF VARIATION[1/] | OBSERVED F[2/] |
|---|---|
| A | 135.27 |
| B | 0.44 |
| C | 1.61 |
| D | 0.29 |
| AB | 4.84 |
| AC | 1.04 |
| AD | 2.30 |
| BC | 0.29 |
| BD | 0.02 |
| CD | 2.43 |
| ABC | 2.18 |
| ABD | 1.40 |
| ACD | 0.11 |
| BCD | 0.33 |

1/

| | | | |
|---|---|---|---|
| A0 = 0 N | | A1 = 100 kg/ha N | |
| B0 = 0 P | | B1 = 80 kg/ha P | |
| C0 = 0 Boron | | C1 = 1 kg/ha Boron | |
| D0 = 0 Zinc | | D1 = 2 kg/ha Zinc | |

2/ Tabular F for 0.05 significance level 4.60

Cont'd. Exercise No. 15

DATA:

| | | |
|---|---|---|
| Cost of capital | = | 50% |
| Yield adjustment | = | 20% |
| Maize Field Price | = | $ 10.00/qq |
| Urea Price | = | $ 34.00/qq |
| TSP | = | $ 39.00/qq |
| Hauling of fertilizer | = | $ 3.00/qq |
| Fertilizer application | = | 1 man-day/ha |
| Wage | = | $ 6.00/day |
| 1 qq | = | 45 kg |

YIELDS

| A | B | C | D | |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 2.03 |
| 1 | 0 | 0 | 0 | 3.66 |
| 0 | 1 | 0 | 0 | 2.48 |
| 1 | 1 | 0 | 0 | 3.68 |
| 0 | 0 | 1 | 0 | 1.98 |
| 1 | 0 | 1 | 0 | 3.30 |
| 0 | 1 | 1 | 0 | 1.52 |
| 1 | 1 | 1 | 0 | 3.69 |
| 0 | 0 | 0 | 1 | 2.42 |
| 1 | 0 | 0 | 1 | 3.20 |
| 0 | 1 | 0 | 1 | 2.13 |
| 1 | 1 | 0 | 1 | 3.61 |
| 0 | 0 | 1 | 1 | 2.41 |
| 1 | 0 | 1 | 1 | 3.28 |
| 0 | 1 | 1 | 1 | 2.05 |
| 1 | 1 | 1 | 1 | 3.77 |

## SECTION 16) PARTIAL BUDGETS FOR PLANNING EXPERIMENTS

The previous sections have focused on the use of partial budgets for the economic analysis of experimental data. These budgeting concepts can also be used, however, in the planning of experiments.

Researchers should use several criteria in the selection of experimental treatments, when the purpose of the research is the formulation of near-term recommendations useful to farmers. Specifically, high priority should be given to experimented treatments that researchers expect to be profitable, not too risky, and that mesh well with the current farming system (e.g. cropping calendar, labor supply, cash flow, consumption needs, etc.).

An estimate of the likely profitability of a treatment may be obtained by calculating the minimum yield increase needed to pay the increment in cost that is incurred. Agronomists can then assess (through intuition or judgement) the likelihood of obtaining this minimum required response.

Consider, for example, a case where weeds are limiting maize production. Farmers currently control weeds through horse cultivation but researchers are considering chemical weed control as an alternative. The increment in costs that vary (when changing from horse cultivation to chemical weed control) is $500/ha. Is this change likely to be profitable?

The minimum yield increase needed to pay the increment in costs may by found as follows:

$$\Delta Y = \frac{\Delta TCV \times (1 + C)}{P}$$

where $\Delta Y$ = minimum required yield increase, per ha

$\Delta TCV$ = increment in costs that vary, per ha

$C$ = cost of capital (%)

P = field price of product

with a cost of capital of 40% and a maize field price of $ 2.00/kg, the minimum required yield increase for our example is:

$$\Delta Y = \frac{500 \times 1.4}{2} = 350 \text{ kg/ha}$$

Agronomists consider a 600 kg/ha yield increase to be likely (averaging over good and bad crop cycles), so chemical weed control emerges as a priority practice for on-farm testing, at least from the viewpoint of expected profitability. (Note that it still be screened, however, for riskiness and consistency with the farming system).

## Exercise No. 16 - Partial Budgets for Planning Experiments

Researchers in one recommendation domain conclude that N deficiency is a major limiting factor in the maize crop. They feel that 150 kg/ha N would overcome this deficiency, and would lead to a yield increase of one ton/ha. Is this level likely to be profitable for local farmers? (If not, researchers might wish to set N treatment levels a bit lower).

