

IRG 65

Partial budget analysis
for on-farm research

1 What is a partial budget?

Improvement in agricultural production technology is necessary for agricultural development. Agricultural scientists develop new production technologies to improve farmers' welfare. Farmers adopt new production technology that is economically superior to the existing one(s). Agricultural researchers should demonstrate, with little or no assistance from agricultural economists, the economic advantage of a proposed production technology over the existing methods.

Before changing from one production method to another, the farmer considers many factors, such as agroecological requirements, availability of required additional production resources (labor, credit, skill, farmland, equipment etc.), additional costs, and additional income resulting from the change. The farmer also considers the compatibility of the new technology with sociocultural circumstances, goals, and the whole farming system. Farmers want to know the implication of the proposed technological change on costs and income. Will the extra income earned by changing to the new technology justify the extra cost?

One of the tools in economics used to compare the economic benefits of technologies is partial budget analysis. A budget is a farm management method that is intended to assist researchers, extensionists, and farmers in the decision-making process. It is a tool that aims at quantifying and comparing the effects of a proposed technology on crop production to those of other alternative technologies. Results from partial budget analysis assist agricultural scientists in identifying

weakness(es) (high cost and/or low income) of the technology being developed. Partial budget analysis aids scientists and extension agents in deciding which technology to recommend to farmers. Partial budget analysis shows the level of profitability of and helps to decide whether to adopt a new technology or not. Budgeting forces management to think ahead, and aids sound decision making.

Partial budget analysis can apply to all crops and cropping systems. For this research guide, reference will be made specifically to on-farm maize research.

2 *Farm budgeting and types of budget*

A farmer makes plans before starting production. For example, in crop production, the farmer decides on the crop types (such as maize, yam, beans, etc.) and resources to put into production (such as farmland, seed, fertilizer, labor for farm operations, etc.). The result of crop production is the output, while the resources are the production inputs.

Production inputs and output are measured in different units—hectares, person-days, kilograms, liters, and so on. Aggregation of the components is possible by using a common unit of measurement. The unit of measurement is usually monetary (currency unit). Thus, the values (quality and quantity) of inputs and output are expressed in monetary terms in a budget. The monetary symbol used in this guide is the Naira ().

A budget is a formal quantitative expression of plans on production inputs and output. Budgets indicate the type, quality, and quantity of production resources or inputs

needed, and the type, quality, and quantity of output or product obtained. Three types of budgets are used in agriculture:

- ▶ whole-farm budget
- ▶ enterprise budget
- ▶ partial budget

Whole-farm budget. A whole-farm budget is a quantitative expression of the total farm plan summarizing the income, costs, and profit (Table 1). Income is what a farmer realizes from farming activities, costs are what the farmer puts into production, and profit is the difference between income and costs. In a whole-farm budget, the unit of analysis is the entire farm. A whole-farm budget may consist of several enterprises.

Enterprise budget. An enterprise is a single crop or livestock type produced on a farm. An enterprise budget lists all income and costs of a specific enterprise to provide an estimate of its profits.

Each enterprise budget is developed on a single common unit, such as hectares for crops or head for livestock. An enterprise budget allows comparison of profits or profitability among different enterprises on the same farm. Enterprise budgets, like whole-farm budgets, are in three parts: income, costs, and profit. Tables 2 and 3 are examples of two types of enterprise budget. Table 2 presents different levels of the same single technology, while Table 3 is an example of changing from one technology to another.

An enterprise budget is different from a whole-farm budget in:

- ▶ the number of enterprises considered (only one in an enterprise budget; in a whole-farm budget, all enterprises in the farm are included)
- ▶ the size of enterprises (a single unit for an enterprise budget, the entire farm for a whole-farm budget)

Partial budget. A partial budget shows the effect of change(s) in farm operations. For example, farmers know that fertilizer application will likely increase maize yield, and thus the gross income. The use of fertilizer also results in additional costs. To decide whether to use fertilizer for maize production or not requires a partial budget analysis. A partial budget could be prepared to ascertain the effect on net benefit of:

- ▶ substituting one enterprise for another without any change in the entire farmland area, for example, substituting 1 ha of soybean for 1 ha of maize
- ▶ changing to different levels of a single technology, for example, estimating the effect on net benefit of changing from one level of N-fertilizer application to another in maize production
- ▶ changing to different technology(ies), for example, changing from hand weeding to herbicide use for weed control

Developing a partial budget for on-farm maize research involves collecting, organizing, and analyzing experimental data in order to quantify the income, costs, and benefits of various alternative maize technologies.

A partial budget, like an enterprise budget, is based on a unit (for example, a 1 ha maize farm) but it is different from an enterprise budget in the type of costs used. An

enterprise budget uses total costs (variable input costs plus fixed input costs) while only variable input costs are used in a partial budget. In a partial budget, income is the gross farm gate benefit. The net benefit is the difference between the gross farm gate benefit and total variable input costs (see section 3 for details on concepts). Results in Tables 4 and 5 are examples of partial budgets. Table 4 concerns different levels of the same single technology while Table 5 concerns different technologies.

The objective of a partial budget in maize production is to recommend technologies that are agronomically different, are economically superior, and are socially acceptable to farmers.

3 *Concepts in partial budget analysis*

An agricultural scientist needs to be aware of common concepts to conduct a sound partial budget analysis. Examples illustrating the concepts are given in sections 5 and 6.

Recommendation domain. A recommendation domain is a group of farmers in similar circumstances to which the same recommendation(s) could be given for better farming practices. Similar circumstances can be a combination of biophysical, economic, and sociocultural conditions. An example of a recommendation domain is a group of farmers not using N-fertilizer in maize production.

Experimental variable. The experimental variable is the characteristic under study. The researcher is interested in how yield responds to change in the quantity of this variable. For example, in an N-fertilizer experiment, the

Table 1. A whole-farm budget showing projected income, input costs, and profit.

	Amount (naira)
Income	
1 Maize	56,000
2 Cassava	48,000
3 Beans	13,600
4 Yam	32,000
5 Poultry	40,000
6 Total income ($\Sigma 1...5$)	189,600
Variable input costs	
7 Fertilizers	12,900
8 Seeds and cuttings	3,000
9 Chemicals	8,900
10 Fuel, oil, and grease	4,000
11 Machinery repairs	3,650
12 Feed	2,600
13 Point-of-lay chickens	35,000
14 Labor	4,100
15 Custom machine hire	9,350
16 Miscellaneous	3,560
17 Total variable input cost ($\Sigma 7...16$)	87,060
18 Income above variable input cost (6 – 17)	102,540
Fixed costs	
19 Land charge	2,000
20 Insurance	4,850
21 Interest on loans	24,000
22 Machinery depreciation	9,200
23 Building depreciation	3,600
24 Total fixed costs ($\Sigma 19...23$)	43,650
Total costs	
25 Total input costs (17 + 24)	130,710
Profit	
26 Profit (6 – 25)	58,890

Table 2. An enterprise budget for the production of an improved open-pollinated maize variety at different N-fertilizer application levels.

		N-fertilizer level (kg N/ha)		
		0 (Treatment 1)	100 (Treatment 2)	200 (Treatment 3)
Gross income				
1	Average yield (kg/ha)	2,592	3,983	4,331
2	Adjusted yield (kg/ha) (1 x 0.9)	2,333	3,585	3,898
3	Price (Naira/kg)	1.25	1.25	1.25
4	Sale revenue (Naira) (2 x 3)	2916	4481	4872
Input costs (Naira/ha)				
5	Land preparation	350	350	350
6	Planting			
	– Materials (maize seed and seed dressing)	40	40	40
	– Labor	20	20	20
7	Weed control (herbicides and application costs)	400	400	400
8	Thinning	25	25	25
9	N-fertilizer	0	150	300
10	Other fertilizers	135	135	135
11	Miscellaneous	200	200	200
12	Harvesting (labor)	70	85	90
13	Shelling	30	32	35
14	Drying	60	64	67
15	Cost of capital (invest 3% monthly)	211	237	261
16	Depreciation costs (₦/ha)	75	75	75
17	Total variable input costs (₦/ha)(Σ5...15)	1,541	1,738	1,923
18	Total fixed costs (₦/ha) (16)	75	75	75
19	Total input costs (₦/ha) (17 + 18)	1,616	1,813	1,998
Net profit				
20	Net profit (₦/ha) (4 – 19)	1,300	2,668	2,871

Table 3. An enterprise budget for maize production under different weed control methods.

