International Board for Soil Research and Management

TOOLS FOR THE ECONOMIC ANALYSIS AND EVALUATION OF ON-FARM TRIALS

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Abbreviations

ASN	Ammonium sulphate nitrate
B/C	Benefit-cost ratio
CBA	Cost-benefit analysis
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
DSP	Double super phosphate
DSSAT	Decision Support System for Agrotechnology Transfer
EDI	Economic Development Institute of the World Bank
FAO	Food and Agriculture Organization of the United Nations
FESLM	Framework for the evaluation of sustainable land management
FRR	Fertilizer response rate
GTZ	Deutsche Gesellschaft fuer Technische Zusammenarbeit
IFDC (Africa)	International Institute for Soil Fertility Management
IFPRI	International Food Policy Research Institute
IITA	International Institute for Tropical Agriculture
IRR	Internal rate of return
K.shs	Kenyan shillings
MRR	Marginal rate of return
ME	Man equivalent
NBI	Net benefit increase
NPV	Net present value
Sh.	Shilling
SCBA	Social cost-benefit analysis
UNDP	United Nations Development Programme
VCR	Value-cost ratio

1. INTRODUCTION

The purpose of on-farm trials is to develop, test, and/or demonstrate innovations that are to be adopted by the land users. However, farmers do not normally have a free choice on whether to adopt. Acceptability is decisive and depends on a complex of factors comprising the nature and effect of innovations, the degree to which they match with the adopter's individual targets, and the impact on the land-use system and the socioeconomic environment. For researchers, the main emphasis regarding innovations has been on combining these subjects with resource conservation so as to meet present and future needs, including those of future generations. In line with this general policy focus, the Food and Agriculture Organization (FAO) of the United Nations and the International Board for Soil Research and Management (IBSRAM) have developed a framework for the evaluation of sustainable land management (FESLM). According to the FESLM "sustainable land management combines technologies, policies, and activities which can simultaneously maintain or enhance production (productivity pillar), reduce the level of production risk (security pillar), protect the potential of natural resources (protection pillar), be economically viable (viability pillar), and be socially acceptable (acceptability pillar)" (Smyth and Dumanski, 1993). The economic analysis and evaluation of innovations or land-use changes are therefore fundamental steps for any innovation assessment in view of their adoption potential and desired sustainability.

This tool kit presents a set of procedures for the economic analysis and evaluation of on-farm experiments by agricultural scientists and extension officers. To some extent there will be an overlap between some tools, and several of them are correlated as most economic indicators are based on the same variables (costs and prices, labour input, etc.). On the other hand, some tools are more adequate for smallholders (than for larger farms), for perennial (than annual) crops, or for labour (than land constraint environments), and vice versa. A careful choice of the most appropriate methodologies is necessary.

Economic indicators are generally more important, the more a farmer is integrated in the market economy. In subsistence-oriented economy, economic and particularly monetary indicators may be of little significance where crops are grown exclusively for home consumption. It is therefore essential to determine only those economic indicators that may influence adoption and acceptability of innovations before a decision is made on the mode of the economic analysis, and its value in comparison to the agronomic analysis and farmer's assessment. In fact, we should be aware that innovations that seem to be promising from agronomic, ecological, and economic points of view may have other shortcomings that only farmers can identify. Examples are the taste of a certain cassava variety, the too dusty texture of rock phosphate, or the odour of poultry manure. Consequently, the economic tools allow us to contribute but not to substitute for judgement. Complementary tools for a participatory assessment of innovations or technologies are part of kits prepared, for example, by Herweg et al. (1998) or Bechstedt (in press). A complementary field guide for on-farm experimentation (surveys, trial design, statistics) was published recently by IITA (Mutsaers *et al.*, 1997).

It is hoped that this work will aid researchers of different disciplines as well as extension officers in understanding and applying economic analyses in on-farm research. For readers with little experience in economic terminology we tried to keep the text simple and to illustrate the different tools and indicators with examples from Africa and Asia. A glossary of terminology is attached, as well as a few exercises, and examples of forms for on-farm data recording.

2. RESOURCES AND PRODUCTION

Population growth and rising expectations demand increased production that is affected by different means, depending on the prevailing conditions of relative factor scarcity and the dynamics of technological change. Economics, in general, is concerned with the sensible use of scarce resources. Resources traditionally and conveniently are classified by economists into four main production factors — land, labour, capital, and management (i.e. skills and knowledge).

While training can improve the productivity of farm management, technological innovations are aimed at, first of all, to increase land and/or labour productivity. Hence, we can differentiate between those innovations that improve:

- productivity of labour (e.g. machines and improved implements);
- productivity of land (e.g. erosion control, compost, manuring, and mulching); and
- productivity of labour and land (e.g. fertilizers, biocides, improved varieties).

Labour is the tool with which capital and managerial skills are used to extract profit from the land. It is needed for all enterprises and differs from land and capital because, like time, it cannot be stored.

2.1 Site specificity of production factors

Land users aim at the highest productivity of the scarcest factor. Relative factor scarcity is site specific and a decisive feature of the socioeconomic environment. In the presence of available land resources, achievement of reasonable labour productivity (or returns to the unit of labour input) is most important. Farmers are eager to substitute labour for increased productivity of this factor by means of mechanization (e.g. semiarid areas, African Guinea and Sudan zones). In densely populated areas, on the other hand, land productivity is more important and, consequently, lower labour productivity has to be accepted. Land users aim at adopting innovations that increase land productivity. Changing production patterns and substitution of scarce factors have therefore to be viewed as a reaction to a changing socioeconomic environment. However, one cannot stress too highly the need to incorporate the farmer's perspective in the assessment of "factor scarcity" and the corresponding analysis of experiments. In this regard returns to labour, rather than yield *per se*, are the critical variables in most African countries, but were very seldom considered in economic analyses.

In the example given below, diminished soil fertility is substituted by increased labour allocation.

In the system of shifting cultivation, intensification along with population growth is affected by a shortening of fallow periods. To cope with decreasing soil fertility, more land has to be allocated to the labour unit. The resultant effect is both lower productivity of land and of labour. This may be exemplified by two farming systems in Tanzania that differ in the length of fallow periods, as indicated by the R-factor (Table 1):

$$\text{R-factor (1)} = \frac{\text{years of cultivation}}{\text{years of cult.} + \text{fallow}} = \frac{2}{2+12} = 0.14$$

$$\text{R-factor (2)} = \frac{\text{years of cultivation}}{\text{years of cult.} + \text{fallow}} = \frac{4}{4+4} = 0.50$$

Table 1. Relationship between length of fallow periods and factor productivity (upland rice, Tanzania).

R-factor	Area (ha ME^{-1})	Yield (kg ha^{-1})	Yield (kg man-day^{-1})
0.14	0.6	1700	6.15
0.50	0.9	1200	4.75

In the humid tropics, it can be presumed generally that the process of decreasing productivity of land and labour will commence when the share of the annually cultivated land moves beyond 15% or, respectively, when the share of the total fallow land becomes less than 85% of the totally occupied area. The critical stage is indicated by the R-factor of 0.15[1]. The process of continuously increased labour allocation, however, is limited by the emergence of labour peaks that are normally particularly distinctive for weeding. Land users whose production is limited

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[1] In subSaharan Africa this situation became very infrequent. Today the average R-factor is about 0.60 in this region.

by labour peaks, and who are unable to expand their cultivated area, are ready to adopt innovation packages that improve both land and labour productivity. Likewise they are willing to diversify their farming systems.

The way in which changes in factor productivity can be visualized is shown in the following example from Kenya (Table 2). The table shows that fertilizer increases productivity of land and labour. Mechanization increases costs that can be justified if high charges for casual labour can be substituted, or the total cultivated area can be expanded. In any case substitution of family labour by mechanization increases labour productivity.

Table 2. Factor productivity resulting from different patterns for 1 ha of maize production in Kenya.

Production level	Low input	High input	High input/mechanized
Yield (bags at 90 kg)	25	37	37
Gross return (350 K.shs. bag^{-1})	8750	12950	12950
Variable costs (K.shs.)			
Seed	470	470	470
Fertilizer	370	870	870
Chemicals	140	140	140
Bags	750	1120	1120
Transport	250	370	370
Contract work (K.shs.)			
Ploughing			1250
Harrowing			660
Sowing			335
Interrow cultivation			450
Spraying			140
Transport			370
Total variable costs (K.shs.)	1980	2970	6175
Family labour (hrs)			
Tilling	320	320	-
Sowing	80	80	-
Weeding	330	330	30
Harvesting	150	220	220
Threshing	72	105	105
Total family labour (hrs)	952	1055	355
Gross margin ha^{-1}	6770	9980	6775
Gross margin hr^{-1}*	7.11	9.46	19.08

Seed rate: 22 kg ha^{-1} i.e. about 44 500 plants ha^{-1}

Fertilizer: low: 3 bags DSP; high: 5 bags DSP, 2 bags ASN + 4 bags ASN for topdressing

Costs in K.shs. do not reflect prices in 1999.

* approx. labour productivity (if no costs for land).

2.2 Labour conversions coefficients

Although the lack of fertile land can be the prime constraint to technological innovations, such as in the case of green manure in densely populated Rwanda (Drechsel *et al.*, 1996), labour is still considered a major constraint to "low external input" technologies in large parts of the tropics and subtropics. Consequently, it is very important to take into consideration all of the changes in labour implied by the different treatments in an experiment. Often it is mistakenly assumed that the farmer's own labour input is an unrestricted (free) resource although the amount of farmwork a self-employed person is willing to do depends on a range of factors (Johnson, 1985):

- The amount of work needed to obtain his/her subsistence needs.
- The potential gain from doing extra work.
- The physical health and diet of the person.
- Climate.
- Presence of markets.
- Other job opportunities (especially off farm).
- His/her own motivation.

Labour availability and labour bottlenecks are two of the most important types of diagnostic information that aid in selecting appropriate treatments for experiments and in defining target groups. If labour is scarce at particular peaks, extreme caution must be used in experimenting with technologies that further increase the labour demand at that time.

Defining how much labour is available is somewhat arbitrary, as it depends on the age at which children are expected to work on the farm, on whether women and old men are included, on how many hours they are able and willing to work, and their work rate. The amount of labour available and the amount used may differ if there is unemployment or underemployment of labour, either permanent or seasonal.

If farmers hire labour for the operations in question, the **field price** of labour is the local wage rate for day labourers in the target area, *plus* the value of nonmonetary payments normally offered, such as meals, drinks, or even accommodation. The **field cost** of labour for a particular treatment is then the field price of labour *multiplied* by the number of hours/days per hectare required. It is not unusual to find the rate higher (and labour availability lower) during some periods of the year than others, and this must be taken into account[2]. For economic purposes

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[2] In cases such as this, it is reasonable (for security) to set the opportunity cost of labour (see next section) above the going wage rate. On the other hand, if additional labour is to be used during a relatively slack period, an opportunity cost below the going wage rate might be appropriate. But in no case should the opportunity cost of labour be set at zero.

and for the comparison to be made between different land management systems and labour inputs and types, it is necessary to express days and hours in terms of a common denominator, like **man-days** or **man-hours**. The total number of man-hours is obtained by multiplying the number of working men by the average number of hours worked. It is therefore assumed that the labour of one man for 60 hours is equivalent to that of two for 30 hours or five for 12 hours. This assumption is slightly unrealistic but adequate for most purposes. It does not pay attention to the fact that for some heavy tasks, or for the need to finish a job during daylight, more than one man may be required.