DATA:

| | |
|---|---|
| Fertilizer application | $ 100/ha |
| Price of urea (in the store) | $ 7.00/kg |
| Transport of urea (store to field) | $ 3.00/kg |
| Cost of capital | 60% |
| Maize sales price | $ 3.00/kg |
| Shelling cost | $ 0.20/kg |
| Harvesting cost | $ 0.70 |
| Transport (for maize, from field to place of sale) | $ 0.30/kg |

## ANSWERS TO EXERCISES

### Exercise No. 1 - Field Price of Maize

| | | | |
|---|---|---|---|
| a) | Sales price | = | $ 5.50/kg |
| | Harvest cost | = | $ 0.40/kg |
| | Shelling cost | = | $ 0.60/kg |
| | Transport cost | = | $ 0.20/kg |
| | Field price | = | $ 4.30/kg |

| | | | |
|---|---|---|---|
| b) | Sales price | = | L 15.00/qq |
| | Harvest cost | = | L 1.20/qq |
| | Shelling cost | = | L 1.40/qq |
| | Transport cost | = | L 0.63/qq |
| | Field price | = | L 11.77/qq |
| | | or | L 0.26/kg |

Exercise No. 2 - Gross Field Benefits

| VARIABLE | TREATMENT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N0 D25 | N0 D50 | N0 D75 | N50 D25 | N50 D50 | N50 D75 | N100 D25 | N100 D50 | N100 D75 |
| Average Yield (kg/ha) | 1360 | 1040 | 940 | 1070 | 1180 | 1200 | 1180 | 860 | 910 |
| Adjusted Yield[1/] (kg/ha) | 1088 | 832 | 752 | 856 | 944 | 960 | 944 | 688 | 728 |
| Gross Field Benefit[2/] ($/ha) | 4570 | 3494 | 3158 | 3595 | 3965 | 4032 | 3965 | 2890 | 3058 |

1/ Yield adjustment = 20%

2/ Field price of maize = $ 4.2/kg

Exercise No. 3 - Adjusting for Lost Sites

| Variable | TREATMENT | | | |
|---|---|---|---|---|
| | Manual Control | Gesaprim | Prow | 2,4D |
| Yield 1 (Kg/ha) | 2500 | 2800 | 3100 | 2600 |
| Yield 2 (Kg/ha) | 2000 | 2500 | 2600 | 2200 |
| Yield 3 (Kg/ha) | 2700 | 3500 | 3700 | 2900 |
| Yield 4 (abandoned) (Kg/ha) | 500 | 500 | 500 | 500 |
| Average yield (Kg/ha) | 1925 | 2325 | 2475 | 2050 |
| Adjusted yield[1/] (Kg/ha) | 1636 | 1976 | 2104 | 1742 |
| Gross Field Benefits (B/ha) | 2454 | 2964 | 3156 | 2614 |

Field price of maize = B 1.50/Kg.

[1/] Yield adjustment = 15%

Excercise No. 4 - Value of By-Products

| Variable | TREATMENT | | | |
|---|---|---|---|---|
| | N0 | N50 | N100 | N150 |
| Grain yield (Kg/ha) | 1500 | 3100 | 2400 | 2500 |
| Straw yield (Kg/ha) | 1800 | 2520 | 2880 | 3000 |
| Adjusted grain yield[1/] (Kg/ha) | 1275 | 1785 | 2040 | 2125 |
| Adjusted straw yield[2/] (Kg/ha) | 1620 | 2268 | 2592 | 2700 |
| Gross field benefit-wheat ($/ha) | 4463 | 6248 | 7140 | 7438 |
| Gross field benefit-straw ($/ha) | 437 | 612 | 700 | 729 |
| Total gross field benefit ($/ha) | 4900 | 6860 | 7840 | 8167 |

1/ 15% adjustment

2/ 10% adjustment

Field price of wheat = $3.50/kg.

Field price of straw = $0.27/kg.

Exercise No. 5 - Net Benefits

| VARIABLE | TREATMENT | | | |
|---|---|---|---|---|
| | NO CONTROL | BIRLANE 1X | BIRLANE 2X | BIRLANE + FURADAN |
| Average yield (kg/ha) | 2717 | 2635 | 2917 | 3233 |
| Adjusted yield[1/] (kg/ha) | 2174 | 2108 | 2334 | 2586 |
| Gross Benefits[2/] (L/ha) | 502 | 485 | 537 | 595 |
| Insecticide cost (L/ha) | 0 | 13.6 | 27.2 | 30.8 |
| Application Cost (L/ha) | 0 | 6.0 | 12.0 | 9.0 |
| TCV (L/ha) | 0 | 19.6 | 39.2 | 39.8 |
| Net Benefits (L/ha) | 498 | 465 | 498 | 555 |