		Weed control method			
		No weeding	Hand weeding	Boom spraying	Knapsack spraying
Gross farm gate benefits					
1	Average yield (kg/ha)	1,266	3,986	3,797	2,833
2	Adjusted yield (kg/ha) (1 x 0.9)	1,139	3,587	3,417	2,550
3	Gross farm gate benefits (₦/ha) (2 x 0.75)	854	2,690	2,563	1,913
Costs (Naira/ha)					
4	Land preparation	300	300	300	300
5	Planting				
	– Material (maize seed)	25	25	25	25
	– Labor	30	30	30	30
6	Thinning – Labor	15	15	15	15
7	Fertilizer – Material	120	120	120	120
	– Labor	30	30	30	30
8	Land (rent)	75	75	75	75
9	Drying	50	50	50	50
10	Miscellaneous	100	100	100	100
11	Weed control				
	– Labor	0	360	10	60
	– Machinery	0	0	50	25
	– Herbicides	0	0	160	160
12	Harvesting	42	70	70	70
13	Shelling	20	30	30	25
14	Cost of capital*	80	120	100	100
15	Total costs (Σ4...14)	887	1,325	1,165	1,180
Net profit**					
16	Net profit (₦/ha) (3 – 15)	(33)	1,365	1,398	733

* Loans were needed for a period of 6 months only, as the business gestation period is a maximum of 6 months

** Numbers in parentheses indicate a loss

Table 4. A partial budget for production of an improved open-pollinated maize variety at different N-fertilizer levels.

		N-fertilizer level (kg N/ha)		
		0	100	200
Gross farm gate benefits				
1	Average yield (kg/ha)	2,592	3,983	4,331
2	Adjusted yield (kg/ha) (1 x 0.9)	2,333	3,585	3,898
3	Price (₦/ha)	1.25	1.25	1.25
4	Gross farm gate benefits (₦/ha) (2 x 3)	2,916	4,481	4,872
Variable input costs (₦/ha)				
5	Fertilizer – Material	0	130	260
	– Labor	0	20	40
6	Harvesting	70	85	90
7	Shelling	30	32	35
8	Drying	60	64	67
9	Total variable input costs (₦/ha) (Σ5...8)	160	331	492
Net benefit				
10	Net benefit (₦/ha) (4 – 9)	2,756	4,150	4,380
11	Change in net benefits between two consecutive treatments* (₦/ha)		1,394	230
12	Change in total variable input costs between two consecutive treatments ** (₦/ha)		171	161
Marginal rate of return				
13	Marginal rate of return (11/12)		8.15	1.43

* Change in net benefits between Treatments 2 and 1 is $4,150 - 2,756 = 1,394$
Change in net benefits between Treatments 3 and 2 is $4,380 - 4,150 = 230$

** Change in total variable input costs between Treatments 2 and 1 is $331 - 160 = 171$
Change in total variable input costs between Treatments 3 and 2 is $492 - 331 = 161$

Table 5. A partial budget for maize production under different weed control methods.

		Weed control method			
		No weeding	Hand weeding	Boom spraying	Knapsack spraying
Gross farm gate benefits					
1	Average yield (kg/ha)	1,266	3,986	3,797	2,833
2	Adjusted yield (kg/ha) (1 x 0.9)	1,139	3,587	3,417	2,550
3	Farm gate price (₦/ha)	0.75	0.75	0.75	0.75
4	Gross farm gate benefits (kg/ha) (2 x 3)	854	2,690	2,563	1,913
Variable input costs (₦/ha)					
5	Weed control				
	– Labor	0	360	10	60
	– Machinery	0	0	50	25
	– Herbicides	0	0	160	160
6	Harvesting	42	70	70	70
7	Shelling	20	30	30	25
8	Total variable input costs (₦/ha) (Σ5...7)	62	460	320	340
Net benefit					
9	Net benefit (₦/ha) (4 – 8)	792	2,230	2,243	1,573
10	Changes in net benefits from Treatment 1 to Treatment 2, 3, or 4* (₦/ha)		1,438	1,451	781
11	Change in total variable input costs from Treatment 1 to Treatment 2, 3 or 4* (₦/ha)		398	258	278
Marginal rate of return					
12	Marginal rate (%) of return (100 x 10/11)		361	562	281

* Calculated as in Table 4 (Treatment 1 is compared to each of the 3 other treatments).

experimental variable is nitrogen. The quantity of nitrogen fertilizer varies while the quantities of other inputs (nonexperimental variables) are constant.

Production. Production is the conversion or transformation of input(s) to output. Maize crop production is the transformation of land, maize seed, labor, herbicide, management and so on, to maize output.

Production function. The production function gives the technical relationships between input(s) (that is, experimental variables) and output(s). The function is continuous if the experimental variables can take any value within a given range. The function is discrete if only certain values of the experimental variables input(s) are used. The discrete type is used in budgeting because only certain quantities of input(s) and the corresponding quantities of output(s) are considered. For example, in an N-fertilizer experiment with maize, only certain levels of N-fertilizer (0, 100, and 200 kg N/ha) and the corresponding quantities of maize output are used in budgeting (Table 4).

Output/product. This is the item being produced. For example, maize grain and maize stover are the output of maize farms; mutton and wool are the output of sheep farms; and meat and milk are the output of dairy farms.

Inputs. Inputs are resources used to produce output. Inputs used in the production of maize are land, maize seed, herbicides, labor, planters, shellers, dryers, the farmer's time and skill, and so on. The resources can be classified into land, labor, capital, and management.

Resources could also be grouped into:

- ▶ fixed inputs
- ▶ variable inputs

Fixed inputs. Inputs that do not change in quantity with change in the level of production are called fixed inputs. The quantity of fixed input used remains constant regardless of the quantity of output and the quantities of other categories of inputs. In maize production, the quantity of any of the inputs used could be held constant. In partial budget analysis for on-farm experiment, land can be cropped for more than one cycle of production, thus making land a fixed input.

Variable inputs. Variable inputs are used once to produce outputs. The quantity of variable inputs varies with the quantity of output, or treatments, or technologies. Examples for maize production are seed and inorganic fertilizer.

Price. Price is the value of resources that is exchanged to obtain the use of some other things. It is expressed in monetary terms per unit, for example, per kilogram of maize seed, per liter of herbicide, per person-day of labor, and per kilogram of maize output. As a result of the market form of most agricultural inputs and outputs, it is assumed that individual farmers cannot influence the market price of input and output.

The price of each unit of input and each unit of output is constant, regardless of the quantity of input purchased and the quantity of output sold by the farmer. Thus, in a partial budget, the same price per unit of input and the same price per unit of output is used for all treatments and technology levels.

Price of purchased input. The price of purchased input is the market price of a commodity. For example, ₦27 is the market price for one bag of N-fertilizer.

Price of owned input. Owned inputs are personal possessions of the farmer which he or she does not have to buy. Examples of such inputs in maize production are inherited maize farmland and family labor. The price of such inputs is determined using the concept of opportunity cost.

Opportunity cost. The value of a forgone alternative or the price of the input in its best alternative use is the opportunity cost. For example, if a maize farmer spends 5 days weeding his/her 1 ha maize farm, the cost of labor is not zero although there is no outflow of cash (the farmer does not pay himself/herself). If the farmer earns 100/day in an alternative job, the cost of weeding is 500/ha (100/day x 5 days/ha), since the farmer could earn that much in the alternative job.

Farm gate price (of an input). In some cases, farms are far from markets. While getting inputs to farms, additional expenses (such as transportation cost) must be added to the market price of the input. Farm gate price is the price of an input at the farm gate. For example, the market price of a bag of N-fertilizer is ₦27, and transportation cost from the market to the farm gate is ₦3 per bag. The farm gate price of N-fertilizer is therefore ₦30 (27 + 3).

Farm gate cost (of an input). The farm gate cost of an input is the product of its farm gate price and the quantity of the input required for a given area.

Total variable input costs. The total variable input cost is the sum of all variable input costs and varies from one

treatment to another. These are farm gate costs of the variable inputs for each of the treatments. If N-fertilizer is the only variable input, its cost will vary with N-fertilizer levels used (Table 6).