To assign **male adult equivalents** to different gender and age groups, two assumptions are usually made. First, that physical labour productivity shows initially a positive correlation and then a negative one with age and, secondly, that the physical labour productivity of women is less than that of men. Little information on the relative work rates is available but the conversion scales in Table 3 are typical (Johnson, 1985; modified).

Table 3. Adult equivalents for labour calculations.

Labour class	Age (years)	Man-units or ME (man equivalent)	Equivalent man-days per month
Small child	less than 7	0.00	0
Large child	7 – 14	0.40	10
Male adult	15 – 64	1.00	25
Female adult	15 – 64	0.75 - 0.80	19-20
Male/female adult	65 or more	0.50	12.5
Small child	< 12	0.25	6.3
Large child	12-16	0.50	12.5

We can assume normally that the average month has 22 working days to allow for market days, sickness, and traditional as well as religious festivities. However, most farmers are prepared to increase to 25 days during peak seasons of labour, which are the critical periods for our calculations. Consequently, Table 3 shows the equivalent man-days per month for peak seasons.

These conversion coefficients have severe limitations. The performance differential between men and women narrows as jobs become lighter, suggesting that physical strength strongly influences performance. The relative working rates of men, women, and children vary from one task to another. When a woman works at half the speed of a man on one job and twice as fast on another. fixing her equivalent value on the basis of the first will grossly underestimate family labour capacity on the second. Assumption of a constant performance differential between men, women, and children, which is implied by using a single coefficient over the whole season, is unrealistic as relative performance varies according to energy requirements. Certain tasks occur at busy times of the year and the relative rates of working on these critical jobs, found by work study, should be used as man-unit equivalents (Johnson, 1985).

2.3 The importance of opportunity costs

In specific cases it may be appropriate to calculate opportunity costs as a realistic value for family labour. This is the potential return to labour that could have been received if the labour had been used for a realistically existing alternative. When considering the farm as a whole, the opportunity cost for family labour is the return that the family could get for its labour in other employment. For example, if farmers must take a day off from working or trading in town to do extra weeding, they are going without the money they could have earned in the other occupation, i.e. they will give up a day's wage in town. This money lost is, in fact, the real cost of weeding. This consideration is of particular importance when opportunity costs are higher than those that occur paying a labourer to do the weeding. It may be added that opportunity costs of zero never occur. Even if the farmer has nothing else to do he might prefer to sit in the shade, rather than to work in the sun (CIMMYT, 1988).

In situations where most farm labour is provided by the family, and where the new technologies being considered change the balance between cash expenditures (i.e. inputs) and labour, special care must be taken in estimating labour costs. If a particular treatment involves a large change in labour input, relatively small differences in the opportunity cost of labour will have significant effects on the estimation of the cost of the treatment and its adoption potential.

In an example, we suppose that experimental evidence shows that a certain herbicide gives the same average yield as the farmers' hand weeding. A comparison of costs that vary is thus the only economic analysis necessary for making the recommendation. Table 4 shows the example. In case A, the researchers have assumed an opportunity cost of labour of US$1.00 day^{-1}. The total costs that vary using the herbicide are lower than those of hand weeding, and therefore the herbicide should be recommended. But if the opportunity cost of labour is only US$0.50 day^{-1}, then hand weeding is the preferred alternative. This illustrates the necessity of carefully studying the availability and utilization of labour before making recommendations for something like weed control.

Table 4. Sensitivity analysis for a weed control experiment; costs in US\$ ha^{-1} (CIMMYT, 1988).

	Case A (opportunity cost of labour = US\$1.00 day^{-1})		Case B (opportunity cost of labour = US\$0.50 day^{-1})	
Costs that vary	Hand weeding	Herbicide	Hand weeding	Herbicide
Herbicide	0	8	0	8
Sprayer	0	1	0	1
Labour cost	20	4	10	2
Total costs that vary	20	13	10	11

Opportunity cost applies not only to those resources for which no price is available, like family labour, but also to purchased inputs, such as fertilizer or (borrowed) capital. *Opportunity costs of capital* refer to the costs of using investment resources (e.g. money) for a certain technology under study rather than in their next best alternative use, or in other words, the reduction in normally possible benefits as a result of using capital for an innovation. In practice it is very difficult to calculate the opportunity costs of capital and they are often expressed in the form of an interest rate (see 4.3.1).

3. CHOICE OF APPROPRIATE TOOLS AND ECONOMIC INDICATORS

In on-farm trials, estimates of labour time, costs, and benefits should come from conversations with farmers. Examples of corresponding field forms for data recording are given in Appendix B. As different farmers — even with the same treatment — will have different opinions as to the time required for a given operation, a number close to the average of these opinions will provide a good estimate. For new activities with which farmers are completely unfamiliar, some demonstrations will have to be made until more reliable estimates can be developed.

In general, the objective of our analysis should be to aid farmers in the best use of their resources in a manner to maximize profits or other ends, and to bring about the most efficient use of agricultural capital, land, labour. and management resources under consideration of costs, benefits, and economical risks. A production factor not affected by the innovation tested in the experiment does not need to be considered in the analysis, i.e. returns are calculated only for those production factors that are actually affected (Tables 5 and 6).

Table 5. Some suitable economic indicators (see glossary for definitions) (Werner, 1993).

Production factor affected	Suitable economic indicator
Capital only	- gross margin + returns to variable costs (benefits) or + MRR (for systematically increasing levels of an experimental factor)
Labour only	- yield/labour ratio
Capital + labour	- gross margin + returns to variable costs or MRR + (monetary) returns to labour

MRR = marginal rate of return

Table 6. Some examples of production factors affected by different trial types and the choice of economic indicators (Werner, 1993, modified).

Type of trial (examples)	Production factor affected*	Suitable economic indicator
Variety trial	Capital (costs of new variety higher than the local standard, but no systematically increasing levels of capital)	- gross margin + returns to variable costs
Fertilizer levels	Capital (costs of fertilizer systematically increasing)	- gross margin + MRR
Method of fertilizer application (e.g. once or split)	Labour (more for split application)	- yield/labour ratio
Application of organic manure	Labour (for collecting, processing, and application)	- yield/labour ratio
Alley cropping**	Capital (for seeds or seedlings) Labour (to establish and maintain alleys)	- gross margin + B/C ratio + (monetary) returns to labour

* The production factor of land is involved in all crop experiments. Returns on land (i.e. gross margins ha^{-1}) are therefore calculated for all these experiments.

** Trials involving perennial crops would, strictly speaking, require a (discounted) cash flow analysis.

The calculation of **returns on capital** is useful when an innovation requires a substantial amount of additional capital. The **returns on labour** should be calculated whenever an innovation affects the labour allocation. The production factor of **land** is involved in all experiments dealing with crop production. The returns on a factor more scarce in the farm economy should be valued higher in the economic analysis than the returns on a factor available in relative abundance. Where there is still enough land available for cultivation, farms are limited by the supply of labour or capital. In other places, where land is scarce, labour has to be considered as relatively abundant. It can be assumed that capital is always scarce in smallscale farming.

Therefore, the choice of the appropriate criteria for the economic analysis should be determined by:

1. The role of the production factor in the specific experiment.
2. The relative availability of the production factor in the farm economy of the target group.

In most African countries, where economic development is virtually synonymous with increased labour productivity, the returns to labour (gross margins per hour or man-day), rather than yield *per se* (kg ha^{-1}) or returns to land (gross margins ha^{-1}), is the critical variable (for calculation see also the example in Appendix B).

Usually, we have to start with the calculation of the variable costs (see 4.1) for each experiment. This is necessary because farmers are first of all interested in costs that are involved in adopting a new practice. It is therefore important to take into consideration all inputs that are affected in any way by changing from one treatment/practice to another. To facilitate the calculation, the production factors are measured in currency units as a common denominator.

In addition to capital, land, labour, and management we have to consider the "time" factor. Production decisions are influenced by time in that transformation of inputs into outputs requires time. The longer the time period of production, the more uncertain producers are of the prices that may be obtained for their products. Also, in farming, there is a great deal of uncertainty as to the amount of products that will result from a given amount of inputs. The time value of money is built into the principle of "compounding" and "discounting", which is a central part of any advanced CBA. Table 7 gives an overview about different methods or tools as well as application examples.

Among the five indicators discussed in the section on CBAs, there is no specific (best) technique for estimation of an innovation's worth. All methods are quite mechanical and have strengths and weaknesses under certain conditions (Gittinger, 1984; Enters, 1998). The real challenge in any CBA is that of obtaining complete records of all cash and noncash returns and expenses incurred over the lifespan of a project (Francisco, 1998). This concerns also noneconomic factors, such as better health, which are certainly of relevance for farmers' decision making.

4. ECONOMIC ANALYSIS AND EVALUATION

A budget provides an opportunity for comparing the income and expenses of alternative plans before putting one of them into operation. It is a forecast. There are different methods and economic indicators for budgeting, the estimation of innovation worth, and risk/stability assessment, which will be discussed in the following chapters.

Table 7. Methods discussed in the tool kit and application examples.

Method	Economic indicator	When/where to apply (examples)
Total/complete budgeting (not considered in the tool kit)		When a large, basic change is being considered that would affect most, perhaps all the farm costs (variable and fixed costs) and receipts, e.g. the establishment of a new farm.
Partial budgeting	Net benefit; MRR	"*Which would pay best*". This looks at the changes in (usually variable) costs and receipts due to a "marginal" change in farming. Useful for most innovations (if the changes in costs are not too small).
Break-even analysis	Break-even point	Determination of the point at which an innovation becomes (non-) profitable.
Cash flow analysis (budget)		Prediction of expected in- and outflows of cash for perennial systems, like agroforestry and soil conservation technologies.
CBAs	1. B/C ratio 2. VCR 3. NPV 4. IRR 5. NBI	1. Standard indicator; used also without discounting. 2. Assessment of fertilizer use adoption without discounting. 3. For mutually exclusive treatments (see footnote in 4.3.1) with discounting. 4. Less appropriate for smallholders (used with discounting). 5. More appropriate for smallholders (partly usable without discounting).
Social CBA		Considers also off-site effects (externalities).
Sensitivity analysis	MRR	Risk and stability assessment

4.1 Partial budgeting

A useful technique for the economic analysis of agricultural innovations is the *partial budgeting* technique. The partial budget is used commonly to estimate the cost and receipt of making relatively small (marginal) changes to only one part of the farm business (e.g. new fertilizer), while all other parts remain the same. Therefore it is sometimes called *marginal analysis*. It is particularly useful for farmers with limited resources who wish to make some modifications in resource allocation for higher profits. Such modifications are often adopted in small steps (rather than in complete packages) over a period of several seasons or years of testing. Partial budgets focus on such small changes and the related **variable costs**. These costs will be incurred only if production is carried on, and the amount of these costs will depend on the kinds and quantities of added new inputs. In making production decisions as to the quantities of variable inputs to use to maximize net revenue, therefore, the variable costs are the relevant costs. **Fixed costs**, on the other hand, apply to the farm as a whole, and are largely independent of land management changes, for example. They do not vary even when quite large changes are made in the number, kind, and size of enterprises. Some examples:

Variable costs

Seeds
Fertilizers
Biocides
Wages for casual labour
Fuel for machines
Depreciation of tree crops
Livestock feed, veterinary costs etc.

Fixed costs

Depreciation of equipment and buildings
Maintenance and repair of equipment and buildings (e.g. stores)
Wages of regular labour
Rent
Interest on borrowed capital

Where are partial budgets applied ?

There are two basic situations where partial budgets can be applied usefully.

