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Intercropping with Cassava

Proceedings of an international workshop held at Trivandrum, India, 27 Nov–1 Dec 1978

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Cosponsored by the
Central Tuber Crops Research Institute (Indian Council for Agricultural Research)
and the
International Development Research Centre

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Agroeconomic Considerations in Cassava Intercropping Research

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Many cropping systems programs do not have agricultural economists as part of their core staff. As a result, if cropping pattern experiments are to be analyzed and interpreted from an economic viewpoint, it is often necessary for the biological scientists to undertake these analyses — in a similar manner as they are responsible for their statistical analysis. In other situations where newly trained agricultural economists are members of cropping systems programs, or where they are new members of teams, it is useful, as a point of departure for the biological scientists to have some notion of what to expect from this particular member of their team.

Within cropping systems programs, agricultural economists should be expected to play major roles in:

(a) helping to define the environment (biophysical, technological, socioeconomic) for which new innovations will be designed;
(b) contributing to the design, analysis, and interpretation of experiments conducted with the view to increasing agricultural productivity in selected target areas;
(c) formulating production recommendations; and
(d) evaluating post release, the impact of new innovations emerging from the cropping systems research.

The contributions of this paper are thus as follows. Initially, a framework in which cassava-based cropping systems research may be set is presented. The purpose of the approach is to increase the probability of relevant technical innovations being developed for specific target groups of cassava farmers. Following this, economic considerations related to crops grown in intercropping patterns are reviewed and the use of budgeting techniques to evaluate cassava-based intercropping patterns discussed. Finally, the environment in which proposed innovations should be evaluated, it is argued, should be derived from farm focus, as opposed to research station studies. The evaluation should include both pre-release and postadoption studies of technology and should be structured in a manner to provide a feedback to contribute to the future orientation and priorities in research programs.

A Model for Cassava Intercropping Research

One possible framework for structuring a problem-oriented research program focusing on cassava-based cropping systems is shown in Fig. 1. The crop, the farmer, and his environment are focal points in the approach. The farmer is included in the scheme in the sense that he contributes, implicitly at least, to the identification of priority areas for biotechnical research and explicitly to the evaluation of the relevance of innovations evolving from the research. By implication, farmer and farm-focused research are stressed when identifying problem areas and potentials for research, and in the adaptive and evaluation phases of the research process (Dillon et al. 1978).

However, although the existing farming system, and the focus on adaptive research with a short-term payoff, are important when attempting to solve the real-world production problems faced by farmers, it is critical that the associated "investment" type research necessary to support the applied research is not ignored in the drive for a short-term payoff from the applied research.1 Often, while the major-

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1The desirable balance between adaptive and investment research, of course, cannot be generalized. Cassava represents an example of a crop where little investment research has been undertaken when compared with other major staples (e.g., rice, maize, wheat, sorghum, potatoes), and where the potential payoff from breeding and associated support research appears to be enormous. Indeed, in the author's view, a number of the high- and stable-yielding varieties of cassava developed by Hahn and his colleagues at IITA represent as significant a technological development for the African continent at least, as the more widely known and acclaimed modern varieties of rices and wheats.
"Phase"

**Research**

**ADAPTIVE RESEARCH**

- AGROECONOMIC SURVEYS AND ANALYSIS OF TARGET FARMERS AND THEIR FARMING SYSTEMS
- IDENTIFY LIMITING FACTORS AND RESOURCE POTENTIALS
- DESIGN IMPROVED CROPPING PATTERNS AND CULTURAL PRACTICES
- CONDUCT CONSTRAINT-ORIENTED APPLIED RESEARCH
- ON-FARM TESTING AND ADAPTATION OF PRACTICES
- INTEGRATED TESTING AND EVALUATION
- RECOMMENDATIONS FOR EXTENSION TO FARMERS
- ACCEPTANCE/MODIFICATION/REJECTION OF TECHNOLOGY BY FARMERS