Table 6. Variable input cost (VIC) by treatment.

		Treatment		
		1	2	3
1	N-fertilizer (bag/ha)	0	6	12
2	Price (₦/bag)	30	30	30
3	VIC (₦/ha) (1 x 2)	0	180	360

If more than one variable input is used, the total variable input cost is the sum of the variable input costs for each treatment which varies with the N-fertilizer level (Table 7).

Table 7. Total variable input costs (TVIC) by treatment.

Variable inputs	Treatment		
	1	2	3
Nitrogen fertilizer (₦/ha)	0	180	360
Harvesting (labor) (₦/ha)	60	75	90
Shelling (₦/ha)	20	30	40
Drying (₦/ha)	10	15	20
TVIC (₦/ha)	90	300	510

Fixed input cost. The cost of the fixed resources is the fixed input cost. Since the quantity of a fixed resource does not change from one treatment to another, the fixed input cost remains constant regardless of the level of input, treatment, or technology. Therefore, the fixed input cost is not relevant in partial budget preparation and analysis. It should however be included in any enterprise budget analysis.

Yield. The yield is the quantity of output (such as maize or milk) produced per unit area. Yield is usually expressed in kg/ha. For example, maize yield of an improved variety in an on-farm experiment can be 3000 kg/ha.

Adjusted yield. The adjusted yield is the experimental yield scaled down by a given proportion to approximate the yield that farmers can obtain on their farms. The scaling down is necessary to prevent overestimation of the returns that farmers are likely to obtain from a treatment. Experimental yields are higher than farmers' yields because of higher management level (recommended number of stands, timely planting, timely weeding, timely application of fertilizer, timely application and recommended doses of chemicals, and so on), smaller plot size, precision in harvesting date, and better harvesting methods. The difference between yields from experimental fields and those from farmers' fields in similar cropping conditions will be the basis for the scaling down. For example, it may be necessary to scale down by 10% an experimental yield of 3000 kg/ha of maize.

$$\begin{aligned} \text{Yield (kg/ha)} &= 3000 \\ \text{Adjusted yield (kg/ha)} &= 90/100 \times 3000 \\ &= 2700 \end{aligned}$$

Scaling down may not be necessary in an on-farm experiment where the experimental design is very close to the farmers' practice.

Farm gate price of the output. Distances between farms and markets account for the difference between the farm gate price and the market price of the output. The farm gate price of the output is the value (price) farmers

receive or can receive for their harvested crops. By this definition, it is the price farmers receive at the end of the production process.

Marketing agents (middlemen or middlewomen) responsible for getting the commodity to the market incur marketing costs. For example, the farm gate price of maize is the market price of maize less the marketing cost (usually transportation cost). Alternatively, the farm gate price of the output is the price the marketing agents pay for the output at the farm gate.

For example, the market price of maize is ₦1.75/kg and the marketing cost from the farm to the market is 0.25 ₦/kg. The farm gate price of maize is:

	Naira/kg
Market price of maize	1.75
Marketing cost of maize	- 0.25
Farm gate price	1.50 ₦/Kg

Gross farm gate benefit. The gross farm gate benefit is the product of the farm gate price of the output and the adjusted yield. If the farm gate price of maize is ₦1.50/kg and the adjusted yield is 2700 kg/ha, the gross farm gate benefit will be:

$$1.50 \text{ ₦/kg} \times 2700 \text{ kg/ha} = 4050 \text{ ₦/ha}$$

Net benefit. The net benefit is the difference between the gross farm gate benefit and the total variable input cost. If the gross farm gate benefit is ₦4050/ha and the total variable input cost is ₦300/ha, the net benefit is

$$\text{₦}4050 - 300 = \text{₦}3750/\text{ha}$$

Dominance analysis. The process of eliminating dominated treatments from further analysis is called dominance analysis. A dominated treatment has the same or lower net benefit than other treatments of a lower total variable input cost. In a dominated treatment, a higher total variable input cost is incurred to earn the same or less net benefit when compared with other treatments. For example, in Table 8, Treatment 3 is dominated by Treatment 2. Treatment 3 should be eliminated at this stage from further analysis.

Table 8. Dominance analysis on four treatments.

	Treatment			
	1	2	3	4
Total variable input cost (₦/ha)	200	300	415	510
Net benefit (₦/ha)	2150	3750	3120	4190

Marginal analysis. Marginal analysis determines the effect of a change in farming activities. In an on-farm maize experiment, marginal analysis shows the economic effect of changing from one treatment to another. It involves calculation of marginal rates of return between treatments.

Marginal rate of return. The marginal rate of return (MRR) is a ratio of the change in net benefits to change in total variable input costs between treatments (see examples in Sections 5 and 6).

Net benefit curve. The net benefit curve shows the relationship between net benefits and total variable input costs. The MRR is estimated from the slope of the curve (see Sections 5 and 6). The steeper the slope, the higher the MRR.

Acceptable minimum rate of return. The minimum return which farmers expect to earn from an enterprise or technology is the acceptable minimum rate of return (AMRR). Returns below this minimum makes the enterprise or technology a failure. AMRR is the sum of return to management and cost of capital (see examples in Sections 5 and 6).

Return to management. The return to management is the benefit which the maize farmer expects for managing a maize farm. In a new technology, it is the benefit which the farmer expects to receive for the time and effort spent in learning and using the new technology.

Cost of capital. This is the benefit forgone for tying up the working capital in one enterprise rather than in another enterprise. In the case of money, it is interest, or rent if the resources are land and equipment. The opportunity cost concept is used if owned inputs are used in production. In areas where the formal credit system is weak and the informal credit system is very active, the opportunity cost of capital should use the high interest rates that are usually applied by moneylenders.

Working capital. The working capital is the value of resources (purchased or owned) used in production with the expectation of returns in future. In maize production, the working capital is the value of land, labor, and capital.

Acceptable minimum return. This is the product of the AMRR and the total variable input cost of each treatment. For the farmer to change to a new technology, it is the least acceptable minimum returns required (see examples in Sections 5 and 6).

Residuals. The difference between the net benefit and the acceptable minimum return gives the residuals of each treatment. Residual analysis is used as a decision criterion to recommend a treatment with the highest residual (see examples in Sections 5 and 6).

Decision criterion. The decision criterion is the guideline for making a recommendation. For example, if the marginal rate of return is equal to or greater than the acceptable minimum rate of return, changing from non-use to the use of fertilizer in maize production is recommended. In this example, an equal or a higher marginal rate of return above the acceptable minimum rate of return is a decision criterion.

The general format and formulae for partial budget analysis in Appendix 1 could be used to calculate key parameters described in this section and obtain results such as those in Tables 4 and 5.

4 Steps in partial budget analysis

Partial budget analysis goes through many steps before reaching a decision criterion. The stages in the preparation and analysis of partial budgets for on-farm maize research are shown in Figure 1. Examples illustrating the stages are given in Sections 5 and 6.

5 Example 1: Varying levels of a single technology

Before adopting a new technology, farmers want to know if the benefits to be derived from the technology justify the cost.