1. Factor substitution: When decisions are being made whether to change/modify the levels of inputs in a production process. Capital in the form of agricultural machinery may be substituted for labour, tractors may be substituted for oxen, chemical fertilizer for farmyard manure or green manure, etc.
2. Product substitution: When decisions are being made whether to change products on a farm, such as the new maize variety. This could mean complete substitution of a production part for an existing one, introduction of a supplementary enterprise, without displacing any existing one, or changing the scale of an enterprise.

4.1.1 Procedure for partial budgeting

In preparing a partial budget, four basic questions must be raised, two of which relate to the financial losses arising from the use of an innovation (income decreasing), and the other two relating to the financial gains (income increasing).

A. Income decreasing

1. What additional (new) cost is incurred?
2. What reduction (present) in returns occurs?

B. Income increasing

1. What additional (new) return is obtained?
2. What reduction (present) in cost occurs?

The items included in the first two questions reduce net income, whereas the last two elements increase net income. When we subtract the summation in A from the summation in B, the change in net income is obtained. If B is greater than A, the increase in net income due to the change is desirable and hence the change appears financially attractive. However, if B is less than A, the net income can be expected to decrease[3].

Examples:

A farmer has grown maize, M-5, for many years in Kumasi (Ghana). He has just learnt about the new maize variety, *Obatampa*, which is resistant to downy mildew, contains more protein, and yields better than M-5. He has decided to try *Obatampa* on a part of his cultivated land. With the help of the following information, he wants to know whether it would be profitable to adopt *Obatampa* in place of the M-5 variety of maize (Table 8). The input data we need are:

1. Yield of M-5 per 1/4 acre	300 kg
2. Yield of *Obatampa* per 1/4 acre	350 kg
3. Seeding rate of both the varieties per 1/4 acre	2 kg
4. Cost of pesticide spray used in M-5 per 1/4 acre	15 000 cedis
5. Cost of M-5 seed per kg	3000 cedis
6. Cost of *Obatampa* seed per kg	6000 cedis
7. Price of both the maize varieties per kg	250 cedis

(2300 cedis = US$1.00 (February, 1998); 1 ha = 2.47 acres).

Table 8. Calculation of the net benefit for the proposed change from M-5 maize to *Obatampa* maize (partial budgeting).

Cedis		Cedis	
A. Income decreasing		B. Income increasing	
1. Additional cost		3. Additional return	
Obatampa seed (2 × 6000) =	12 000	*Obatampa* maize sale (350 × 250) =	87 500
2. Reduced return		4. Reduced cost	
Sale of M-5 (300 × 250) =	75 000	M-5 seed (2 × 3000) =	6000
		Spray =	15 000
Total (A) =	87 000	Total (B) =	108 500
Net income (B - A) in cedis = 21 500			

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[3] In estimating the effects of changes, realistic standards such as prices of both inputs and outputs, wages, and yield per unit of land must be used. In addition, the change must be technically feasible and should not impose strain on the existing farm organization.

Conclusion: Proceed with substituting M-5 maize with *Obatampa* since additional benefits (B) will be more than additional costs (A).

In tables 9 and 10 we compare the profitability of different management options for a maize/cassava intercrop by calculating the **marginal rate of return (MRR) to additional investment**. The MRR is the marginal net benefit divided by marginal costs; i.e. the incremental gross margin between two treatments divided by incremental costs between two treatments. The MRR indicates what farmers can expect to gain, i.e. which additional gross margin is obtained per unit of additional variable costs between two treatments. Consequently, the MRR is always related to the change from one treatment to another, but does not belong to a particular treatment.

The example comes from IBSRAM trials in Ghana in collaboration with the Kwame Nkrumah University of Science and Technology (KN-UST), Kumasi. We compared different manure and fertilizer inputs. Three different levels (T_0, T_1, T_2) are used here for illustration: The crop budgets indicate net returns in cedis of 1 003 302 (approx. US$502), 2 112 859 (US$ 1056), and 2 115 334 (US$1058) for residue only ($T_0$), residue + poultry manure (T_1) and residue + poultry manure + fertilizer treatments (T_2), respectively. A calculation of the MRR to additional investment due to the changing of one management option to another shows the MRR to decrease with increasing external input. The percentage MRR to additional investment was nearly 100% for T_0 to T_1, 85% for T_0 to T_2, and about 1% for T_1 to T_2.

To make recommendations from a marginal analysis, we have to estimate the *minimum rate of return* acceptable to farmers in their recommendation domain. This rate is usually between 50 and 100%. If the technology is new to the farmers and requires that they learn some new skills, a minimum rate of return near to 100% is a reasonable estimate. One hundred percent means a "2 to 1" return, and seems to be safe to recommend in most cases. If the technology simply modifies a current farmer's practice (such as a higher/lower fertilizer rate), then a minimum rate of return as low as 50% may be acceptable. A rate of return below 50% is unlikely to be accepted (CIMMYT, 1988). The range (50-100%) should serve as a guideline for innovations that concern crop cycles of one season. If the crop cycle is longer, the minimum rate of return will be correspondingly higher.

In our example, the analysis indicates a high probability that a change from T_0 to either T_1 or T_2 is acceptable for the farmer. A change from T_1 to T_2 is in any case not acceptable.

In certain experiments, such as those that look at different seeding rates or varieties, involved changes in costs may be very small, but the yield effect can be rather high. In these cases the MRR will be very high and is of little use in comparing treatments.

Table 9. Method of analyzing partial budget profitability of different maize/cassava production technologies.

	Changes in practice from:		
	Residue + no external input (T_0) to residue + manure (T_1)	Residue + no external input (T_0) to residue + manure + fertilizer (T_2)	Residue + manure (T_1) to residue + manure + fertilizer (T_2)
Marginal cost (cedis ha^{-1})	$Tc_1 - Tc_0 = x$	$Tc_2 - Tc_0 = x$	$Tc_2 - Tc_1 = x$
Marginal net benefit (cedis ha^{-1})	$Tr_1 - Tr_0 = y$	$Tr_2 - Tr_0 = y$	$Tr_2 - Tr_1 = y$
MRR to additional investment (%)	$y - x = z$ $z/x * 100 = \%MRR$	$y - x = z$ $z/x * 100 = \%MRR$	$y - x = z$ $z/x * 100 = \%MRR$

Tc = Total cost of production; Tr = Total revenue

Table 10. Partial budget profitability analysis of different maize/cassava production technologies (IBSRAM/Ghana).

	Changes in practice from:		
	Residue + no external input (T_0) to residue + manure (T_1)	Residue + no external input (T_0) to residue + manure + fertilizer (T_2)	Residue + manure (T_1) to residue + manure + fertilizer (T_2)
Marginal cost (cedis ha^{-1})	1 132 100	1 311 587	179 487
Marginal net benefit (cedis ha^{-1})	2 241 657	2 4236 19	181 962
MRR to additional investment (%)	98%	85%	1.4%

4.1.2 Break-even analysis

Break-even analysis is especially useful when a single item in a partial budgeting is uncertain. The method is applied by representing the uncertain figure with a symbol, say Y, and completing the rest of the partial budget in the usual way. The rise or fall in profit is assumed to be nil; that is, it is assumed that the change just breaks even so that the two sides of the budget equate and the break-even value for the uncertain figure can be calculated. The level at which gross receipts or benefits equal total costs is called the "break-even point".

Johnson (1985) gave an example of a partial budget to estimate the effect of replacing a hectare of tobacco for a hectare of maize. He assumed that the farmer wanted to find the break-even yield of tobacco and the break-even cost of tobacco fertilizer. This is done separately in tables 11 and 12 as only one variable could be calculated at a time.

Table 11. Break-even budget to estimate the break-even yield of tobacco needed.

Income lost	US$	New income	US$
Maize (36 bags at US$5.20 bag^{-1})	187.20	Y kg tobacco at US$0.50	0.5 Y
New costs		*Costs saved*	
Fertilizer - 7 bags at US$10.50	73.50	Seed	4.50
Specific casual labour	54.00	Fertilizer	37.50
Depreciation of 7 curing barns at US$3.50 each.	24.50	Fumigant	3.30
	339.20		45.30+0.5 Y

At the break-even point there would be no profit or loss from the proposed change.
i.e. 45.3 + 0.5 Y = 339.2
therefore 0.5 Y = 293.9 and Y = 588 kg tobacco ha^{-1}

At a lower tobacco yield, maize production is recommended.

Table 12. Break-even budget to estimate the break-even cost of tobacco fertilizer.

Income lost	US$	*New income*	US$
Maize	187.20	900 kg tobacco at US$0.50	450.00
New costs		*Costs saved*	
Fertilizer - 7 bags at P	7 P	22.5 kg maize seed at US$0.20	4.50
Labour	54.00	Fertilizer - 5 bags at US$7.50	37.50
Barn depreciation	24.54	Fumigant for storage	3.30
	265.70 + 7 P		495.30

i.e. 265.70 + 7 P = 495.30
therefore 7 P = 229.60 and P = US$32.80 per bag of tobacco fertilizer.

Up to this price, tobacco production is worthwhile.

4.2 *Cash flow analysis*

In agricultural production costs have to be met before returns can be expected, i.e. we have to consider a time-lag. While this is particularly pertinent for perennial crops and soil conservation treatments, it also concerns annuals. For subsistence production, costs of external inputs have to be paid for through sales. Hence, it has to be presumed that resource-poor farmers face a problem of liquidity, in particular when expensive innovations are being considered. Loans that have to be taken decrease net returns, apart from the constraint of risk increases. To assess the liquidity problem that is always linked to the adoption of innovations, a cash flow analysis has to be made. An example is given in Table 13.

Table 13. Cash flow of a 4-year cycle of sugarcane production in Kenya (1 ha, in K.shs.)

Year	Gross returns	Planting	Fertilizer	Weeding	Harvesting	Net cash flow
1		8500	1400	900		-10 800
2	12 600		1400	900	2500	7800
3	9800		1400	900	2500	5000
4	7000		1400	900	2500	2200
sum						+ 4200

1st harvest after 18 months, yield = 90 t ha^{-1}; 1st ratoon after 15 months, yield = 70 t ha^{-1}; 2nd ratoon after 15 months, yield = 50 t ha^{-1} (costs in K.shs. do not reflect actual prices)

Cash flow	A matrix in which receipts and payments are put in their timely sequence.
Net cash flow	Cash surplus or deficit that remains at the end of a time period (generally one year or a month) after payments have been deducted from the receipts.

For annual crops a cash flow analysis can show the liquidity problem if loan and debt services are included in the analysis. Development of debts and resultant charges for interest are demonstrated in Table 14.

Cash flow analysis is particularly important, when an innovation results *in a considerable change of production patterns*. The purpose is to check whether liquidity is maintained, increased incomes are being materialized, and subsistence requirements can still be met. A case of this is demonstrated in Table 15, where a farmer cultivating 2.75 ha of maize in year 0 substitutes part of his area for *Pyrethrum*. Between years 1 to 4 a quarter of a hectare is planted with *Pyrethrum*. Being a crop with a 4-year cycle and requiring a pronounced investment phase, *Pyrethrum* must cause a liquidity problem at the time of crop establishment.

Table 14. Monthly cash flow for maize production in Kenya (K.shs.).

	March	April	May	June	July	August	Sept.-Nov.	December	January	February	Year
Receipts											
Gross return									648	648	1296
Inputs:											
Seed		47									47
Fertilizer		55			32						87
Chemicals						14					14
Bags									56	56	112
Contract work:											
Ploughing	125										125
Harrowing	66										66
Sowing		34									34
Interrow cultivat.			45								45
Spraying						14					14
Transport									19	19	38
Casual labour											
Weeding			56	56							112
Harvesting								23	23		46
Total payments	191	136	101	56	32	28	-	23	98	75	740
Net cash-flow	-191	-136	-101	-56	-32	-28	-	-23	550	573	556
Monthly interest	21.0	13.6	10.1	5.0	2.5	2.0	-	0.7	1.9	0.7	57.5
Accum. credit	212	362	473	534	568	598	598	621	721	797	
Net cash flow											498.5

Costs do not reflect actual prices (1999).