1/ Yield adjustment = 20%

2/ Field Price of Maize = L 0.23/kg

Exercise No. 6 - Field Price of Fertilizer

$$\text{N field price} = \frac{4.8 + 3.0}{.335} = \$\ 23.3/\text{kg}$$

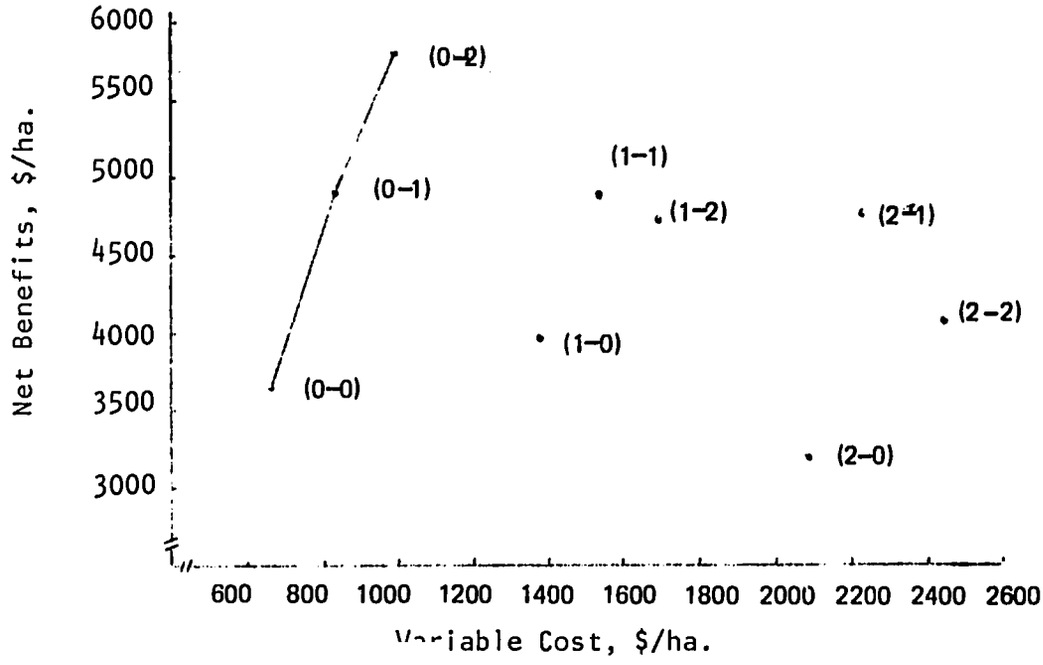
$$\text{P field price} = \frac{7.5 + 3.0}{.46} = \$\ 22.8/\text{kg}$$

| VARIABLE | TREATMENT | | | | | |
|---|---|---|---|---|---|---|
| | N0 P0 | N0 P40 | N50 P0 | 150 P40 | N100 P0 | N100 P40 |
| N cost ($/ha) | 0 | 0 | 1165 | 1165 | 2330 | 2330 |
| P cost ($/ha) | 0 | 912 | 0 | 912 | 0 | 912 |
| Fertilizer cost ($/ha) | 0 | 912 | 1165 | 2077 | 2330 | 3242 |

Exercise no. 7 - Dominance Analysis and the Net Benefit Curve

| TREATMENT | NET BENEFIT ($/HA) | TCV ($/HA) | |
|---|---|---|---|
| N0 D0 | 3670 | 670 | |
| N0 D1 | 4963 | 830 | |
| N0 D2 | 5870 | 990 | |
| N1 D0 | 3984 | 1373 | D |
| N1 D1 | 4877 | 1533 | D |
| N1 D2 | 4717 | 1693 | D |
| N2 D0 | 3174 | 2074 | D |
| N2 D1 | 4758 | 2234 | D |
| N2 D2 | 4075 | 2444 | D |

All treatments marked "D" are dominated, in this example by a single treatment (N0 D2).



Exercise No. 8 - Marginal Rate of Return

| VARIABLE | TREATMENTS | | | |
|---|---|---|---|---|
| | N0 | N50 | N100 | N150 |
| Average yield-RD1 (kg/ha) | 1140 | 2012 | 2340 | 2450 |
| Adjusted yield[1/] (kg/ha) | 969 | 1710 | 1989 | 2083 |
| Gross benefits[2/] ($/ha) | 4118 | 7268 | 8453 | 8850 |
| Cost of N[3/] ($/ha) | 0 | 468 | 935 | 1403 |
| Application cost ($/ha) | 0 | 300 | 300 | 300 |
| TCV ($/ha) | 0 | 768 | 1235 | 1703 |
| Net Benefits ($/ha) | 4118 | 6500 | 7218 | 7148 |