For example, use of N-fertilizer in maize production is the innovation. The use of an input (N-fertilizer) involves some

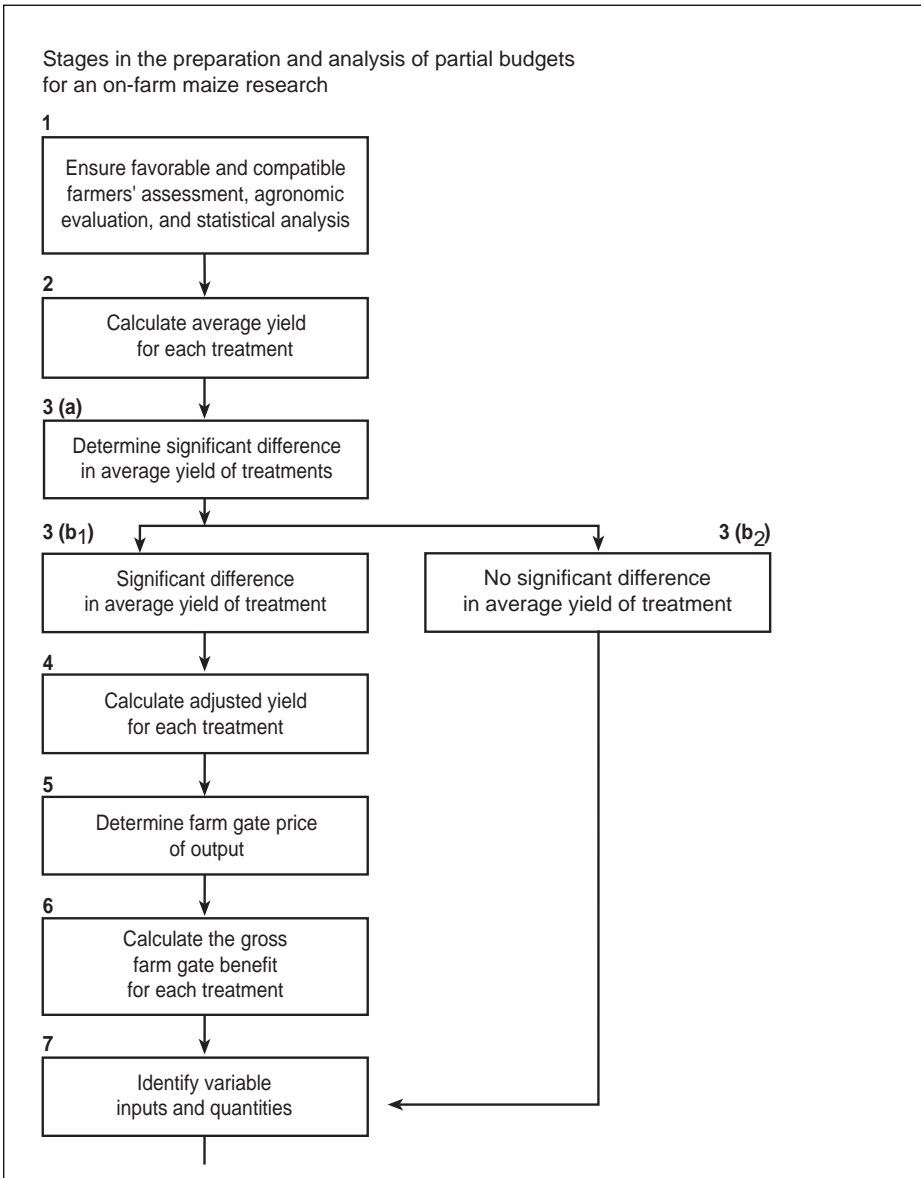
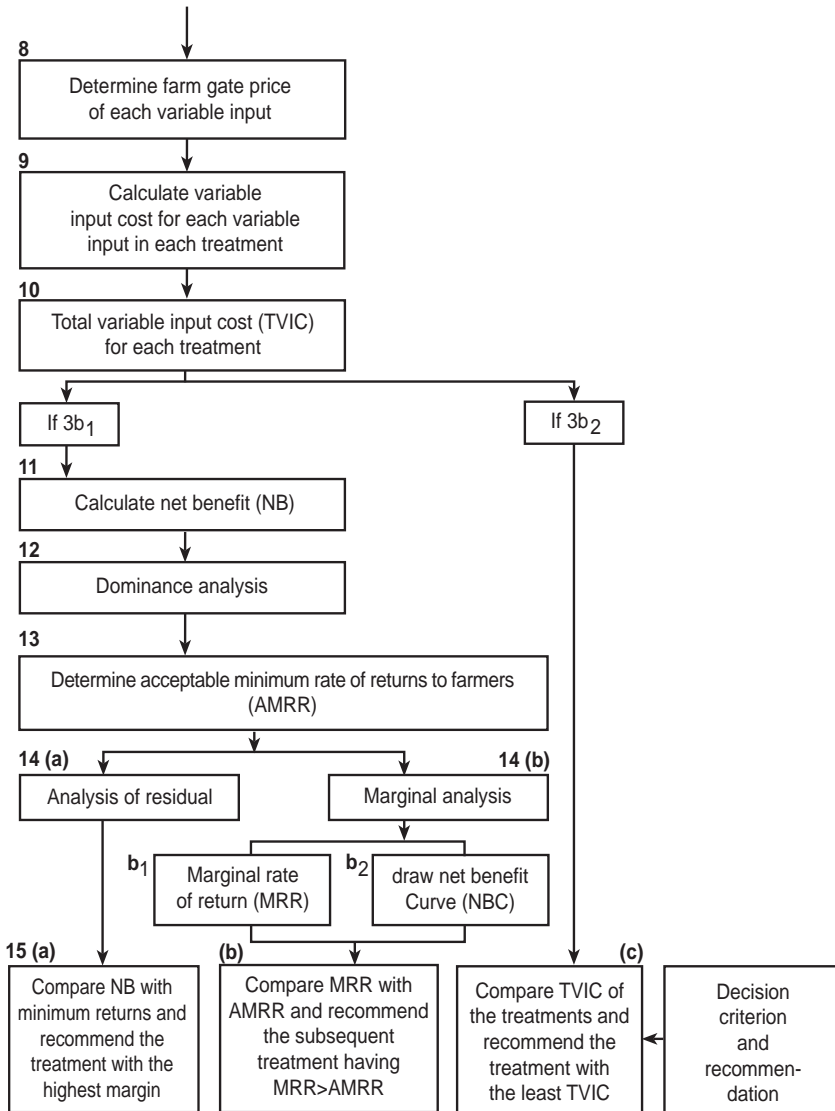


Figure 1



expenses (cost of N-fertilizer, transportation, labor for application, capital, and so on). Before deciding whether or not to change to the use of N-fertilizer, farmers want to know:

- ▶ if the use of N-fertilizer will increase the net benefits of maize production
- ▶ if so, by how much
- ▶ what quantity of N-fertilizer to use

An on-farm maize experiment with three treatments was set up to determine whether application of N-fertilizer will increase maize yield, and the level of N-fertilizer which brings the highest profits. The first treatment used no fertilizer, the second used 100 kg/ha, and the third 200 kg/ha.

The financial analysis of the result of the experiment is presented in Table 2 as an enterprise budget. The information in the enterprise budget will be used in preparing the partial budget according to the steps in Figure 1. Partial budget analysis will be along the three scenarios based on the relationships of the average yields (from 5 replications) of treatments. The three scenarios are:

- ▶ significant difference in average yields of all treatments (Scenario A)
- ▶ no significant difference in average yields of the treatments (Scenario B)
- ▶ no significant difference in the average yields of some of the treatments (Scenario C)

Scenario A. Significant difference in average yields of all treatments

For this scenario, all the steps indicated in Figure 1 must apply for the partial budget analysis.

Steps Activities and results

Step 1: The use and application of N-fertilizer is socially acceptable to farmers and compatible with the farming systems in the research locations. The agronomic evaluation and statistical analysis of the experimental data indicate a positive response to N-fertilizer for maize production. The next step is the economic evaluation using partial budget analysis.

Step 2: Average yield (maize)

The average yield for Treatments 1, 2, and 3 is 2592, 3983 and 4331 kg/ha, respectively (Table 4).

Step 3a: Mean yield difference

There is a significant difference in the average yield of treatments. Therefore go to Step 3b₁.