Table 15. Cash flow analysis of *Pyrethrum* establishment in Kenya (in K.shs.).

	Year 0	Year 1	Year 2	Year 3	Year 4
Maize					
Area in ha	2.75	2.50	2.25	2.00	1.75
Gross return	11 220	10 200	9 180	8 160	7 140
Costs	4 950	4 500	4 050	3 600	3 150
Consumption	1 080	1 080	1 080	1 080	1 080
Net cash flow	5 190	4 620	4 050	3 480	2 910
Pyrethrum					
Area in ha		0.25	0.50	0.75	1.00
Yield (kg)	0	30	165	200	100
	0	0	30	165	200
	0	0	0	30	165
	0	0	0	0	30
Total yield (kg)	0	30	195	395	495
Gross return		324	2 106	4 266	5 346
Establ. costs		1 280	1 280	1 280	1 280
Running costs		65	120	71	71
			65	120	120
				65	65
Total costs		1 345	1 465	1 536	1 536
Net cash flow *Pyrethrum*		-1 021	641	2 730	3 810
Net cash flow holding	5 190	3 599	4 691	6 210	6 720

Parameters of maize production per ha: Yield 3400 kg, price kg^{-1} 1.20 K.shs., running costs 1800 K.shs. subsistence requirements of the family 900 kg maize y^{-1}.

Parameters of *Pyrethrum* production ha^{-1}:

Year	1	2	3	4
Yield in kg	120	660	800	400
Costs of establishment (K.shs.)	5 121			
Running costs (K.shs.)	259	478	285	

Price per kg = 10.80 K.shs.
Costs in K.shs. do not reflect actual prices (1999).

4.3 Comparing project costs and benefits

When costs and benefits have been identified and priced, the analyst is ready to determine which among various treatments or innovations under study is likely to be accepted or rejected by the farmer. He wants to know the system of land management that gives the highest (economic) worth, and not to support any system innovation for which benefits are less than costs. For comparing costs and benefits of alternative actions or investments, we will discuss five appraisal and evaluation criteria: Benefit-cost ratio (B/C), internal rate of return (IRR), net present value (NPV), net benefit increase (NBI), and value-cost ratio (VCR). The essential element that the first four measures have in common is that they consider the development of costs and benefits over time.

The time aspect is crucial when **soil conserving practices** or **agroforestry** options are compared with normal exploitative practices. Benefits of such technologies are supposed to become more distinguishable only in the future. In other words, yields between improved and control treatments are expected to differ more significantly in the future than at present. The production of perennial crops has similar characteristics (Enters, 1998). Some examples in view of soil conservation were calculated by Francisco (1998), for example, for IBSRAM sites in Asia.

4.3.1 The benefit-cost ratio (B/C)

The B/C ratio can simply be the revenue divided by the expenditure or cost. Otherwise, by taking the time value of money into consideration, the ratio is obtained when the discounted benefit stream is divided by the discounted cost stream (see below).

For the analysis of annual systems, e.g. whether beans as an intercrop are economically worthwhile, given the additional cost of liming required to neutralize soil acidity, the B/C ratio is used to evaluate if, in the final analysis, the benefits outweigh the cost or otherwise. Benefits are taken as revenue accrued, with the cost being all the expenditure incurred from the land preparation to the harvesting and marketing of the crop. If revenue equals expenditure (= break-even point; see 4.1.2), the B/C ratio is obviously 1, i.e. no profit is accrued. Any excess of revenue over expenditure would give a B/C ratio of greater than one. While for smallholders a B/C ratio of approximately 1.5 or above is usually of interest, for commercial farmers ratios just above the break-even point can be of interest. It is certainly true that land management systems that fail to break even from an economic point of view will not be sustained (Tisdell, 1995).[4]

An advantage of expressing profitability in B/C ratios is that being a relative term it ignores the local currencies for cross-country comparisons. An example of B/C ratios is given by Yin Dixin *et al.* (1996) for the introduction of alley cropping and hillside ditches in China (Table 16). The B/C ratios of 1.6 to 1.7 indicate that the investment is viable as every US$1.00 invested brings in a return of US$1.60 to 1.70 or a net revenue (profit) of US$0.60-0.70 for every dollar spent.

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[4] On the other hand, a system that breaks even or yields a net benefit may not be sustained if, for instance, a more profitable form of land management is discovered.

Table 16. B/C ratios of different treatments, 1994-1996.

		Economic analysis (US\$ ha^{-1})		
	Item	Farmers' practice	Alley cropping	Hillside ditch
1994	Input	302.60	299.80	304.10
	Output	472.80	453.60	479.70
	B/C ratio	1.60	1.50	1.60
1995	Input	452.60	452.60	428.60
	Output	703.00	856.70	373.20
	B/C ratio	1.55	1.87	0.87*
1996	Input	405.90	440.30	339.90
	Output	761.80	774.00	588.10
	B/C ratio	1.88	1.76	1.73
Average B/C ratio		1.68	1.71	1.67*

* In 1995 (hillside ditch treatment) the B/C ratio was low because some income data were not included. The average considers only 1994 and 1996.

However, the economic analysis of hillside ditches as well as alley-cropping systems requires also the consideration of the time factor. The usual method of addressing future costs and benefits of innovations that will last several years, is through discounting. That means that future costs and benefits are not included at face value, but are reduced usually by a fraction, i.e. discounted to some extent (corresponding to the folk wisdom that present values are better than the same values in the future, and earlier returns are better than later). This kind of analysis is also called **discounted cash flow analysis**. An example is given in 4.3.2.

The longer the time period of production, the more uncertain producers are of the prices that may be received for their products. In comparing the returns from investments that require different amounts of time, it is necessary to convert future incomes to present values. Since money obtained at some future date has in general less current value than money owned at present, some method must be available for discounting future incomes to obtain present values. **Discounting** is a process by which incomes received at some future time are converted to present values.

Estimation of the "right" discount rate

The most adequate rate of discount is a much debated issue (Enters, 1998). It is a mathematical function of the rate of interest for the time period (e.g. years) under observation and of the number of these years (see Appendix C). The selected interest rate has a significant impact on the results of the CBA and needs careful consideration. An "appropriate" interest rate is according to Gittinger (1984) often the rate at which the farmer is able to borrow money. However, borrowing and saving rates frequently do not indicate appropriate discount rates because such facilities are not available to smallfarmers. According to Hoekstra (1985) the discount rate differs among farmers and is based on several factors regarding the farmers' current status, outlook, attitude towards risk and uncertainty, and the length of waiting time before consumption. Using this approach, well-fed farmers who are pessimistic about the future because they face sustainability problems on their farms have a lower discount rate than poorly fed farmers with an optimistic outlook regarding future production. As a result, applying the same discount rate to all farmers should be avoided. It is therefore recommended to use a range of discount rates in financial analysis because of the difficulty in specifying appropriate rates. A review of various studies by Enters (1998) shows that several analysts are following this suggestion. Common rates used are 5 to 20%. In most developing countries, it is assumed to be somewhere between 8 and 15% in real terms (Gittinger, 1984). However, farmers can face in certain cases much higher interest rates of 40-50%, for example, if they borrow money. This includes bank service charges, insurance fees, transport costs to the bank and home, etc.

Economists usually discount future costs and benefits by a larger fraction when the rates of interest are higher and the future values are more distant. The values estimated by economists in this way are called "present values" (for calculations see Appendix C). The lower the rate of interest allowed in these calculations, the greater will be the weight placed on future net benefits compared to current benefits, and consequently there is more emphasis on the long-term sustainability of benefits.

The *formal selection criterion* for the B/C ratio measure of treatments is to accept all independent treatments with a B/C ratio of 1 or greater when the cost and benefit streams are discounted at the appropriate interest rate. Although in practice, treatments with higher B/C ratios are often regarded as being preferable, ranking by benefit cost can lead to an erroneous investment choice. The B/C ratio discriminates against projects with relatively high gross returns and operating costs, even though these may be shown to have a greater wealth-generating capacity than those of alternatives with a higher B/C ratio. The danger can be avoided most easily by using the NPV criterion (see next chapter) especially for *mutually exclusive treatments* or technological innovations[5] (Gittinger, 1984).

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[5] Mutually exclusive treatments are of a kind that implementing one necessarily precludes implementing another, such as surface irrigation vs. tubewell irrigation; planting now or two weeks later; manual clearing vs. mechanical clearing; etc.

4.3.2 Net present value (NPV)

The net present value, NPV, (or net present worth) is the difference between discounted benefit stream less the discounted cost stream. The basic technique of calculating the NPV is "to discount costs and benefits occurring in different periods and express them all in a common value at any one point of time" (Squire and Van der Tak, 1975). If the NPV is positive, the investment earns a surplus. A negative NPV implied a case in which, at the discount rate assumed, the present value of the benefit stream is less than the present value of the cost stream — that is, insufficient to recover investment. It would be better to put the money in a bank at the assumed interest rate (or, more likely, to invest it in a better project) than to invest it in the project analyzed. An example from Thailand is given in tables 17a and 17b.

Table 17a. Establishment of an irrigated rice field in Thailand (2 harvests per year).

Years	0	1 - 3	4 - 5	6 - 10
Area in ha		4.8	4.8	4.8
Gross return (kg ha^{-1} $year^{-1}$)		6 000	6 000	6 000
Price in baht kg^{-1}		1.4	1.4	1.4
Monetary gross return (baht)		40 320	40 320	40 320
Investments				
Two buffaloes and plough	14 500			
Irrigation field	12 300			
Running costs				
Inputs		12 700	12 700	12 700
Labour		3 200	3 200	3 200
Feed		600	600	600
Transport		1 400	1 400	1 400
Sum of running costs		17 900	17 900	17 900
Monetary net return	(26 800)	23 820	23 820	23 820
Consumed rice				
In kg		1 750	1 750	1 750
In baht		2 450	2 450	2 450
Net cash flow before debt service	(26 800)	19 970	19 970	19 970
Debt service:				
Two buffaloes and plough		6 380		
Irrigation field		3 518	3 518	
Seasonal loan		19 690	19 690	19 690
Net cash flow after debt service		8 282	14 662	18 180

25 baht ≈ US$1.00 (1996).
Credit terms: for running cost at 10% p.a.
Medium term: (Buffalo and plough) to repay at constant rates plus 10% interest in years 1-3.
Long term: (Irrigation) to be repaid plus 10% interest in years 1 to 5.

If we calculate the B/C ratio based on the NPV up 10 years with an interest rate of 10% we get the following result, as stated in Table 17b.

Table 17b. NPV and B/C ratio.

Year	Discount factor at 10%	Discounted costs (baht)	Discounted returns (baht)	Discounted cash flow (baht)
0	0.91	26 800	0	(26 800)
1	0.83	16 273	36 655	20 382
2	0.75	14 793	33 322	18 529
3	0.68	13 449	30 293	16 844
4	0.62	12 226	27 539	15 313
5	0.56	11 114	25 036	13 921
6	0.51	10 104	22 760	12 656
7	0.47	9 186	20 691	11 505
8	0.42	8 350	18 810	10 459
9	0.39	7 591	17 100	9 508
10	0.32	6 901	15 545	8 644
NPV		136 788	247 749	110 961

The NPV (costs) is 136 788 baht; the NPV (returns) is 247 749 baht. The B/C ratio is 1.8.