**INVESTMENT-ORIENTED RESEARCH**

- DISCIPLINARY-FOCUSED RESEARCH PRIORITIES
- BREEDING
  - PHYSIOLOGY
  - PATHOLOGY
- SOILS
  - etc.
- MARKETING
  - DECISION-MAKING
  - INSTITUTIONS
- INFRASTRUCTURE POLICY

**Fig. 1.** Conceptual outline of a farmer-focused cropping systems research and application program.
ity of the adaptive research and evaluation will be conducted by multidisciplinary agronomically focused programs, the more "pure" research may more efficiently be conducted within disciplinary-oriented research programs.

In Fig. 1, the focus is on research designed to ameliorate biotechnical factors that limit the productivity of cassava-based cropping systems. Yet many constraints to increasing the supply of food crops are not biological or farm-based in nature. For example, problems or limitations in processing the cassava or related crops, transporting them to markets, procuring inputs when required, and crop and input prices, may be dominant constraints — and more difficult to change — than the biological ones (Flinn 1976). Thus, an effective program in cassava-based cropping systems must be designed with an awareness of the implications of these constraints on the feasible set of new innovations emerging from the research program.

Agroeconomic Studies of Cassava-Based Cropping Systems

Often, scientists, extension workers, marketing and consumer groups, and planners do not provide the directors and administrators of agricultural research projects with the necessary information to enable them to make the best decisions as to priorities in agricultural research. This problem tends to be more acute in the developing than the so-called developed world, and for cassava-related research in particular. There are several reasons for this. First, in many instances where the farm family provides the majority of the labour, where land is not freely sold, and where the bulk of the crop produced is for family sustenance, the market prices for these items that planners and entrepreneurs gain access to, need not reflect their true values to the farmer. As a result, the "demand-induced" concept with prices influencing priorities for agricultural research as demonstrated by Hayami and Ruttan (1971) may not be terribly effective in such cases. Secondly, low resource farmers may not recognize or relate the yield-limiting factors in cassava production to the real causal agents, nor, even if they do, are they often in the position to make researchers aware of the factors that effectively limit the yield of crops. Thirdly, in many cases, the priorities, methods of production, and the environment in which the small farmer operates are not well appreciated or related to by researchers. As a result, researchers tend to have an imperfect understanding of the real constraints and the interaction of these constraints at the farm level, and may have difficulty translating the real production problems faced by farmers into research projects with design criteria for fabricating new technologies that are appropriate, given the conditions of low resource farmers.

Given the above problems of identifying research projects with the highest expected payoff to farmers, farm-focused agroeconomic studies provide a basis to either confirm, modify, or establish the scientist's impressions of priorities in cassava-related research (including design criteria), and provide background information for site selection for field trials and for farmer evaluation of technology. Four types of studies are particularly useful as sources of information for the design of research programs in those instances where farming systems are imperfectly understood or where there is a communications gap between the researcher and the farmer (Table 1).

Initial descriptions of cassava production, processing, consumption, and marketing may be obtained through single visit enumeration of informants and by focusing on cassava-related aspects of the farming systems. These surveys, referred to as baseline surveys in this paper, often combine broad cross-sectional surveys of a large number of farmers with more in-depth surveys of key informants, and enable the researchers to identify at least quantitatively:

(a) by whom and how the cassava crop is grown, in which cropping patterns and soil types is it an important component;
(b) what are the major factors (biophysical and agroeconomic) influencing the crop's production;
(c) for what purposes does the farmer produce various cultivars of cassava;
(d) how, and which components of the crop are consumed, processed, and marketed, and at what prices;

The methodologies and problems involved in conducting different types of agroeconomic surveys of low resource farmers have been widely discussed (e.g., Collinson 1972; Kearl 1976; Binswanger and Jodha 1976). Categories of information that are regarded as valuable from baseline surveys are provided by Banta (1977), Collinson (1978), and Norman and Palmer-Jones (1977).
Table 1. Typologies of agroeconomic surveys for production-oriented research in cassava.