1/ Yield adjustment = 15%

2/ Maize field price = $ 4.25/kg

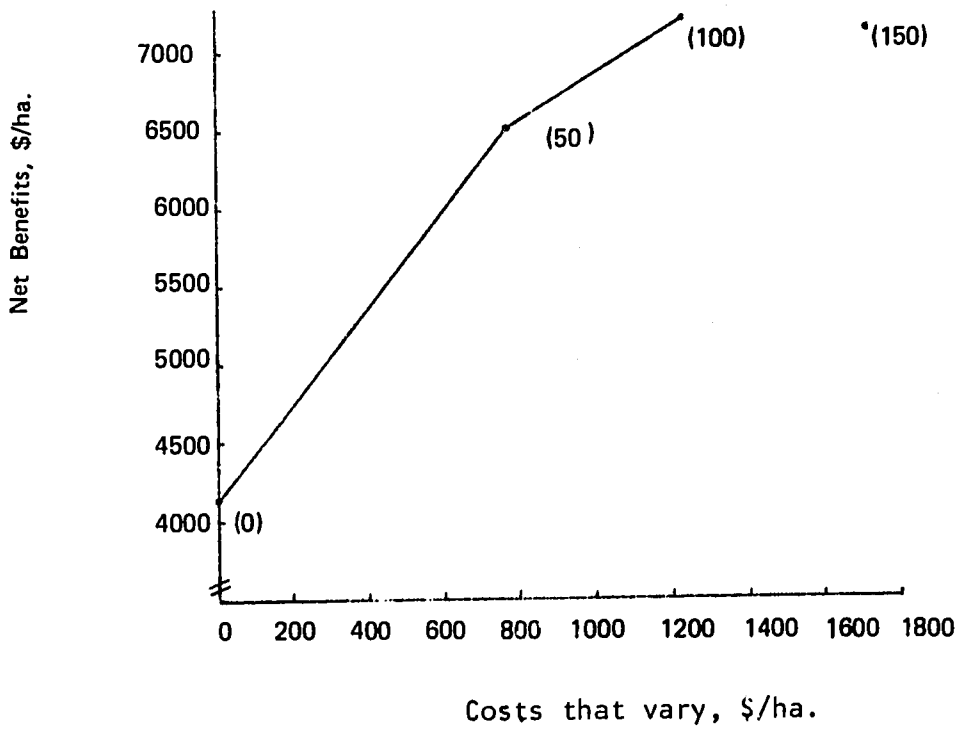
3/ Field price of N = $ 7.35/kg

MARGINAL ANALYSIS:

N150 is dominated

$$\text{MRR N0} \rightarrow \text{N50} = \frac{6500 - 4118}{768 - 0} \times 100 = 310\%$$

$$\text{MRR N50} \rightarrow \text{N100} = \frac{7218 - 6500}{1235 - 768} \times 100 = 154\%$$


Net Benefits, $/ha.
7000
6500
6000
5500
5000
4500
4000
(0)
(50)
(100)
(150)
0
200
400
600
800
1000
1200
1400
1600
1800
Costs that vary, $/ha.

Exercise No. 9- Cost of Capital

a) $ 3000 borrowed
x .20 annual interest rate
$ 600 annual interest charge

$ 600 x $\frac{8}{12}$ = $ 400 interest charge - 8 month loan

60 service charge
+ 140 personal expenses
90 crop insurance
$ 690 total expenses re loan

$\frac{\$\ 690}{\$\ 3000}$ = 23% cost of borrowed capital
20% "risk premium"
43% cost of capital (minimum required rate of return)

b) $ 2000 borrowed
x .10 monthly interest rate
$ 200 monthly interest charge
x 7 months
$ 1400 interest charge - 7 month loan

$\frac{\$\ 1400}{\$\ 2000}$ = 70% cost of borrowed capital
+ 20% "risk premium"
90% cost of capital (minimum required rate of return)