The formal selection criterion for the NPV measure is to accept all independent treatments with a zero or greater NPV when discounted at the opportunity cost of capital. An obvious problem of the NPV measure is that the selection criterion cannot be applied unless there is a relatively satisfactory estimate of the opportunity cost of capital, such as an appropriate interest rate (see 4.3.1). No ranking of acceptable, alternative independent treatments[6] is possible with the NPV criterion because it is an absolute, not relative, measure. However, NPV is the preferred selection criterion to choose among mutually exclusive treatments or technologies (see 4.3.1), which is not possible with the B/C ratio or the IRR.

Graphing NPV over time reveals the ranking of the various farming methods in each year of the analysis so that the effect of different planning horizons can be assessed. The distribution of NPV in each year can be used to indicate the risk associated with adopting each farming method, and to analyze the sensitivity of predicted NPV to variability in inputs (Nelson *et al.*, 1998).

However, the farmer may not be merely interested in determining the NPV and may want to find out how much the NPV translates to in terms of annual income. The sum of money received yearly over the lifespan of a project, which corresponds to the project's NPV, is called

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[6] Independent treatments mean that all can be undertaken in contrast to mutually exclusive alternatives.

the "**annualized income**" (Francisco, 1998). The number is sometimes more useful in explaining to the farmer as this can be translated easily to an additional income. The annualized income (AI) can be calculated as follows:

$AI= r\ (NPV\ (1+r)^n / (1+r)^n - 1)$; where: r = discount rate, n = considered project lifespan.

4.3.3 Internal rate of return

Return to investment, i.e. productivity of capital invested in agricultural production, may be expressed in various ways. It has become common practice (e.g. of the World Bank) to use the internal rate of return (IRR) as an indicator of an innovation's worth. It is the maximum interest that a project could pay for the resources used if the project is to recover its investment and operating costs and still break even. As in most cases smallfarmers contribute very little or no capital to investments, the IRR is used mostly for larger farms and to measure investment incentives. A simplified example of sugarcane production in Kenya is given in Table 18.

Table 18. Internal rate of return calculation for sugarcane (K.shs.).

		Discounted at 20%		Discounted at 25%	
Year	Net cash flow	Factor	Value	Factor	Value
1	- 10 800	0.833	- 8 996.40	0.800	- 8 640.00
2	7 800	0.694	5 413.20	0.640	4 992.00
3	5 000	0.579	2 895.00	0.512	2 560.00
4	2 200	0.482	1 060.40	0.410	902.00
Total	4 200		372.20		- 186.00
	(372.20 + 186.00) = 558.20 (signs ignored)				
	= 372.20 / 558.20 = 0.67				
Interpolation	= 20 + 5 x 0.67 = 20 + 3.33 = 23.33		IRR	= 23%	

The method uses the cash flow that is discounted to the present value. The correct rate has been found when the sum total of the discounted cash flow equals zero. In other words, the IRR is the discount rate at which a net present value (NPV) would equal zero. An IRR of a series of values such as a cash flow can exist *only* when at least one value (e.g. in the year 0 or 1) is negative. If all the values are positive, no discount rate can make the NPV of the stream equal zero. No matter how high the discount rate, the NPV of a series would have to be positive if it included no negative number. The IRR is also called the discounted cash flow rate of return.

For practical purposes it is sufficient if the sum totals of discounted cash flows of the two nearest 5% points are interpolated (Table 18). In the following example, the actual value of

IRR is found by interpolation between those discount rates that give the smallest positive and negative net present values[7]. For example, if the NPV at 12% is US$4.10 and at 13% is US$-0.88, the IRR (with an NPV of zero) must lie between 12 and 13%. It is found by interpolation, for example:

	Discount rate	Net present value
	12%	US$ + 4.10
	13%	US$ - 0.88
Differences	1%	US$ 4.98

$IRR = 12\% + (4.10/4.98)\% = 12.82\% \approx 13\%$

The formal selection criterion for the IRR measure of different treatment worth is to accept all independent treatments having an IRR equal to or greater than the cut-off rate[8]. However, the IRR may give incorrect ranking among independent projects. Moreover, like the B/C ratio, it cannot be used directly for choosing among mutually exclusive alternatives (Gittinger, 1984).

4.3.4 Net benefit increase (NBI)[9]

Small farm development is in most instances the main focus of rural development projects. As farmers are free to participate in a project or not, projects must provide adequate incentives to join them. Smallfarmers certainly do not base their decisions on economic considerations alone but economic benefits play a major role in motivating them to participate in a project. These incentives need to be measured when appraising the attractiveness of a rural development project. This is done usually by calculating the IRR. As major farmers normally aim at maximizing the return to the capital owned by them, the IRR is calculated for the net benefit stream after loan financing. However, for small farms this is not an adequate indicator because:

- in most cases smallfarmers contribute very little or no capital at all to the investment so that calculating an IRR is meaningless or impossible; and
- they do not aim at maximizing the return to capital but want to increase their net income, derived also from labour supplied by the farming family.

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[7] Computing the IRR is a trial-and-error procedure to find the discount rate that will make the NPV equal zero. One has to find a whole percentage discount rate that is somewhat too low and another that is somewhat too high and then interpolate between the two to find our IRR. It is better not to try interpolation between a spread wider than about five percentage points. The rates should always be rounded to the nearest whole percentage point, a greater precision is not justified (Gittinger, 1984).

[8] The rate below which an innovation is considered unacceptable; e.g. the discount rate used to calculate NPV or the B/C ratio (see 4.3.1).

[9] Adopted from Schaefer-Kehnert and Olivares (1984); see also Gittinger (1984)

Few efforts have been made so far to express the increase of the smallfarmer's income in a single figure like the IRR. Usually the incremental net benefit stream derived from an investment is shown year by year for the whole life of the project.

No single figure can be a complete substitute for a cash flow, but it may express its main characteristic and may even be clearer in this respect than a whole series of figures. The IRR is a typical example for this, but as mentioned before, it is often not relevant for smallfarmers. Therefore another indicator is needed that can express the investment incentive to smallfarmers with similar simplicity.

Schaefer-Kehnert and Olivares (1984) suggested measuring the investment incentives to smallfarmers by the *relative increase in their average annual net income* generated by the project. This can be done by expressing the incremental net benefits in percent of the without-project net benefits. This will be called net benefit increase (NBI) and measured in percent. The proposed measure could be used in an appraisal report for example by saying, "farmers participating in the project would increase their average annual net income by 40%."

As the NBI is based on the without-project net benefit this basis must be defined clearly as to its contents. If for instance, partial budgeting is used, (e.g. for a livestock enterprise only) the net income from other farm enterprises needs to be added to the without-project income before the percentage increase is calculated; or it must be specified to what the increase is related, for example by saying "farmers participating in the project will increase the net benefits derived from livestock production by 60%."

Another problem is that the without-project net benefit stream usually neglects the depreciation of existing assets whereas the NBI stream takes (indirectly) the depreciation of the additional assets into account by including the initial cost in the outflow and the residual value in the inflow stream. For a correct comparison, therefore, a depreciation allowance for existing assets should be included in the without-project stream. On undeveloped small farms this depreciation may be so small that neglecting it would not make much difference. (In any event, neglecting it would only understate the NBI because the without-project net benefit would be higher.)

Necessary calculations are:

(i) If both the without-project and the with-project net income streams are completely stable a simple percent calculation is sufficient to establish the measure (i.e. without discounting).

(ii) If one benefit stream is stable (usually assumed to be the case for the without-project net benefit stream) and only the other fluctuates both streams are discounted and the NPV is used for comparison.

If the percentage figures are higher than say 25% they should be rounded to the next 5 and over 50% to the next 10 percentage points, e.g. 60% (NBI=56%). If the increase is more than 100% e.g. (NBI=107%), it may be said simply that farmers making this investment would "more than double" their net income (see example in Table 19).

Table 19. Comparing net benefits (US$ ha^{-1}) of irrigation (project) and rainfed cropping (control) in Afghanistan (Schaefer-Kehnert and Olivares, 1984).

Year	Net benefits			Discount	Present value		
	Without irrigation	With irrigation	Increment	factor 12%	Without irrigation	With irrigation	Increment
1	86	85	-1	0.893	77	76	-1
2	86	74	-12	0.797	69	59	-10
3	90	121	31	0.712	64	86	22
4	96	270	174	0.636	61	172	111
5	96	286	190	0.567	54	162	108
6	96	286	190	0.507	49	145	96
7	96	366	270	0.452	43	165	122
	NPV				417		448

NBI = 448/417 = 107%

Note: To calculate the IRR would not make much sense in this case because the net investment (farmers' equity) is negligible.

4.3.5 Value-cost ratio (VCR)

A common indicator used to predict (forecast) decreases or increases in fertilizer use due to changes in input and output prices is the value-cost ratio (VCR). The VCR is calculated as the value of additional crop output (yield increase) due to fertilizer use divided by the cost of additional fertilizer applied. In other words, the VCR is the ratio of the product unit price to fertilizer unit price multiplied by the fertilizer response rate. There is some evidence from surveys that farmers use a simple output price/input price ratio also in their decisions (Donavan and Casey, 1998).

VCR = FRR x product price/fertilizer price
where FRR = the fertilizer response rate = kg output per kg fertilizer.

For example, if fertilizer costs US$2.00 kg^{-1}, and 1 kg of fertilizer produces 4 kg of output that sells for US$3.00 kg^{-1}, then the VCR is 4 x 3/2 = 6; i.e. US$6.00 are additionally generated by one additional dollar spent on plant nutrients. By definition, it is relevant to calculate a VCR only if there is an additional cost (>0).

For fertilizer use to be attractive enough to induce adoption, i.e. to cover labour input and other expenditures involved, it has been estimated that the VCR must be 2 or greater. However, recent studies by IFDC suggest that a VCR of 4 or more is required to accommodate price and climatic risk and still provide an incentive to farmers (Donovan and Casey, 1998).

While the VCR is useful as a rough measure for ex-post analysis, it is a static indicator that reflects, other things being equal, technical conditions. The critical questions that remain are:

- What factors explain the product price for any crop in a given year: Weather, increased demand, market liberalization policies?
- What explains the unit price of fertilizer: Supply infrastructure, manufacturing costs, currency policy?
- What are the technical and managerial elements that determine crop response to fertilizer?

These questions must be addressed in considering alternatives for improving fertilizer use and marketing (Donovan and Casey, 1998).

Table 20 shows an example from southern Togo (Van Reuler and Tamelokpo, 1998), where the fertilizer subsidy amounts to about 20%. In case the price is corrected then the VCR at harvest will decrease to 2, and increase during the following three months to 3.5. It is important to note that the maize prices and consequently the VCR vary strongly during the year. For instance in 1996, the maize price nearly doubled between harvest and three months later.

This example shows that investing in maize storage facilities may be very profitable.

Table 20. Maize grain yield and VCR of farmer-managed experiments in southern Togo.

Treatment	Grain yield (t ha^{-1})	VCR	
		At harvest	3 months after harvest[1]
Traditional practice	1.8 a[2]	-	-
Recommended practice 200 kg NPK ha^{-1} and 100 kg urea ha^{-1}	3.1 b	2.4	4.3
Recommended practice plus 120 kg P_2O_5 ha^{-1} (rock phosphate)	3.4 b	2.5	4.5
Recommended practice plus 120 kg P_2O_5 ha^{-1} rock phosphate plus *Mucuna utilis*	3.4 b	2.1	3.8

[1] Storage costs are not taken into account.