Step 3b₁: Significant differences in average yield of treatments

Step 4: Adjusted yield (maize)

Let us assume that farmers can only achieve 90% of the yield obtained in experimental fields. Therefore, reduce average yields by 10%. Adjusted yields for the treatments are:

		Treatment		
		1	2	3
1	Average yield (kg/ha)	2,592	3,983	4,331
2	Adjusted yield (kg/ha) (1 x 90/100)	2,333	3,585	3,898

Step 5: Farm gate price of maize output

The market price of maize output is ₦1.50/kg and the marketing cost (transport, bagging etc.) is estimated at

₦0.25/kg. Thus, the farm gate price of maize output is:

	₦/kg
Market price	1.50
Market cost	- 0.25
Farm gate price	1.25

Step 6: Gross farm gate benefits

Multiply the gross farm gate price of each treatment by the adjusted maize yield of each treatment to obtain the gross farm gate benefit:

		Treatment		
		1	2	3
1	Adjusted yield (kg/ha)	2,333	3,585	3,898
2	Gross farm gate benefits (₦/ha) (1 x 1.25)	2,916	4,481	4,872

Step 7: Variable inputs

The variable inputs in this experiment are N-fertilizer, labor for N application and harvesting, and machine hours for shelling and drying. The quantities of each input are:

		Treatment		
		1	2	3
N-fertilizer				
—	Material (kg/ha)	0	100	200
—	Application (person-days)	0	1	2
	Harvesting (person-days)	3.5	4.25	4.50
	Shelling (machine-hours)	1	1.07	1.15
	Drying (machine-hours)	2	2.13	2.23

Step 8: Farm gate price of variable input

The farm gate price of fertilizer is its market price plus transportation cost. If the market price of N-fertilizer is ₦1.20/kg, and the transportation cost is ₦0.10/kg, the farm gate price of N-fertilizer will be:

	₦/kg
Market price	1.20
Transportation cost	0.10
Farm gate price	1.30

The farm gate price of labor for N-fertilizer application is ₦20/person-day. The farm gate price of labor for harvesting is ₦20/person-day. The price of shelling and drying is ₦30/machine-hour.

Step 9: Variable input cost

The variable input cost for each treatment is the product of the farm gate price for the variable input (Step 8) and the quantity of the same variable input for each treatment (Step 7):

	Treatment		
	1	2	3
N-fertilizer			
— Material (₦/ha)	0	130	260
— Labor for application (₦/ha)	0	20	40
Harvesting (₦/ha)	70	85	90
Shelling (₦/ha)	30	32	35
Drying (₦/ha)	60	64	67

Step 10: Total variable input cost

The total variable input cost is the sum of all variable input costs. The total variable input cost for each treatment is:

	Treatment		
	1	2	3
N-fertilizer			
— Material (₦/ha)	0	130	260
— Labor for application (₦/ha)	0	20	40
Harvesting (₦/ha)	70	85	90
Shelling (₦/ha)	30	32	35
Drying (₦/ha)	60	64	67
Total variable input cost	160	331	492

Step 11: Net benefit

The difference between gross farm gate benefits and the total variable input cost of N-fertilizer application in each treatment is the net benefit:

	Treatment		
	1	2	3
Gross farm gate benefit (₦/ha)	2,916	4,481	4,872
Total variable input cost (₦/ha)	160	331	492
Net benefit (₦/ha)	2,756	4,150	4,380

Step 12: Dominance analysis

Treatments are arranged in ascending order of the amount of total variable input costs and their corresponding net benefits. In this example, the arrangement in Step 11 stays. There is no dominated treatment as increasing total variable input costs correlate with increasing net benefits.

Step 13: Farmers' acceptable minimum rate of return

Farmers' AMRR is the sum of the cost of capital and returns to management. Most maize farmers have no access to formal loans which attract lower interest. However, in rural areas, opportunities for informal loans exist.

Assume that the interest rate of informal loans in the area of the experiments varies from 3 to 10% per month, and the gestation period of maize enterprise (that is, the period between farm land preparation and realization of income from maize output) is 6 months. If the interest rate is 3%, the cost of capital is 18% (3%/month x 6 months), and it is 60% (10%/month x 6 months) if the interest rate is 10%. Assume that the majority of farmers in the study area consider that a business is profitable only when it gives 100% returns to management. The AMRR will be

118% (100 + 18) for 3% and 160% (100 + 60) for 10% interest rate per month. Assume that a significant proportion of farmers obtain loans at 10%; then the AMRR of 160% is retained for further analysis.

From Step 13, move either to Step 14(a) (analysis of residuals) or Step 14(b) (marginal analysis). Consider the analysis of residuals first.

Step 14a: Analysis using residuals

The maize farmers' AMRR of 160% is multiplied by the total variable input costs of each treatment to obtain the acceptable minimum returns of treatment. The difference between the net benefit and the acceptable minimum returns of each treatment gives the residual of each treatment:

	Treatment		
	1	2	3
1 Net benefit (₦/ha)	2,756	4,150	4,380
2 Total variable input cost (₦/ha)	160	331	492
3 Acceptable minimum return (₦/ha) (2 x 160/100)	256	529	787
4 Residuals (₦/ha) (1-3)	2,500	3,620	3,593

Step 15a: Decision criterion and recommendation: analysis using residuals

The residual margin of each treatment is indicated below. According to this criterion the treatment with the highest residual (Treatment 2) is chosen and recommended.

	Treatment		
	1	2	3
Net benefit (₦/ha)	2,756	4,150	4,380
Total variable input costs (₦/ha)	160	331	492
AMRR (%)	160	160	160
Acceptable minimum return (₦/ha)	256	529	787
Residuals (₦/ha)	2,500	3,600	3,593

Step 14b₁: Marginal analysis: marginal rate of returns by arithmetic process

The marginal rate of returns of changing from one treatment to another in the N-fertilizer experiment is:

	Treatment		
	1	2	3
Net benefit (₦/ha)	2,756	4,150	4,380
Change in net benefit (₦/ha)		1394	230
Total variable input cost (₦/ha)	160	331	492
Change in total variable input cost (₦/ha)		171	161
Marginal rate of return (%)		815	143

For example, the marginal rate of returns of changing from Treatment 1 to Treatment 2 is:

$$\frac{4150 - 2756}{331 - 160} = \frac{1394}{171} = 8.15 \text{ or } 815\%$$

A farmer's investment of ₦1 in 100 kg/ha N-fertilizer on maize recoups the ₦1 and gives an additional ₦8.15.

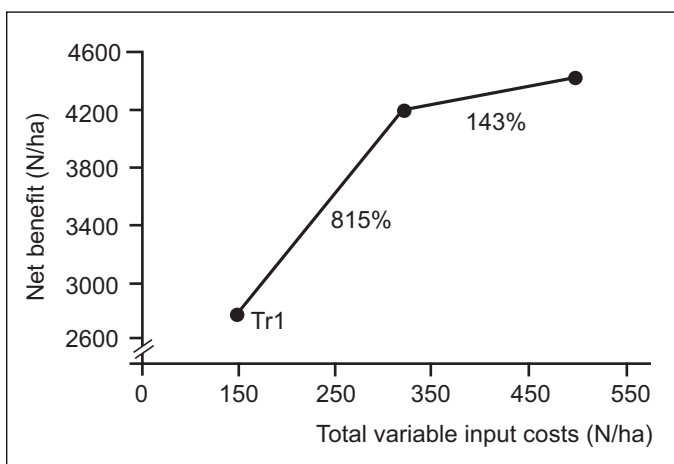


Figure 2. Net benefit curve for the N-fertilizer experiment: Scenario A. Tr = Treatment

Step 14b₂: Marginal analysis: net benefit curve (Figure 2)

The slope (gradient) between two consecutive treatments is the difference between the two consecutive net benefits divided by the difference between the total variable input costs of the two consecutive treatments. For example, the slope between Treatments 1 and 2 is:

$$\frac{4150 - 2756}{331 - 160} = \frac{1394}{171} = 8.15 \text{ or } 815\%$$

The slope between Treatments 2 and 3 is 143% (work this out). The slope between Treatments 1 and 2 is greater than the AMRR of 160%, thus the change is worthwhile. The slope between Treatments 2 and 3 is smaller than the AMRR, therefore the change is not worthwhile. Treatment 2 is recommended.

Step 15b: Decision criterion and recommendation: analysis using marginal rate of return

A change from Treatment 1 to Treatment 2 gives a marginal rate of return of 815% which is higher than the acceptable minimum rate of return of 160%. Changing from Treatment 2 to Treatment 3 gives a marginal rate of return of 143% which is lower than the acceptable minimum rate of return of 160%, therefore, the change is not lucrative. Treatment 2 of 100 kg N/ha is recommended.

Changing from:	MRR (%)	AMRR(%)	
Treatment 1 to 2	815	> 160	Recommended
Treatment 2 to 3	143	< 160	Not recommended

The same recommendation of Treatment 2 is acceptable using the net benefit curve (Step 14b₂).

Scenario B. No significant difference in average yields of all treatments

Follow the procedure for partial budget analysis in Figure 1.

Steps Activities and results

Steps 1 & 2: Same as Scenario A

Step 3a: Mean yield difference

Statistical analysis shows no significant difference in the average yield of all the treatments. Therefore go to Step 3(b₂).