Exercise No. 10 - Recommendations and the MRR

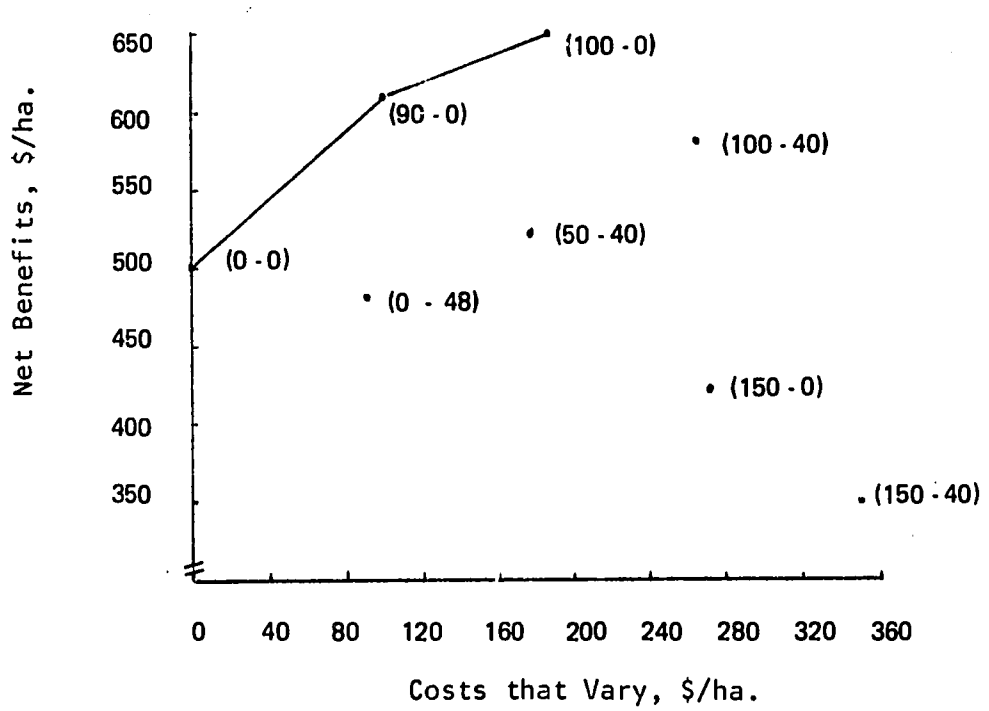
a) N x P Experiment

Dominated treatments:

N0P40, N50P40, N100P40, N150P0, N150P40

| TREATMENT CHANGE | INCREMENT NET BENEFIT | INCREMENT TCV | MRR |
|---|---|---|---|
| N0P0 → N50P0 | 110 | 99 | 111% |
| N50P0 → N100P0 | 40 | 87 | 46% |

If the cost of capital = 30%, recommend N100P0. If the cost of capital = 60%, recommend N50P0.

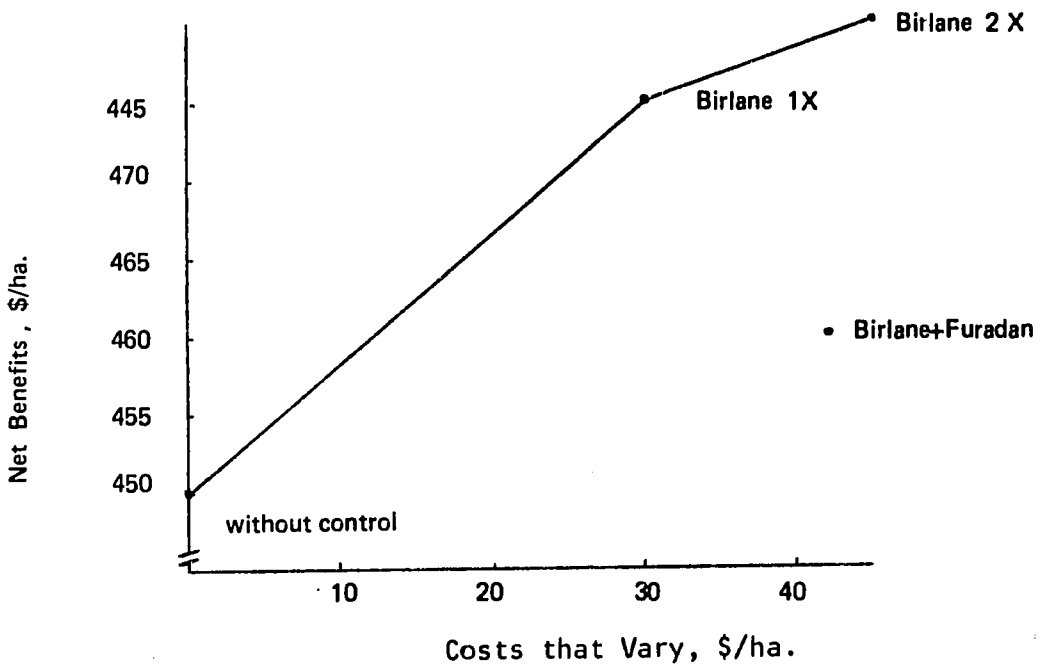


b) Insect Control Experiment

Dominated treatment: Birlane + Furadan

| TREATMENT CHANGE | INCREMENT NET BENEFIT | INCREMENT TCV | MRR |
|---|---|---|---|
| No Control → Birlane 1X | 25 | 30 | 83% |
| Birlane 1X → Birlane 2X | 5 | 15 | 33% |

If the cost of capital = 30%, recommend Birlane 2X. If the cost of capital = 60%, recommend Birlane 1X