[2] Values followed by the same letter are not significantly different (5%).

4.3.6 Off-site effects

The above discussion refers to private CBAs, that is to the landholder. This may, however, fail to take account of the full social costs imposed, or of the full social benefits obtained from a system of land management. Social CBAs and private CBAs will only give the same results if there are no significant environmental spillovers or externalities (off-site effects) from private decisions. For example, clearing of vegetation and more frequent cultivation of land in the headwaters of a river valley may increase the frequency and severity of flooding downstream, and may result in the increased deposition of sand and gravel. This would be factored into a social CBA as a cost in excess of the costs borne by landholders in the upland region (Tisdell, 1995).

In the majority of economic analyses downstream or off-site costs (e.g. of erosion), are omitted. The quantification of off-site impacts is still a major obstacle to their valuation. For instance, the redistribution of soil, a particular problem in scaling up results, has not been tackled yet in economic analyses. In most economic analyses soil is not moved but lost. This erroneous assumption results in cost overestimates (Enters, 1998).

Economists appear to agree that a CBA is the preferred method for valuing the costs of soil erosion, whether from a private or social perspective (Enters, 1998). The most critical question is not the cost of soil erosion *per se* but rather whether the long-term benefits of soil conservation measures make the current conservation costs worth bearing. To compare the benefits and costs over time the discount rate is crucial and a controversial topic especially where the project has environmental impacts. Approaches to solve this problem are discussed by Enters (1988) and Harou (1983, 1984), examples are presented by Francisco (1998).

4.4 Risk and stability

Farm enterprises are among those systems where disturbances are frequent as the laws of nature have an upper hand in agriculture. Fluctuations may occur due to erratic variations in rainfall, storms, insect attacks, diseases, and other factors. The objective of on-farm research should therefore not only be to improve the productivity of farmers' resources, and/or to reduce the costs of production, but also to increase the stability of production. It is usually necessary to consider stability and risks in both the agronomic and the economic analyses as well as for any sustainability assessment (see Introduction). Risk and stability are important factors for many farmers, especially subsistence farmers, whose practices often reflect attempts to reduce the natural risks of failure through diversification, flexibility, and a certain amount of liquidity to meet any calamities or misfortunes that may occur in the future. A common example of diversification is the use of mixed (local) bean varieties instead of a proposed selected one.

Risks and uncertainties affect the farmers' attitudes towards innovations and their adoption behaviour. They have to be differentiated between:

- Innovation-related risks. Their significance under farmers' socioeconomic conditions can be assessed together with the farmer in a participatory approach.
- Natural risks, which can be calculated by using statistical methods to indicate probability.
- Uncertainty, when there is no reliable information on future events.

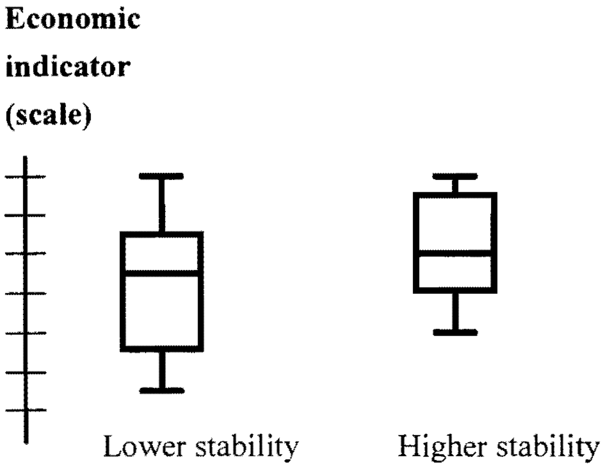
Risk is a probability phenomenon where outcomes are unknown and can be predicted only in a probability sense. By uncertainty, we mean any outcome or event that cannot be predicted precisely. One can, at best, guess a range within which an uncertainty can occur. While data on mean annual rainfall and variability indicate natural risk, uncertainty occurs on and off farm: On farm with respect to, for example, sickness and labour availability, off farm in view of, for example, market prices for inputs and outputs.

An example of an innovation-related risk is the introduction of *Mucuna* green manure as a substitute for cowpea or groundnut in the minor rainy season. This will reduce the availability of protein-rich food for the family and affect the gender-specific distribution of income over the year. Both can cause instability at different levels and may result in nonadoption. Participatory research, starting from the discussion of possible treatments to joint trial monitoring and evaluation will help to assess the importance of such risks for the farmer under his/her own socioeconomic situation.

4.4.1 Range of stability

A simple way to estimate and compare natural risks or the stability of treatment means over different farms, their socioeconomic and biophysical environments, as well as years, is possible by the computation of frequency distributions. The Box-Whisker-Plot, is a common and simple tool found in nearly all statistic software programmes; it allows us to visualize treatments that are stable over a range of conditions.

Box-Whisker-Plots show the median, range, and quartiles of, for example, C/B ratios across farms. A narrower range of treatment values means higher stability or better adaptability to different conditions. If two treatments show no significant different mean values, the one with the narrower range is preferable (Werner, 1993). This technique is appropriate if a relatively large number (n > 10) of participating farmers (treatment replications) is available.



Box-Whisker-Plots

An estimated margin around different likely means is a way to describe risks and uncertainties. Both can be addressed by analyzing the impact of these variations on the outputs by way of sensitivity analysis or systems' simulation through modelling. A very common method to reduce uncertainty about future prices ("discounting") was discussed in section 4.3.

4.4.2 Sensitivity analysis

Reworking an analysis to see what happens under changed circumstances is called sensitivity analysis. Sensitivity analysis is defined as the analysis of how errors (or variations) in one or more estimates could affect the conclusions drawn from these estimates (Johnson 1985).

All treatments or new technologies should be subjected to sensitivity analysis. In agriculture, most technologies are sensitive to change in four principal areas. These include: price, delay in implementation, cost overrun, and yield (Gittinger, 1984, p.365). In agroforestry systems, for instance, of special interest is the sensitivity of (relative) returns to changes in tree or crop yields (to take account of the effects of site conditions or climatic variability across sites or seasons); prices of tree or crop products, or their substitutes (to take account of variations in market access and seasonal prices); and prices of key inputs, such as labour (to take account of inter-household and inter-community differences in labour availability and cost) (Scherr, 1995). Sensitivity checks show the effect on the expected return of varying any one of these factors independently by, for example, *simply redoing a marginal analysis (partial budgeting) with alternative prices*. While providing no overall measure of the level of uncertainty, sensitivity analysis can identify the most critical areas of an investment project. It indicates the relative stability of an intervention and also the risks associated with adoption. In this way it may help to assess the second pillar of the FESLM, i.e. "the reduction of production risks" (see Introduction).

Examples of sensitivity analysis:

Two examples from IBSRAM and CIMMYT trials are given below to demonstrate different ways of conducting sensitivity analysis. A third example can be found in section 2.3. As revenue and expenditure vary with changes in output, price, and cost, a sensitivity analysis is undertaken normally to examine changes in the result of the B/C ratio due to probable changes in expenditure and/or revenue. This is done by simply changing cost and revenue by plus or minus a certain percentage. As revenue is a product of price and output, a 10% increase in revenue can be interpreted as a change singly in price or output or a combination of both.

In a test of different intercrops under *Hevea* by the Rubber Research Institute of Malaysia an actual profit of M$743 ha^{-1} was realized for groundnut as an intercrop (Table 21). Assuming no change in expenditure, a drop of 10% in revenue would result in the profit being reduced to M$513 ha^{-1}. As revenue is a product of price and output, a 10% drop in revenue could be interpreted as a drop singly in the price of groundnuts from M$1.10 to M$1.00 or the harvest dropping by 10% (price remaining the same). It could also be a combined 10% change of say 6% drop in price and a 4% decrease in output (Hassan *et al.*, 1991).

Table 21. Profit at +/- 10% changes in revenues and expenditures of groundnut in an experiment by IBSRAM's *ASIALAND* sloping lands network (Hassan *et al.*, 1991).

	Expenditures (M$)		
Revenue	-10%	0%	+10%
-10%	669	513	356
0%	899	743	587
+10%	1130	974	817

The overall result indicates that even in the adverse situation where a price drop of 10% is followed by an increase in expenditure by the same percentage, the investment is still viable as profit remains positive at M$356.00.

It is important to define clearly the assumptions made in the study to allow for a common basis for comparison with similar studies undertaken elsewhere. In an area where part of the field is used for the establishment of hedgerows or rubber trees, for example, it is essential to indicate if the cost and returns provided refer only to the area covered by the interplanted food crop or on a per unit area (e.g. hectare basis). In addition, the impact of the intercrop on rubber (benefit or competition) and the eventual increased returns from the rubber will be a factor that will also have to be taken into consideration (Hassan *et al.*, 1991).

As distances to markets differ, it is best that all costs be computed ex-farm. For comparison of revenue between crops, the price of the crop sold must be standardized to a common unit. For example while corn is sold on per fresh cob basis, groundnuts are sold on a per kilogramme basis. Standardization to price per kilogramme is therefore required.

In the second example, the increase of the N-fertilizer price was simulated (Table 22).

Table 22. Sensitivity analysis for nitrogen fertilizer experiment (CIMMYT, 1998).

	Case A (current field price of N = US$0.625 kg^{-1})			Case B (future field price of N = US$0.75 kg^{-1})		
	0 kg N	40 kg N	80 kg N	0 kg N	40 kg N	80 kg N
Adjusted yield (kg ha^{-1})	2000	2580	2930	2000	2580	2930
Gross field benefits (US$ ha^{-1})	400	516	586	400	516	586
Cost of fertilizer (US$ ha^{-1})	0	25	50	0	30	60
Cost of labour (US$ ha^{-1})	0	5	10	0	5	10
Total costs that vary (US$ ha^{-1})	0	30	60	0	35	70
Net benefits (US$ ha^{-1})	400	486	526	400	481	516
	MRR (change of benefit/change of costs)					
	0 kg N to 40 kg N = 287%			0 kg N to 40 kg N = 231%		
	40 kg N to 80 kg N = 133%			40 kg N to 80 kg N = 100%		

In case A, a field price for N of US$0.625 kg^{-1} was used. Our assumption is that the MRR will not reach the break-even point of 100% (additional benefit = additional costs). If the field price of N increases to US$0.75 kg^{-1}, would this assumption hold? Recalculating the partial budget (case B) with the higher price of N shows that an application of 80 kg N is now in doubt, because the MRR of changing from 40 kg N to 80 kg N is just equal to 100%. Any higher N prices would necessitate lowering the fertilizer recommendation.

Sensitivity analysis allows to map the *range* of viability, which is often of far greater utility than the estimation of probable rates of return based on current conditions.

Software used in this context is, for instance *@RISK* (Palisade Cooperation, 1995), which allows assessment of the uncertainty associated with the quantity and costs of labour, material inputs, etc. (Nelson *et al.*, 1998).

However, sensitivity analysis is not restricted to economic variables. Crop and soil modelling software packages, like DSSAT 3.1, allow simulations where the user can change as well the crop variety, the rainfall distribution, or the amount of N applied, to estimate the impact of such changes on crop yield and economic indicators. Systems simulation through modelling can largely facilitate the examination of the variability in output associated with selected strategies, and to identify those strategies that maximize returns and minimize risks. A special risk analysis component of DSSAT can evaluate several strategies simultaneously and provides an interpretative summary for decision makers (Godwin and Singh, 1989). Several examples for the application of systems approaches, including risk assessment, are given by Penning de Vries *et al.* (1993).