Step 3b₂: Since there is no difference in average yield of treatments, there will be no significant difference in gross farm gate benefits of treatments. Thus, proceed to Step 7.

Steps 7–10: Same as Scenario A. The total variable input costs of the treatments are obtained at the end of Step 10 Scenario A which is shown again as follows:

	Treatment		
	1	2	3
Total variable input costs (₹/ha)	160	331	492

Steps 11–14: Not relevant because all calculations involving net benefits and net benefit analyses are not needed. There is no significant difference in yield and no significant difference in net benefits of treatments.

Step 15c: Decision criterion and recommendation

For Scenario B, the treatment with the least total variable input cost is recommended in a situation of no differences in yields, gross farm gate benefits, or net benefits of treatments.

A comparison of the total variable input costs of treatments favors Treatment 1 (farmers' practice, that is, non-use of N-fertilizer) as it has the least total variable input cost.

Farmers should continue their practice as application of N-fertilizer does not increase yield, gross farm gate benefits, or net benefits.

Scenario C. No significant difference in the mean yields of some treatments.

Follow the procedure for partial budget analysis in Figure 1.

Steps Activities and results

Steps 1 &2: Same as Scenario A

Step 3(a): Mean yield difference

For example, statistical analysis shows no significant difference between the average yields of Treatments 2 and 3, but shows that Treatments 2 and 3 are significantly different from the average yields of Treatment 1

	Treatment		
	1	2	3
Average yield (kg/ha)	2,592 ^b	3,983 ^a	4,331 ^a

Figures with the same letter are not statistically different.

Follow Scenario B for the comparative analysis of Treatments 2 and 3 to select Treatment 2 which has a lower total variable input cost than Treatment 3:

	Treatment	
	2	3
Total variable input costs (₦/ha)	331	492

Then, compare Treatment 2 with Treatment 1.

Steps 3b₁-15 Follow Scenario A for the analysis of Treatments 1 and 2. Treatment 2 is recommended because the marginal rate of return of changing from Treatment 1 to Treatment 2 (815%) is higher than the farmers' acceptable minimum rate of return (160%).

Therefore, farmers should change from non-use of N-fertilizer to the use of N-fertilizer at 100 kg/ha (Treatment 2). Farmers should not use 200 kg N/ha (Treatment 3) because there is no significant difference in net benefits between Treatments 2 and 3, and there are higher expenses in Treatment 3.

6 Example 2: Different technologies

Example 2 examines the benefits of changing from one technology to another.

The different weed control technologies or methods examined here are

- ▶ Treatment 1: no weeding
- ▶ Treatment 2: hand weeding
- ▶ Treatment 3: herbicide, boom spraying
- ▶ Treatment 4: herbicide, knapsack spraying

The enterprise budget for the on-farm experiment is presented in Table 3. The main objective of the research is to show the profits involved using the different weeding methods. Partial budget analysis for changing from one weed control method to another is prepared from the information on that enterprise budget.

The result of the partial budget analysis is the net benefit of each weed control method (Table 5).

Follow the steps for partial budget analysis (Figure 1).

Steps Activities and results

Step 1: Agronomic evaluation and farmers' assessment

The agronomic evaluation and farmers' assessment of the different weed control methods are favorable. There is no

social sanction against the use of herbicide in the research area. Economic evaluation of each technology using partial budgeting is needed.

Step 2: Average maize yield

The average yield for each treatment is:

	Treatment			
	1	2	3	4
Average yield (kg/ha)	1,266	3,986	3,797	2,833

Step 3a: Mean yield difference

The average yields are assumed to be significantly different. This classifies it under Scenario A.

Step 3b₁: Significant differences in average yields of treatments

Step 4: Adjusted yield

The experimental yield of each treatment reduced by 10% gives the farmers’ obtainable yield.

	Treatment			
	1	2	3	4
Average yield (kg/ha)	1,266	3,986	3,797	2,833
Adjusted yield (kg/ha)	1,139	3,587	3,417	2,550

Step 5: Farm gate price of maize output

The market price of maize output is 1.00 ₦/kg and the marketing cost (transportation, etc.) is 0.25 ₦/kg. Therefore, the farm gate price of maize output is 0.75 ₦/kg (1.00 - 0.25).

Step 6: Gross farm gate benefits

The gross farm gate benefit of each treatment is the product of the farm gate price of output and the adjusted yield:

	Treatment			
	1	2	3	4
Adjusted yield (kg/ha)	1,139	3,587	3,417	2,550

Gross farm gate benefit (/ha) 854 2,690 2,563 1,913

Step 7: Type and quantity of variable inputs used

The variable inputs are labor, machinery, and herbicides.

	Treatment			
	1	2	3	4
Labor (person-days)				
– Hand weeding	0	6	0	0
– Machine operating	0	0	0.17	1
Knapsack sprayer rent (days)	0	0	0	1
Boom sprayer rent (ha)	0	0	1	0
Herbicide (Liters)	0	0	4	4
Harvesting (person-days)	2.1	3.5	3.5	3.5
Shelling (person-days)	1.0	1.50	1.50	1.25

Step 8: Farm gate price of variable inputs

- ▶ Herbicide ₦40/liter
- ▶ Labor for weeding and machine operators ₦60/person-day
- ▶ Rent of knapsack sprayer ₦25/day
- ▶ Rent of boom sprayer ₦50/ha
- ▶ Labor for shelling and harvesting ₦20/day

Step 9: Variable input costs

The variable input cost for each treatment is a product of the quantity of the variable input and the farm gate price.

	Treatment			
	1	2	3	4
Labor	0	360	10	60
Machinery	0	0	50	25
Herbicides	0	0	160	160
Harvesting	42	70	70	70
Shelling	20	30	30	25

Total (₦/ha)	62	460	320	340
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Step 10: Total variable input cost

This is the sum of variable input costs as shown above.

Step 11: Net benefits

Calculate the difference between the gross farm gate benefit and the total variable input cost. For the 4 treatments, the net benefits are:

	Treatment			
	1	2	3	4
Gross farm gate benefits (₦/ha)	854	2,690	2,562	1,912
Total variable input costs (₦/ha)	62	460	320	340
Net benefit (₦/ha)	792	2,230	2,243	1,573

Step 12: Dominance analysis

The treatments are arranged in ascending order of magnitude of the total variable input and corresponding net benefit.

	Treatment			
	1	3	4	2
Net benefit (₦/ha)	792	2,243	1,573	2,230
Total variable input costs (₦/ha)	62	320	340	460

Treatments 4 and 2 are dominated by Treatment 3.
Eliminate Treatments 4 and 2 from further consideration.

Step 13: Farmer’s acceptable minimum rate of return

The farmers’ acceptable minimum rate of return is the cost of capital plus the return to management. The cost of capital is 10% per month which amounts to 60% in 6 months. The return to management is assumed to be 100%. Therefore, farmers’ acceptable minimum rate of return is 160%.

Step 14a: Analysis using residuals

The farmers' acceptable minimum return in each treatment is the product of the total variable input cost of each treatment and the farmer's acceptable minimum rate of return (160%). The difference between the net benefit of each treatment and the farmer's acceptable minimum return gives the residual for each treatment.

Note: Treatments 4 and 2 were eliminated at Step 12 because they were dominated by the other two. However, for demonstration purposes, they are included at Step 14a to show additional evidence that they are not economically attractive at all, as shown by the results from the residuals analysis.

	Treatment			
	1	2	3	4
Net benefit (₦/ha)	792	2,230	2,243	1,573
Total variable input costs (₦/ha)	62	460	320	340
Acceptable minimum return (₦/ha)	99	736	512	544
Residual (₦/ha)	693	1,494	1,731	1,029

Step 15a: Decision criterion and recommendation: analysis using residual

The decision criterion is that the treatment with the highest residual is selected and recommended. Results from Step 14a show that Treatment 3 has the highest residual; it is recommended.

Step 14b₁: Marginal rate of return by the arithmetic process

The marginal rate of return of changing from no weeding to any of the other 3 control methods is given below. Treatments 4 and 2 have been eliminated from further analysis because they are dominated by Treatment 3 (Step 12). Analysis using the marginal rate of return will be on

Treatments 1 and 3 only. The marginal rate of return for changing from Treatment 1 to Treatment 3 is 5.62 or 562%.