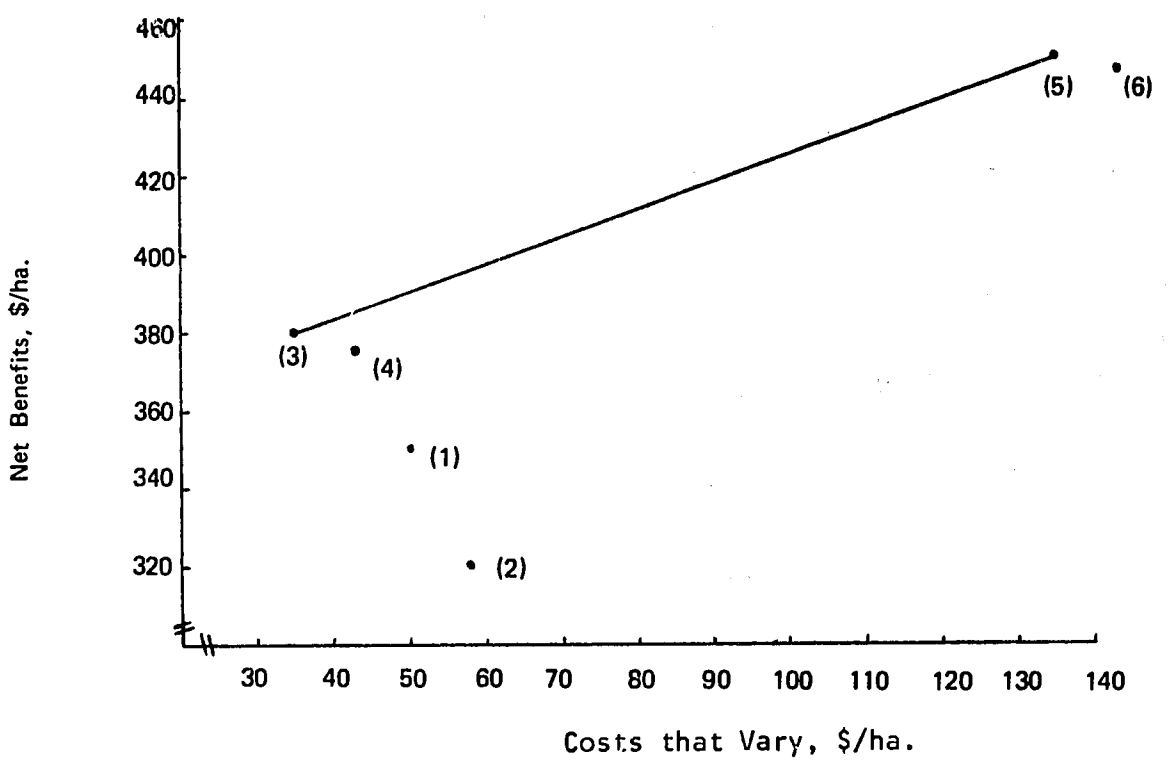


c) Verification Trial

Dominated treatments: 1, 2, 4, 6

| TREATMENT CHANGE | INCREMENT NET BENEFIT | INCREMENT TCV | MRR |
|---|---|---|---|
| 3 → 5 | 70 | 100 | 70% |

If the cost of capital = 30% or 60%, recommend treatment (5).



## Exercise No. 11 - Partial Budgets and Fixed Costs

| VARIABLE | TREATMENT | | | |
|---|---|---|---|---|
| | N0P0 | N0P40 | N50P0 | N50P40 |
| **Data Set 1** | | | | |
| Yield (kg/ha) | 2000 | 2100 | 2500 | 2600 |
| Gross Benefits ($/ha) | 5600 | 5880 | 7000 | 7280 |
| TCV ($/HA) | 0 | 450 | 500 | 800 |
| Net Benefits ($/HA) | 5600 | 5430 | 6500 | 6480 |
| **Data Set 2** | | | | |
| Yield (kg/ha) | 2000 | 2100 | 2500 | 2600 |
| Gross Benefits ($/ha) | 5600 | 5880 | 7000 | 7280 |
| TCV ($/ha) | 3275 | 3725 | 3775 | 4075 |
| Net Benefits ($/Ha) | 2325 | 2155 | 3225 | 3205 |

For both data sets:

N0P40 and N50P40 are dominated

| TREATMENT CHANGE | INCREMENT NET BENEFITS | INCREMENT TCV | MRR |
|---|---|---|---|
| N0P0 → N50P0 | 900 | 500 | 180% |