<table>
<thead>
<tr>
<th>Type of survey</th>
<th>Characteristics</th>
<th>Typical visiting frequency</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline studies</td>
<td>Broad overview of cassava-based production systems</td>
<td>Single</td>
<td>Ezelo et al. 1975</td>
</tr>
<tr>
<td>Bioeconomic studies of yield-limiting factors</td>
<td>Identify factors that reduce on-farm yields of cassava and quantify their importance</td>
<td>Few visits, based on physiological development of the crop</td>
<td>Pinstrup-Andersen et al. (1975)</td>
</tr>
<tr>
<td>Intensive (&quot;cost-route&quot;) farm management surveys</td>
<td>Detailed description and analysis of cassava production and use within a whole farm context</td>
<td>Multiple, frequent visits</td>
<td>Lagemann (1976)</td>
</tr>
<tr>
<td>Adoption and evaluation surveys</td>
<td>Evaluate the farmer’s reaction and attitudes to new packages, evaluate factors limiting packages’ adoption</td>
<td>Single</td>
<td>Okali and Borti Doku (1978)</td>
</tr>
</tbody>
</table>

*aExcluding marketing and policy-oriented studies, see Johnson (1963) and Jones (1959) in this regard. The survey, of course, should not be the first activity in the process. A review, analysis, and interpretation of relevant background information available for the region are vital to help guide the field work and focus the investigation.*
(e) what are the farm resources and infrastructural support available that will influence the farmer's capacity and desire to adopt new innovations.

Ideally, the baseline studies should focus on cassava from a wide range of viewpoints; to be most effective, and to increase the probability of the inferences drawn from the work being credible to others requires that the studies be collaborative; for example, with a core staff of an agronomist and a farm management economist and where necessary, drawing on the expertise of pathologists, entomologists, etc.

A merit of single-visit, baseline surveys is that they can be completed quickly and provide rapid feedback to scientists on a range of problems and potentials related to cassava research. The procedure also serves as a basis to (Price 1977, p. 3):

(a) identify practices currently used by farmers that can be further and rapidly exploited by applying existing scientific knowhow;

(b) determine the benefits that farmers receive from present practices so that by comparison, the likely acceptability of new patterns can be assessed; and

(c) obtain a measure of present conditions in target areas so that the impact of the cropping systems research can be eventually evaluated.

Although baseline surveys provide a broad overview of cassava within existing farming systems, and provide in most cases qualitative data on factors limiting production, they do not normally enable the relative magnitude and importance of these factors to be precisely quantified. A more intensive approach using multiple visits to selected respondents is usually required to quantify these relationships at the field or farm level. Pinfstrup-Andersen and Diaz (1975) and Pinfstrup-Andersen et al. (1976) provide excellent examples of how repeat observations on farmers' crops (timed to coincide with the major physiological stages of its development) when plots are scored for pest, environmental, and management parameters, enable the impact of various yield-limiting factors on yields to be quantified. The basis of the approach adopted by Pinfstrup-Andersen requires that observations are taken from a large number of farmers' fields; due to differences between fields in relation to the incidence of pests and diseases, climate, soil characteristics, crop management and yield, the impact of each of these factors on productivity is assessed.

If the contribution of the various yield-limiting factors are to be quantified, it is necessary that considerable differences exist between observed plots in the incidence of factors that influence yields. The required variability between plots is not always found. For example, some cassava diseases may be endemic over very large areas (e.g., CMD in West Africa), or there may be a high degree of similarity in some aspects of crop management (e.g., minimal or no use of fertilizer). In this instance, an alternative approach, one adopted by the "Constraints Program" Network of the International Rice Research Institute may be considered.