A key criterion for the quality of a potential innovation is the *risk of failure*, or seen positively, the chance of success to be expected. An appropriate basis for comparison is the farmer's present practice, which is usually the control treatment. Failure therefore means that the potential innovation did not achieve the yield level (returns to labour, IRR, etc.) obtained through the farmers' present practice on a particular farm. The simple calculation is:

$$\text{Risk of failure} = \frac{\text{Number of farms where the innovation failed}}{\text{Total number of farms involved in the trial}} \times 100\%$$

A better basis for comparison would be the result of the farmer's present practice *plus* a defined margin (e.g. 30%) because an innovation would be expected to be not only superior, but clearly superior to present cultivation practice (Werner, 1993).

GLOSSARY OF ECONOMIC TERMS

Benefits are goods and services that increase the income of farmers.

Costs are goods and services that reduce the income of farmers

Capital productivity per currency unit = gross return *minus* labour costs and land charges, divided by the number of currency units.

Compounding. To convert present expenditures to future values (see Appendix C)

Discounting. To convert future incomes to present values (see Appendix C)

Efficiency in general refers to the ratio of valuable output per unit of valuable input. One method of production is said to be more efficient than another when it yields a greater valuable output per unit of valuable input used.

Fixed costs apply to the farm as a whole, and are largely independent of, for example, land management changes, such as rent.

Gross margin per ha = gross returns ha^{-1} - variable costs ha^{-1}. The gross margin is the monetary value of total production (or a crop) per unit area after deduction of the variable input costs required (to produce this crop). It is a measure of what that enterprise is adding to farm profits. When a farmer has a choice between two or more possible uses of spare resources, he/she should choose the plan that gives the biggest gross margin.

Intensification is the process of increasing inputs per area unit. The level of intensity is determined by the total of inputs in terms of labour and capital that are allocated to an area unit. It has to be distinguished between

- labour intensity = labour input per unit area (e.g. man-days ha^{-1})
- capital intensity = capital input per unit area (currency units ha^{-1}).

Labour productivity per work unit (man-day, man-hour, man equivalent; see section 2.2) = gross return *minus* capital costs and land charges, divided by the number of work units.

Land productivity per area unit (ha, acre, feddan) = gross return *minus* capital and labour costs, divided by the area units.

Liquidity refers to the maintenance of balances of money or assets that can be readily converted into cash.

Marginal analysis. Analysis of the change in one variable (e.g. yield) when a small change is made in another variable (e.g. fertilizer level). The economic principle of marginal analysis states that it is profitable to continue to supply inputs to an enterprise, for example, fertilizer or seed, so long as the return from adding each unit, for example, each kilogram or bag of input exceeds the cost of that unit of input.

Marginal costs = change in costs

Marginal net benefit = change in net benefits

Marginal rate of return (MRR) = marginal net benefit divided by marginal costs; i.e. incremental gross margin between two treatments divided by incremental costs between two treatments.

ME (man equivalent): 1 man = 1; 1 woman = 0.75 ME; children <12 years = 0.25 ME; 12 - 16 years = 0.5 ME; >65 years = 0.5 ME (for other definitions see 2.2)

Mutually exclusive treatments are of a kind that implementing one necessarily precludes implementing another, for example surface irrigation vs. tubewell irrigation; planting now or two weeks later; manual clearing vs. mechanical clearing; etc.

Net farm income is sometimes called net income or net profit. It is the income from the business that pays for the farmer and his family's physical and managerial effort and interest on his own capital invested in the business. It includes the value of farm products consumed by him and his family so therefore it is not necessarily cash income.

Receipts = gross returns, gross income

Returns on labour = gross margin per unit of labour used to obtain the gross margin. The indicator shows the magnitude of gross margins obtained in relation to one unit of labour applied. It replaces the yield/labour ratio where labour and capital are affected by an innovation.

Return to investment refers to the productivity of capital invested in agricultural production.

Returns to variable costs = gross returns divided by the variable costs. The returns to variable costs relate the gross returns of the farm activity to its variable cost.

Revenue is a product of price and output, e.g. US$2 kg^{-1} x 100 kg = US$200.

Variable costs are the costs of adding the variable inputs, e.g. due to cropping changes, such as fertilizers or seeds.

Viability. If the efforts involved in a type of land management are smaller than the perceived benefits or rewards obtained, it is economically viable.

Yield/labour ratio = Yield of crop per unit of labour applied on crop. This ratio shows how much yield is obtained in relation to one unit of labour applied. It is used for experiments in which only the factor labour but not capital is affected by a potential innovation.

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Appendix A
Handouts and exercises

List of handouts:

1) Choice of economic methods and indicators
2) Labour conversions factors
3) Exercise: Factor productivity changes for 1 ha of maize production
4) Exercise: Cash flow of a 4-year cycle of sugarcane production
5) Exercise: Cash flow analysis of *Pyrethrum* establishment
6) Exercise: Internal rate of return calculation for sugarcane

All exercises refer to examples (and complete data sets) presented in the text.

HANDOUT 1 — Choice of economic methods and indicators (3 tables)

Some suitable economic indicators (Werner, 1993)

Production factor affected	Suitable economic indicator
Capital only	- gross margin + returns to variable costs (benefits) or + MRR (for systematically increasing levels of an experimental factor)
Labour only	- yield/labour ratio
Capital + labour	- gross margin + returns to variable costs or MRR + (monetary) returns to labour

MRR = marginal rate of return

Some examples of production factors affected by different trial types and the choice of economic indicators (Werner, 1993; modified)

Type of trial (examples)	Production factor affected*	Suitable economic indicator
Variety trial	Capital (costs of new variety higher than the local standard, but no systematically increasing levels of capital)	- gross margin + returns to variable costs
Fertilizer levels	Capital (costs of fertilizer systematically increasing)	- gross margin + MRR
Method of fertilizer application (e.g. once or split)	Labour (more for split application)	- yield/labour ratio
Application of organic manure	Labour (for collecting, processing, and application)	- yield/labour ratio
Alley cropping**	Capital (for seeds or seedlings) Labour (to establish and maintain alleys)	- gross margin + B/C ratio + (monetary) returns to labour

* The production factor of land is involved in all crop experiments. Returns on land (i.e. gross margins ha^{-1}) are therefore calculated for all these experiments.

** Trials involving perennial crops would, strictly speaking, require a (discounted) cash flow analysis.

Methods discussed in the tool kit and application examples

Method	Economic indicator	When/where to apply (examples)
Total/complete budgeting (not considered in the tool kit)		When a large, basic change is being considered that would affect most, perhaps all the farm costs (variable and fixed costs) and receipts, e.g. the establishment of a new farm.
Partial budgeting	Net benefit; MRR	"*Which would pay best*". This looks at the changes in (usually variable) costs and receipts due to a "marginal" change in farming. Useful for most innovations (if the changes in costs are not too small).
Break-even analysis	Break-even point	Determination of the point at which an innovation becomes (non-) profitable.
Cash flow analysis (budget)		Prediction of expected in- and outflows of cash for perennial systems, like agroforestry and soil conservation technologies.
CBAs	1. B/C ratio	1. Standard indicator; used also without discounting.
	2. VCR	2. Assessment of fertilizer use adoption without discounting.
	3. NPV	3. For mutually exclusive treatments with discounting.
	4. IRR	4. Less appropriate for smallholders (used with discounting).
	5. NBI	5. More appropriate for smallholders (partly usable without discounting).
Social CBA		Considers also off-site effects (externalities).
Sensitivity analysis	MRR	Risk and stability assessment

MRR = Marginal rate of return
CBAs = Cost-benefit analyses
B/C ratio = Benefit-cost ratio
VCR = Value-cost ratio
NPV = Net present value
IRR = Internal rate of return
NBI = Net benefit increase

HANDOUT 2 — Labour conversions factors

Labour conversion factors (Johnson, 1985; modified)

Labour class	Age (years)	Man-units or ME (man equivalent)	Equivalent man-days per month
Small child	less than 7	0.00	0
Large child	7 – 14	0.40	10
Male adult	15 – 64	1.00	25
Female adult	15 – 64	0.75 - 0.80	19-20
Male/female adult	65 or more	0.50	12.5
Small child	< 12	0.25	6.3
Large child	12-16	0.50	12.5

HANDOUT 3 — EXERCISE "Calculation of gross margins"

Factor productivity changes for 1 ha of maize production (Kenya)

Production level	Low input	High input	High input/mechanized
Yield (bags per 90kg)	25	37	37
Gross return (350 K.shs. bag^{-1})	8750		
	12 950		
	12 950 .		
Variable costs (K.shs.)			
Seed	470	470	470
Fertilizer	370	870	870
Chemicals	140	140	140
Bags	750	1120	1120
Transport	250	370	370
Contract work (K.shs.)			
Ploughing			1250
Harrowing			660
Sowing			335
Interrow cultivation			450
Spraying			140
Transport			370
Total variable costs (K.shs.)	1980	2970	6175
Family labour (hrs)			
Tilling	320	320	-
Sowing	80	80	-
Weeding	330	330	30
Harvesting	150	220	220
Threshing	72	105	105
Total family labour (hrs)	952	1055	355
Gross margin ha^{-1}			
gross margin hour^{-1}*			

Seed rate: 22 kg ha^{-1} i.e. about 44 500 plants ha^{-1}

Fertilizer: low: 3 bags DSP; high: 5 bags DSP, 2 bags ASN + 4 bags ASN for topdressing

* approx. labour productivity (if no costs for land).

HANDOUT 4 — EXERCISE "Calculation of net cash flow"

Cash flow of a 4-year cycle of sugarcane production in Kenya (1 ha, in K.shs.)

Year	Gross returns	Planting	Fertilizer	Weeding	Harvesting	**Net cash flow**
1		8500	1400	900		
2	12600		1400	900	2500	
3	9800		1400	900	2500	
4	7000		1400	900	2500	
Sum						

1st harvest after 18 months, yield = 90 t ha^{-1}, 1st ratoon after 15 months, yield = 70 t ha^{-1}, 2nd ratoon after 15 months, yield = 50 t ha^{-1}

HANDOUT 5 - EXERCISE “Is the innovation feasible?”

Cash flow analysis of *Pyrethrum* establishment in Kenya (in K.shs.)

	Year 0	Year 1	Year 2	Year 3	Year 4
Maize					
Area in ha	2.75	2.50	2.25	2.00	1.75
Gross return	11 220	10 200	9 180	8 160	7 140
Costs	4 950	4 500	4 050	3 600	3 150
Consumption	1 080	1 080	1 080	1 080	1 080
Net cash flow	5 190	4 620	4 050	3 480	2 910
Pyrethrum					
Area in ha		0.25	0.50	0.75	1.00
Yield (kg)	0	30	165	200	100
	0	0	30	165	200
	0	0	0	30	165
	0	0	0	0	30
Total yield (kg)	0	30	195	395	495
Gross return		324	2 106	4 266	5 346
Establ. costs		1 280	1 280	1 280	1 280
Running costs		65	120	71	71
			65	120	120
				65	65
Total costs		1 345	1 465	1 536	1 536
Net cash flow *Pyrethrum*		-1 021	641	2 730	3 810
Net cash flow holding	5 190	3 599	4 691	6 210	6 720

Parameters of maize production per ha: Yield 3400 kg, price kg^{-1} 1.20 K.shs., running costs 1800 K.shs, subsistence requirements of the family 900 kg maize y^{-1}.

Parameters of *Pyrethrum* production ha^{-1}:

Year	1	2	3	4
Yield in kg	120	660	800	400
Costs of establishment (K.shs.)	5 121			
Running costs (K.shs.)	259	478	285	

Price per kg = 10.80 K.shs.