Exercise No. 12 - Verification

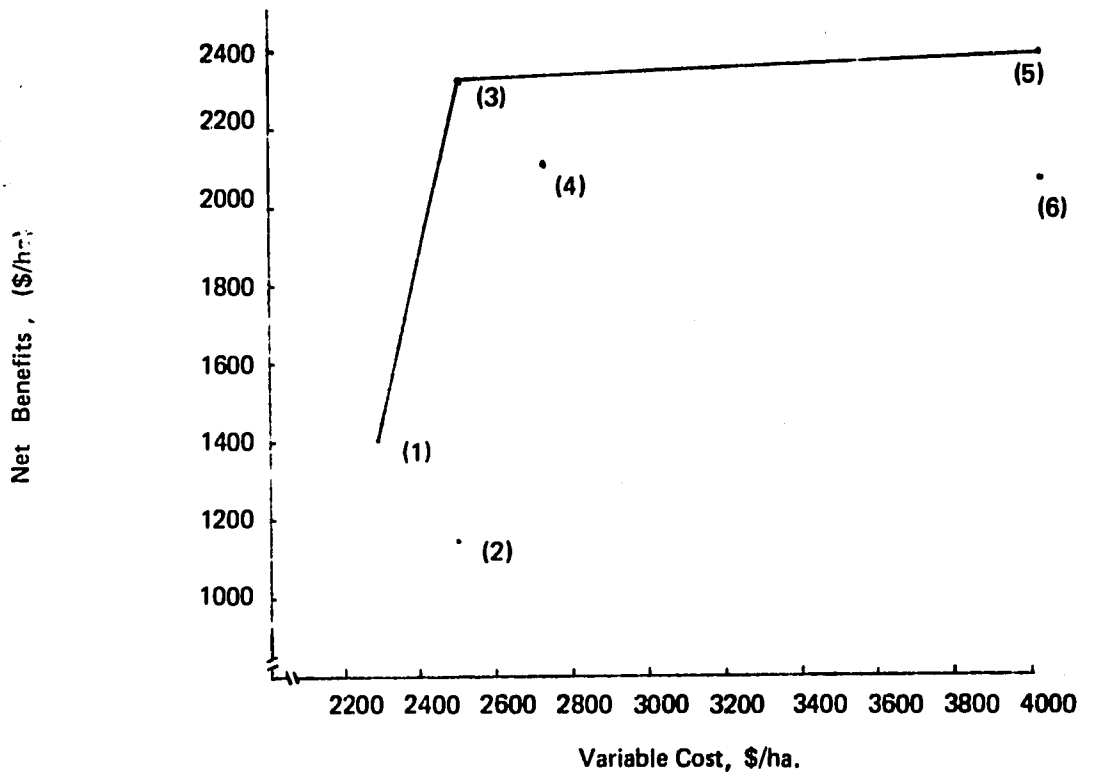
| VARIABLE | TREATMENT 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Average yield-RD2 (kg/ha) | 1125 | 1115 | 1475 | 1475 | 1963 | 1975 |
| Adjusted yield (kg/ha) | 900 | 892 | 1180 | 1180 | 1570 | 1580 |
| Gross benefits ($/ha) | 3690 | 3657 | 4838 | 4838 | 6439 | 6478 |
| Local seed ($/ha) | 84 | 0 | 84 | 0 | 140 | 0 |
| Improved seed ($/ha) | 0 | 300 | 0 | 300 | 0 | 500 |
| Increased planting ($/ha) | 0 | 0 | 0 | 0 | 150 | 150 |
| Conventional tillage and weed control ($/ha) | 2200 | 2200 | 0 | 0 | 0 | 0 |
| Gramoxone ($/ha) | 0 | 0 | 750 | 750 | 750 | 750 |
| Gesaprim 50 ($/ha) | 0 | 0 | 720 | 720 | 720 | 720 |
| Sprayer rental ($/ha) | 0 | 0 | 50 | 50 | 50 | 50 |
| Herbicide application and hauling water ($/ha) | 0 | 0 | 900 | 900 | 900 | 900 |
| Insecticides ($/ha) | 0 | 0 | 0 | 0 | 384 | 384 |
| Insecticide application ($/ha) | 0 | 0 | 0 | 0 | 150 | 150 |
| N ($/ha) | 0 | 0 | 0 | 0 | 500 | 500 |
| N Application ($/ha) | 0 | 0 | 0 | 0 | 300 | 300 |
| TCV ($/ha) | 2284 | 2500 | 2504 | 2720 | 4044 | 4044 |
| Net benefit ($/ha) | 1406 | 1157 | 2334 | 2118 | 2395 | 2434 |

Dominated Treatments: 2, 4, and 6

Marginal analysis:

| TREATMENT CHANGE | INCREMENT IN NET BENEFITS | INCREMENT IN TCV | MRR |
|---|---|---|---|
| 1 → 3 | 928 | 220 | 422% |
| 3 → 5 | 61 | 1540 | 4% |

If cost of capital = 55%, treatment 3 should be recommended. (The only profitable change is from conventional to chemical tillage and weed control).


Net Benefits, ($/ha)
2400
2200
2000
1800
1600
1400
1200
1000
(1)
(2)
(3)
(4)
(5)
(6)
2200 2400 2600 2800 3000 3200 3400 3600 3800 4000
Variable Cost, $/ha.

Exercise No. 13 - Minimum Returns Analysis

| VARIABLE | TREATMENT | | | |
|---|---|---|---|---|
| | N0 | N50 | N100 | N150 |
| TCV | 0 | 1000 | 2000 | 3000 |
| Net benefits (average) | 4000 | 6000 | 6480 | 6600 |
| Net benefits (average of two worst cases) | 2250 | 3500 | 1100 | - 500 |

Dominated Treatment: None

Marginal Analysis (risk not considered)

| TREATMENT CHANGE | INCREMENT IN NET BENEFITS | INCREMENT IN TCV | MRR |
|---|---|---|---|
| N0 → N50 | 2000 | 1000 | 200% |
| N50 → N100 | 480 | 1000 | 48% |
| N100 → N150 | 120 | 1000 | 12% |

If the cost of capital is 40% and risk is not considered, N100 should be recommended.