	Treatment	
	1	3
Net benefit (₦/ha)	792	2,243
Change in net benefits (₦/ha)		1,451
Total variable input costs (₦/ha)	62	320
Change in total variable input cost (₦/ha)		258
Marginal rate of return (%)		562

Step 14b₂: Marginal analysis by graphical process

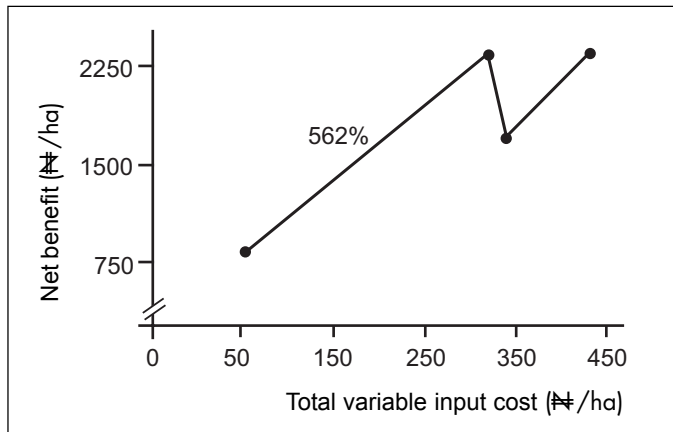


Figure 3. Net benefit curve for weed control methods: Scenario B.

Figure 3 is a net benefit curve for the weed control experiment. For each treatment the net benefit and the total variable input costs are plotted. The dominated treatments are not connected: Treatment 3 is recommended because the slope between Treatments 1 and 3 (562%) is greater than the acceptable minimum rate of return (160%).

**Step 15b: Decision criterion and recommendation:
analysis using marginal rate of return**

Treatment 3 (boom spraying) is recommended because the rate of return (562%) is greater than the acceptable minimum rate of return (160%). The same recommendation was made using the net benefit curve (Step 14b).

Caution. Recommendations made from a partial budget analysis should be revisited if there is variability in either yields or relative prices of inputs and output or both. Variation in relative input and output prices (change in economic situations) occurs more frequently than variation in yield, most especially in an inflationary economy or an economy characterized by unstable currency that is dependent on imported agricultural input and export-oriented output, as in most developing countries.

Sensitivity analysis addresses the problem of variability in prices.

7 *Sensitivity analysis*

Scientists are aware that certain factors usually beyond the control of the farmers could negatively affect (decrease) the net benefit and the marginal rate of return of shifting from the present practice to a proposed practice. Examples of these factors are technology failure and adverse weather condition (drought, flood, insect infestation, etc.) which reduce yield. A change in market situation, price policies, or inflation can increase variable input price(s), decrease output price, or both.

Researchers cannot accurately predict the occurrence of these factors and their effects on net farm benefits before committing resources to the proposed technology. The factors bring about risk or uncertainty associated with the

proposed technology. Farmers, most especially in developing countries, cannot afford to take risks because of lack of resources. Therefore researchers and farmers want to know the range of crop yields or prices for which the proposed practice may be recommended. Sensitivity analysis is used to test a proposed technology for ability to withstand yield or price changes.

Sensitivity analysis uses different prices or yields to determine what would happen to the net benefits and the choice of proposed technology if it were to occur in different price or yield conditions to those expected.

Assume that one level of N-fertilizer was recommended when its farm gate price was heavily subsidized. Removal of the subsidy would result in an increase in the farm gate price of the N-fertilizer. The anticipated farm gate price may be substituted in the analysis.

Table 9 illustrates a similar situation. The current farm gate price of N-fertilizer is 1.30 ₦/kg with subsidy, and 100 kg N/ha was recommended, assuming an acceptable minimum rate of return of 160%. If with the removal of the fertilizer subsidy the farm gate price of N-fertilizer increases by 600% (i.e. N-fertilizer costs 9.10 ₦/kg), will the recommendation of 100 kg N/ha hold?

Redoing the partial budget using the higher N-fertilizer farm gate price makes the recommendation of 100 kg N/ha invalid or uneconomical, because the marginal rate of return of 147% is lower than the acceptable minimum rate of return of 160%. Figure 4 shows that the marginal rate of return decreases with increase in the farm gate price of N-fertilizer.

The point where the minimum rate of return curve intersects the acceptable minimum rate of return line is the break-even price of N-fertilizer. This is the price at which the proposed practice (100 kg N/ha) is as good as the current practice (0 kg N/ha). Above this price, the proposed practice is no longer economically attractive, therefore there is no benefit in adopting it and the current practice should be maintained.

Table 9. Sensitivity analysis for the N-fertilizer experiment at different N-fertilizer prices.

	Treatment		Sensitivity analysis	
	1 0 kg N/ha	2 100kg N/ha	on Treatment 2 price price +538% +600%	
N-fertilizer price (₦/kg)	1.30	1.30	8.30*	9.10
Increase in N-fertilizer price (%)	0	0	538	600
Adjusted yield (kg/ha)	2,333	3,585	3,585	3585
Gross farm gate benefit (₦/ha)	2,919	4,481	4,481	4,481
Fertilizer material	0	130	830	910
Other variable inputs (₦/ha)	160	201	201	201
Total variable input cost (₦/ha)	160	331	1,031	1,111
Net benefit (₦/ha)	2,756	4,150	3,450	3,370
Change in total variable input costs between two consecutive treatments at different N-fertilizer prices		171	871	951
Marginal rate of return		8.15	1.60	1.46

Note that change in gross farm gate benefit between Treatment 1 and Treatment 2 at varying prices of N-

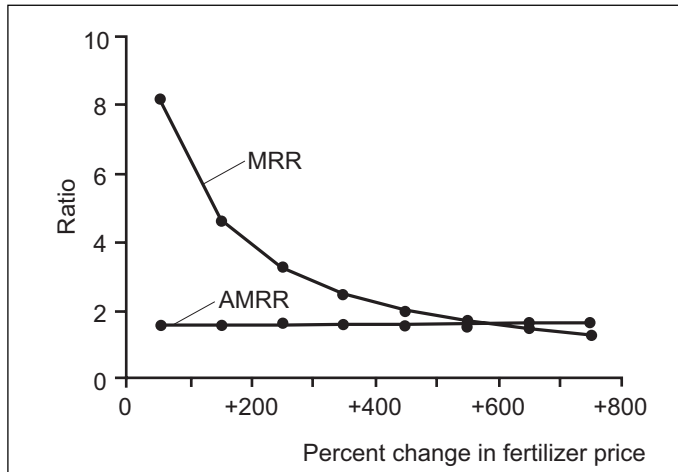


Figure 4. Sensitivity analysis for N-fertilizer experiment at different fertilizer prices (base = 1.3 ₦/kg)

Table 10. Sensitivity analysis for the N-fertilizer experiment at different maize yield levels.

	Treatment		Sensitivity analysis on Treatment 2	
	1 (0 kg N/ha)	2 (100 kg N/ha)	-25% yield	-30% yield
Adjusted yield (kg/ha)	2333.00	3585.00	2688.48*	2509.50
Decrease in adjusted yield (%)	0	0	25	30
Gross farm gate benefit (₦/ha)	2916	4481	3360.60	3136
Total variable input cost (₦/ha)	160.00	331	331	331
Net benefit (₦/ha)	2756	4150	3029.60	2806
Change in net benefit between Treatment 1 and 2 at different yields of Treatment 2		1394	273.60	50
Marginal rate of return		8.15	1.60	0.29

fertilizer is constant at ₦1565/ha, since yield and price per unit of maize output for Treatment 2 do not change.

• Indicates the break-even price (the price at which the proposed practice is as good as the current practice),

above which the proposed practice is not economically superior.

The break-even price of N-fertilizer could also be obtained using the formula in Appendix 2.

If the prices of N-fertilizer and of other inputs and outputs are constant, and only maize yield changes, we can also define a break-even yield—that is, the yield at which the proposed technology is as good as the current technology. Below the break-even yield, the proposed technology is not economical. Table 10 shows an example. The general formula to derive the break-even yield is given in Appendix 3.