Costs in K.shs. do not reflect actual prices (1999).

HANDOUT 6 — FOR EXERCISE "Calculation of IRR"

Internal rate of return calculation for sugarcane

Year	Net cash flow	Discounted at 20%		Discounted at 25%	
		Factor	Value	Factor	Value
1	- 10 800	0.833	- 8 996.40	0.800	- 8 640.00
2	7 800	0.694	5 413.20	0.640	4 992.00
3	5 000	0.579	2 895.00	0.512	2 560.00
4	2 200	0.482	1 060.40	0.410	902.00
Total	4 200				

Interpolation

IRR = 23%

Appendix B
Examples of field forms for data collection and analysis

- Farmer identity sheet
- Record sheet for field trials - innovation plot
- Record sheet for field trials - control plot
- Gross-margin calculation form
- Gross-margin calculation for control and innovation plots - an example

Source: Sedentary Farming Systems Project, Sunyani, Ghana (courtesy of Dr. Zschekel/ GTZ, modified).

Farmer identity sheet

Farmer ID: ______

Farmer's name: (household head)

Sex:

Location:

District:

Residential status:

Educational background:

Birth date:

Ethnic group:

Inventory date:

Size of farm:

Farmer's social context

Inventory date:

Farmer ID:

Persons living in the household:	Age groups of persons living on the farm: under 7 years of age	7 to 15 years of age	16 to 25 years of age	26 to 50 years of age	above 50 years of age

Farm relevant characteristics

Involvement of household head in farming:

full time	
part time	
seldom	

Distance from home to market: km

Number of persons regularly involved in farm activities: persons

Other sources of income for household head:

Employed persons regularly involved in farming:

Membership in associations:

ID = Identification number

Record sheet for field trials - Innovation plot

Farmer: ____________________ Location: ____________ District: __________

Area name: ____

Farm name: ________________ Tenancy agreement: __________________________

Type of innovation: ____

Plot size in sq m: ______	Soil type: ____________	Slope: _____ %	
Previous crop/land use:		Date:	Labour person hours:
Labour for clearing:			
Labour for soil preparation: crop/variety (main crop):			
Application of fertilizer/ manure (type, amount, application method date:	Type of fertilizer: Amount: kg Method:		
Planting date and person hours (main crop):			
Planting spacings in cm (main crops):			
Crop/variety (inter crop):			
Planting date and person hours (inter crop):			
Plant spacings in cm (inter crop):			
First weeding, date, and person hours:	Weed control method: Type of herbicide:		
Second weeding, date, and person hours:	Weed control method: Type of herbicide:		
Plant protection measures (type, method, date, person hours):	Control method: Type of pesticide:		
Harvesting main crop (date, yield, person hours):	Crop 1 yield:		
Harvesting intercrop (date, yield, person hours):	Crop 2 yield:		
Other comments:			

Record sheet for field trials - Control plot

Farmer: ______________ Location: ____________ District: __________

Area name: ____

Farm name: ______________ Tenancy agreement: ______________________

Type of control: ____

Plot size in sq m: ______	Soil type: __________	Slope: ____%	
Previous crop/land use:		Date:	Labour person hours:
Labour for clearing:			
Labour for soil preparation: crop/variety (main crop):			
Application of fertilizer/ manure (type, amount, application method date:	Type of fertilizer: Amount: kg Method:		
Planting date and person hours (main crop):			
Planting spacings in cm (main crops):			
Crop/variety (inter crop):			
Planting date and person hours (inter crop):			
Plant spacings in cm (inter crop):			
First weeding, date, and person hours:	Weed control method: Type of herbicide:		
Second weeding, date, and person hours:	Weed control method: Type of herbicide:		
Plant protection measures (type, method, date, person hours):	Control method: Type of pesticide:		
Harvesting main crop (date, yield, person hours):	Crop 1 yield:		
Harvesting intercrop (date, yield, person hours):	Crop 2 yield:		
Other comments:			

Gross-margin calculation form

Farmer: Location: District:
Entry date: Plot type: **Innovation plot**
Acreage: sq meters Test description:
Acquisitional status: Soil type: Slope: %

		Labour (hours)	Means of production	Specification	Quantity	Price/unit	Expenses
1st Crop cultivated							
	Soil preparation		Seeds Crop 1:		kg		
	Fertilizing		Seeds Crop 2:		kg		
	Planting Crop 1		Fertilizer		kg		
	Planting Crop 2		Pesticide		ltr		
			Herbicide		ltr		
2nd Crop cultivated							
	1st weeding		Tractor service		h		
	2nd weeding		Transport Crop 1				
	Harvesting Crop 1		Transport Crop 2				
	Harvesting Crop 2		Hired labour		md		
	Processing						
	Total						

Yield Crop 1: kg Farmgate Price/unit: Present value: Balance Crop 1+2:
Yield Crop 2: kg Farmgate price/unit: Present value: Gross margin/h:
Yield/ha Crop 1: kg Gross margin/ha:
Yield/ha Crop 2: g md = man-day

Farmer: Location: District:
Entry date: Plot type: **Control plot**
Acreage: sq meters Test description:
Acquisitional status: Soil type: Slope: %

		Labour (hours)	Means of production	Specification	Quantity	Price/unit	Expenses
1st Crop cultivated							
	Soil preparation		Seeds Crop 1:		kg		
	Fertilizing		Seeds Crop 2:		kg		
	Planting Crop 1		Fertilizer		kg		
	Planting Crop 2		Pesticide		ltr		
			Herbicide		ltr		
2nd Crop cultivated							
	1st weeding		Tractor service		h		
	2nd weeding		Transport Crop 1				
	Harvesting Crop 1		Transport Crop 2				
	Harvesting Crop 2		Hired labour		md		
	Processing						
	Total						

Yield Crop 1: kg Farmgate Price/unit: Present value: Balance Crop 1+2:
Yield Crop 2: kg Farmgate price/unit: Present value: Gross margin/h:
Yield/ha Crop 1: kg Gross margin/ha:
Yield/ha Crop 2: g md = man-day

Gross-margin calculation for control and innovation plots - Example

Farmer: Ashong Kwasi	Location: Behlehem/Adawi	District: Sunyani
Entry date: 04/09/97	Plot type: **Innovation plot**	
Acreage: 400 sq meters	Test description: *Mucuna* cover crop under maize	
Acquisitional status:	Soil type: Acrisol	Slope: 5%

		Labour (hours)	Means of production	Specification	Quantity		Price/unit	Expenses
1st Crop cultivated								
Maize	Soil preparation	4.0	Seeds Crop 1:	Maize	0.5	kg	1500 ¢	750 ¢
	Fertilizing	0.0	Seeds Crop 2:	*Mucuna*	0.0	kg	0 ¢	0 ¢
	Planting Crop 1	4.0	Fertilizer		0.0	kg	0 ¢	0 ¢
	Planting Crop 2	4.0	Pesticide		0.0	ltr	0 ¢	0 ¢
			Herbicide		0.0	ltr	0 ¢	0 ¢
2nd Crop cultivated								
Mucuna	1st weeding	6.0	Tractor service		0	h	0 ¢	0 ¢
	2nd weeding	6.0	Transport Crop 1		0		0 ¢	0 ¢
	Harvesting Crop 1	4.0	Transport Crop 2		0		0 ¢	0 ¢
	Harvesting Crop 2	0.0	Hired labour		0	md	0 ¢	0 ¢
	Processing	0.0						
	Total	28.0						750 ¢

Yield Crop 1: 108.4 kg	Farmgate Price/unit: 200 ¢	Present value: 21 680 ¢	Balance Crop 1+2: 21 830 ¢
Yield Crop 2: 5.0 kg	Farmgate price/unit: 180 ¢	Present value: 900 ¢	Gross margin/h: 780 ¢
Yield/ha Crop 1: 2710 kg			Gross margin/ha: 545 750 ¢
Yield/ha Crop 2: 125 g	md = man-day	¢ = cedis (2300 ¢ ≈ 1 US$)	

Farmer: Ashong Kwasi	Location: Behlehem/Adawi	District: Sunyani
Entry date: 04/09/97	Plot type: **Control plot**	
Acreage: 400 sq meters	Test description: Weeding neglected on control plot	
Acquisitional status:	Soil type: Acrisol	Slope: 5%

		Labour (hours)	Means of production	Specification	Quantity		Price/unit	Expenses
1st Crop cultivated								
Maize	Soil preparation	4.0	Seeds Crop 1:	Maize	0.5	kg	1500 ¢	750 ¢
	Fertilizing	0.0	Seeds Crop 2:	*Mucuna*	0.0	kg	0 ¢	0 ¢
	Planting Crop 1	4.0	Fertilizer		0.0	kg	0 ¢	0 ¢
	Planting Crop 2	0.0	Pesticide		0.0	ltr	0 ¢	0 ¢
			Herbicide		0.0	ltr	0 ¢	0 ¢
2nd Crop cultivated								
Mucuna	1st weeding	6.0	Tractor service		0	h	0 ¢	0 ¢
	2nd weeding	6.0	Transport Crop 1		0		0 ¢	0 ¢
	Harvesting Crop 1	4.0	Transport Crop 2		0		0 ¢	0 ¢
	Harvesting Crop 2	0.0	Hired labour		0	md	0 ¢	0 ¢
	Processing	0.0						
	Total	18.0						750 ¢

Yield Crop 1: 61.8 kg	Farmgate Price/unit: 200 ¢	Present value: 12 360 ¢	Balance Crop 1+2: 11 610 ¢
Yield Crop 2: 0.0 kg	Farmgate price/unit: 0 ¢	Present value: 0 ¢	Gross margin/h: 645 ¢
Yield/ha Crop 1: 1545 kg			Gross margin/ha: 290 250 ¢
Yield/ha Crop 2: 0 g	md = man-day	¢ = cedis (2300 ≈ 1 US$)	

Appendix C
Discounting and compounding

Discounting: The information needed to convert future incomes to present values includes the amount of the future income, the time at which the income is expected, and the rate of interest which the producer is willing to accept. This can be shown by the following equation:

$$P = F/(1 + r)^n \text{ or } P = F[1/(1 + r)^n]$$

where P = present value, F = future value, r = rate of interest for the time period in decimals, n = number of time periods (e.g. years). The expression **$[1/(1 + r)^n]$** is called the discount factor (or discount rate) or present value factor.

The appropriate rate of interest depends upon the earning power of investment in alternative uses. With high rates of interest, short-term investments are relatively more profitable than long-term investments. On the other hand, a decrease in the rate of interest will tend to cause people to invest in enterprises with longer production periods. For long-term environmental impact studies the real discount rate instead of a nominal discount rate to take care of inflation is recommended (cf. Harou, 1983; Johnson, 1985, p. 88).

Compounding: An alternative means of comparing net revenues received over different periods of time is to compare the future value of present costs with future incomes. Converting present expenditures to future values is called compounding of costs. In the event that an investment of funds is made in the production of, for example, orange trees that have a production period of several years, costs are compounded from the initial investment, using the rate of interest and the time period under consideration. It is expressed by the following equation:

$$F = P(1 + r)^n$$

where F = future value, r = rate of interest for the time period in decimals, P = present value, n = number of time periods.

For example, the future value of US\$5000 invested now at 25% compound interest paid annually for three years is US\$5000 $(1 + 0.25)^3 = 5000 \times 1.25^3 = 5000 \times 1.953125 = 9765.62$. If US\$5000 now, at an interest rate of 25% paid at the end of each year, is worth US\$9766 in three years' time, then conversely, the present value of US\$9766 to be received in three years' time is US\$5000 (cf. Johnson, 1985).