Minimum Returns Analysis

Despite the fact that N100 is just profitable (on the average), net benefits for the worst cases are quite low, even in comparison to N0. Researchers might wish to consider N50 as a possible recommendation if target farmers are small and risk-averse. Net benefits for N50 are higher even in the worst cases than N0 net benefits.

Exercise No. 14 - Sensitivity Analysis

| VARIABLE | TREATMENT | | | | |
|---|---|---|---|---|---|
| | FARMER PRACTICE | ZERO TILL 1 + SUB-SIDY | ZERO TILL 1 - SUB-SIDY | ZERO TILL 2 + SUB-SIDY | ZERO TILL 2 - SUB-SIDY |
| Average yield-RD 1 (kg/ha) | 2000 | 2100 | 2100 | 2400 | 2400 |
| Adjusted yield (kg/ha) | 1600 | 1680 | 1680 | 1920 | 1920 |
| Gross Benefits ($/ha) | 8000 | 8400 | 8400 | 9600 | 9600 |
| Farmer practice ($/ha) | 2000 | 0 | 0 | 0 | 0 |
| Machete chopping ($/ha) | 0 | 480 | 480 | 480 | 480 |
| Herbicide application ($/ha) | 0 | 240 | 240 | 240 | 240 |
| Hauling water ($/ha) | 0 | 240 | 240 | 240 | 240 |
| Sprayer ($/ha) | 0 | 50 | 50 | 50 | 50 |
| Gramoxone ($/ha) | 0 | 250 | 360 | 625 | 900 |
| Gesaprim ($/ha) | 0 | 400 | 680 | 600 | 1020 |
| TCV ($/ha) | 2000 | 1660 | 2050 | 2235 | 2930 |
| Net Benefits ($/ha) | 6000 | 6740 | 6350 | 7365 | 6670 |

Marginal Analysis:

With the Subsidy on Herbicides

Dominated treatments: Farmer practice

| TREATMENT CHANGE | INCREMENT N B | INCREMENT TCV | MRR |
|---|---|---|---|
| Zero till 1 → Zero till 2 | 625 | 575 | 109% |

Without the Subsidy on Herbicide:

| TREATMENT CHANGE | INCREMENT N B | INCREMENT TCV | MRR |
|---|---|---|---|
| Farmer practice → Z T 1 | 350 | 50 | 700% |
| Z T 1 → Z T 2 | 320 | 880 | 36% |

If the subsidy on herbicides were to be dropped, zero tillage would remain profitable, but farmers should reduce their herbicide dose. Herbicide dose is sensitive to the herbicide subsidy.

Exercise No. 15 - combining Economic and Statistical Analysis - $2^4$ Factorial

Factor A: (Significant, and with a significant interaction with factor B).

| | TREATMENT | | | |
|---|---|---|---|---|
| VARIABLE | A0 B0 | A1 B0 | A0 B1 | A1 B1 |
| Average yield[1/] (kg/ha) | 2210 | 3360 | 2045 | 3688 |
| Adjusted yield (kg/ha) | 1768 | 2688 | 1636 | 2950 |
| Gross benefits ($/ha) | 389 | 591 | 360 | 649 |
| N cost ($/ha) | 0 | 178 | 0 | 178 |
| P cost ($/ha) | 0 | 0 | 162 | 162 |
| Application ($/ha) | 0 | 6 | 6 | 6 |
| TCV ($/ha) | 0 | 184 | 168 | 246 |
| Net Benefits ($/ha) | 389 | 407 | 192 | 303 |

1/ The average yield for each noted combination (A0 B0 etc.) is found by averaging the four of sixteen individual treatment yield containing that combination.

Dominated treatments: A0 B1, A1 B1

Marginal Analysis: MRR for A0 B0 → A1 B0 = 10%

Recommendation: A0 B0

Factor B: (interacts with factor A, included with factor A)

Factor C: (Not significant, no significant interaction, so recommend the least cost level, C0)

Factor D: (Not significant, no significant interaction, so recommend the least cost level: D0)

Recommendation: A0 B0 C0 D0

Exercise No. 16 - Partial Budgets for Planning Experiments

$$\text{Field price of N} = \frac{\$\ 7.00 + \$\ 3.00}{.46} = \$\ 21.74/\text{kg}$$

| | | | |
|---|---|---|---|
| TCV Increment | = | \$ 21.74/kg | N field price |
| | | x 150 kg/ha | N dose |
| | | \$ 3261/ha | N cost/ha |
| | + | 100/ha | N application/ha |
| | | \$ 3361 | Increment TCV |

Field price of maize = \$ 1.80/kg

$$\Delta Y = \text{minimum yield increase required to pay costs} = \frac{3361 \times 1.6}{1.8} = 2988 \text{ kg/ha}$$

Almost a three ton yield increase is needed to pay treatment costs, but the treatment is only expected to give a one ton increase. This treatment should be re-considered.