Note that the change in Total variable input cost between Treatment 1 and Treatment 2 at varying yield levels remains constant at ₦171 because the quantity and prices of variable inputs for Treatment 2 used remain constant.

*Shows the break-even yield (the yield at which the proposed practice is as good as the current practice) below which changing to the proposed practice will not be economical.

8 Further reading

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9 ***Suggestions for trainers***

If you use this Research Guide in training ...

Generally:

- ▶ Distribute handouts (including this Research Guide) to trainees one or several days before your training activity, or distribute them at the end of your presentation.
- ▶ Do not distribute handouts at the beginning of a presentation, as trainees will read instead of listening to you.
- ▶ Ask trainees not to take notes, but to pay full attention to the training activity. Assure them that your handouts (or this Research Guide) contain all relevant information.
- ▶ Keep your training activities practical. Reduce theory to the minimum that is necessary to follow the practical exercises.
- ▶ Use the list of questions which follows for testing. Allow consultation of handouts and books during examinations.
- ▶ Promote interaction of trainees. Allow questions, but do not deviate from the subject.
- ▶ Control your time.

Specifically:

- ▶ Discuss with trainees about experiences and problems of (10 minutes).
- ▶ Present and discuss the content of this Research Guide, using the study materials listed on page 3 (?? minutes).

- ▶ Have real samples, diseased plants, seeds, tubers available for each trainee.
- ▶ You may photocopy the illustrations and tables of the Research Guide on transparencies for projection with an overhead projector
- ▶ Conduct the practicals suggested on page 3 in groups of 3–4 trainees per group (?? hours). Make sure that each trainee has the opportunity to practice. Have resource persons available for each group and practical.
- ▶ Organize your practicals and demonstrations well. Keep trainees busy. Prevent trainees from scattering around the field

Appendix 1. General format and formulae for partial budget analysis

The following data are required for partial budget analysis of on-farm maize research:

- ▶ the average maize grain yield (kg/ha), and maize grain qualities (and by-products if applicable) of each treatment
- ▶ the adjusted maize yield percentage (if necessary)
- ▶ the farm gate price of maize output (grain and by-product if applicable)
- ▶ the type, qualities, and quantities of variable inputs
- ▶ the farm gate prices of the variable inputs used in the treatments
- ▶ the maize farmers' acceptable minimum rate of return

Symbols used in the formulae for partial budget:

Q	maize grain (in case of multi-output, add another symbol, for example, z for maize stover)
x	variable input
n	number of treatments
m	number of variable inputs
$q_1, q_2 \dots q_n$	experimental maize yield for Treatment 1 to Treatment n
$q_{1,1} q_{2,1} \dots q_{n,1}$	the adjusted yields for Treatment 1 to Treatment n
$X_1, X_2 \dots X_m$	variable inputs (for example X_1 for labor, X_2 for seed, and so on)

$x_{1,1}, x_{1,2} \dots x_{1,n}$	quantities of variable input X_1 used in Treatment 1 to Treatment n
$x_{2,1}, x_{2,2} \dots x_{2,n}$	quantities of variable input X_2 used in Treatment 1 to Treatment n
$x_{m,1}, x_{m,2} \dots x_{m,n}$	quantities of variable input X_m used in Treatment 1 to Treatment n
$r_1, r_2 \dots r_m$	the farm gate prices of variable input X_1 to X_m
P	farm gate price of maize output (in case of multi-output, split P into P_1 for maize output, P_2 for maize stover, and so on)
Adjusted maize yield (%) is: $q_{1,1}/q_1 = q_{2,1}/q_2 \dots q_{n,1}/q_n \dots < 100\%$	

Table A1. General format and formulae for partial budget analysis for n treatments and m variable inputs.

	Treatment		
	1	2	n
Yield (kg/ha)	q_1	q_2	q_n
Adjusted yield (kg/ha)	$q_{1.1}$	$q_{2.1}$	$q_{n.1}$
Gross farm gate benefits (GFB) (₹/ha)	$pq_{1.1}$ GFB ₁	$pq_{2.1}$ GFB ₂	$pq_{n.1}$ GFB _n
Variable input cost (₹/ha)			
X_1	$r_1 X_{1.1}$	$r_1 X_{1.2}$	$r_1 X_{1.n}$
X_2	$r_2 X_{2.1}$	$r_2 X_{2.2}$	$r_2 X_{2.n}$
.	.	.	.
.	.	.	.
X_m	$r_m X_{m.1}$	$r_m X_{m.2}$	$r_m X_{m.n}$
Total variable input cost (TVIC _i) (₹/ha)			
X_1	$r_1 X_{1.1}$	$r_1 X_{1.2}$	$r_1 X_{1.n}$
+	+	+	+
X_2	$r_2 X_{2.1}$	$r_2 X_{2.2}$	$r_2 X_{2.n}$
+	+	+	+
.	.	.	.
.	.	.	.
+	+	+	+
X_m	$r_m X_{m.1}$	$r_m X_{m.2}$	$r_m X_{m.n}$
TVIC _i	TVIC ₁	TVIC ₂	TVIC _n
Net benefits (NB _i) (₹/ha)	$pq_{1.1}$ -	$pq_{2.1}$ -	$pq_{n.1}$ -
	$r_1 X_{1.1}$ -	$r_1 X_{1.2}$ -	$r_1 X_{1.n}$ -
	$r_2 X_{2.1}$ -	$r_2 X_{2.2}$ -	$r_2 X_{2.n}$ -
.	.	.	.
.	.	.	.
	-	-	-
	$r_m X_{m.1}$	$r_m X_{m.2}$	$r_m X_{m.n}$
NB _i	GFB ₁ - TVIC ₁	GFB ₂ - TVIC ₂	GFB _n - TVIC _n
MRR between two consecutive treatments	$NB_2 - NB_1$ TVIC ₂ - TVIC ₁	$NB_n - NB_{n-1}$ TVIC _n - TVIC _{n-1}	

Appendix 2. Formula for calculating the break-even price (example, N-fertilizer)

$$P^*_X = \frac{\frac{\Delta NB}{AMRR} - \Delta VIC_{X^1}}{\Delta X}$$

ΔNB = change in net benefits

$AMRR$ = acceptable minimum rate of return

ΔVIC_{X^1} = change in variable input cost other than input X

X = N-fertilizer input

ΔX = change in quantity of N-fertilizer

X^1 = other variable inputs (excluding X)

P^*_X = break-even price or price of N-fertilizer per kg above which the proposed practice becomes unviable

Example

Using data in Table 6

ΔNB = ₦1394

$AMRR$ = 1.60

ΔVIC_{X^1} = ₦41

ΔX = 100 kg N/ha

To obtain the maximum field price of N-fertilizer in order for the application of 100 kg N/ha to be better than 0 kg N/ha:

$$P^*_X = \frac{\frac{1394}{1.60} - 41}{100} = ₦8.30/\text{kg N-fertilizer}$$

The price of N-fertilizer should be less than ₦8.30/kg (or 538% of its present price of ₦1.30/kg) for the proposed practice (100 kg N/ha) to be economically better than the current practice of non-use of N-fertilizer (0 kg N/ha).

Appendix 3. Formula for calculating the break-even yield (example, N-fertilizer)

NB_1 = net benefit of Treatment 1

$$q^* = \frac{(\Delta TVIC \times AMRR) + TVIC_2 + NB_1}{P}$$

$TVIC_2$ = total variable input cost of treatment 2

$\Delta TVIC$ = change in total variable input cost

$AMRR$ = acceptable minimum rate of return

q^* = level of adjusted yield below which the proposed practice becomes unviable

P = price of maize output

Example

Using data in Table 7

NB_1 = ₦2756

$TVIC_2$ = ₦331

$\Delta TVIC$ = ₦171

$AMRR$ = 1.60

P = ₦1.25

To calculate the minimum adjusted maize yield below which the recommendation of 100 kg N/ha will be worse than 0 kg N/ha.

$$q^* = \frac{(171 \times 1.60) + 331 + 2756}{1.25}$$

$$= 2688.48 \text{ kg/ha}$$

For the proposed technology to be economically better than the current practice, the adjusted yield of the proposed technology should be higher than 2688.48 kg/ha or more than 75% of the adjusted yield obtained for 100 kg N/ha.