The purpose of the Constraints Program was to develop a procedure to measure the contribution of biological and socioeconomic factors that result in farmers' yields of rice being lower than potentially achievable on their fields (De Datta et al. 1978; IRRI 1977a). Briefly, the approach used a combination of field experiments located on farmers' fields and farm surveys. The field experiments were used to estimate potential farm yield, actual farm yield, and the contribution of the various management factors to this yield gap. The agroeconomic farm surveys were designed to provide insights to explain why the levels of inputs necessary for higher rice yields were not being applied by farmers. Although the procedure was developed for rice, the principles and logic of the approach suggest it could be adapted to evaluate the on-farm yield potential of cassava-based intercropping systems, and the contribution of important management factors to the gap that exists between actual production and potential production.7

A feature of plot-focused field investigations of cropping patterns is that they tend to be more successful in quantifying the impact of various management and biophysical factors on yields than explaining why farmers apply some inputs at what appear to be suboptimal ways or levels. This limitation is partly because the decision-making framework of the farmer is imperfectly incorporated in the analysis at the field level, and partly because the analysis of a field fails to consider the allocation of resources between competing uses at the farm level.

Intensive, often referred to as "cost-route" studies, of cassava-based farming systems have been conducted and provide extremely detailed information on the production and role of cassava within a whole farm framework (e.g. Lagemann 1976). A feature of the cost route approach is that through frequent visits to a select group of farmers, an extremely detailed picture of cassava production sys-

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6Baseline surveys will provide the researcher with evidence of the variability in the levels of pest incidences and management factors (and the level of confounding that exist between variables) and as a result an indication of the likely success if this approach is adopted.

7Some interesting statistical challenges may emerge in the analysis of the yield components of the cassava and the companion crop. Pearce and Gilliver (forthcoming) are developing statistical procedures related to the intercrop situation.
tems within an integrated farm framework may be developed. These studies are demanding on personnel, expensive and time consuming, and specific findings of the research are unlikely to be available for at least 2 years after the project is initiated. By that time, scientists and administrators will have already made their minds up as to what are research priorities, so such studies tend to be more noted for their interest as opposed to effectiveness in short-run research decision-making. However, the long-term payoffs from such studies in fostering collaborative research between scientists, in their training as to the realities of farm families and their farming systems are substantial.

Economic Analysis of Cassava-Based Intercrops

Competition and the Principle of Marginality

When two or more crops are grown on the same piece of land, with a given level of inputs and their growth cycles overlap, their production will be related in one of three basic ways (Fig. 2). The two crops may be competitive, wherein the output of one crop can only be increased at the expense of the other; or complementary, wherein an increase in the output of one crop will also bring about an increase in the production of the other; or supplementary, wherein the output of one crop tends to be independent of the output of the other.8

Within many "agronomically realistic" cassava-based intercropping systems it appears that the yields of the two crops tend to be biologically independent over normal ranges of plant populations. IITA (1976), for example, cites examples of cassava/maize intercrops where supplementation existed in production. This particular relationship is most likely in those cases where the maximum demands on the environment by the two crops occur at different times. However, in most instances, increasing the output of one component crop, at the limit, is only achieved at the expense of the other. That is, the crops are competitive in the production system, which seems to be the situation, for example, when cassava is light stressed by the companion crop during the early stages of its growth. CIAT (1976, p. B-66), for example, reported a

8Heady (1952) provides an extensive presentation of production relationships.

![Fig. 2. Production possibilities for two crops, Y1 and Y2, in an intercrop.](image)
competitive relationship for a series of cassava/bean intercrop.

Even if there tends to be a degree of biological independence between cassava and the alternative crop grown in the mixture under normal management practices, the farmer is still faced with the question of deciding:

(a) which crop is it “best” to grow in association with the cassava;
(b) what are the “best” populations of cassava and the companion crop to grow;
(c) what are the “best” combinations of other inputs (e.g., labour, fertilizer, insecticide) to apply to the intercrop?

The low resource farmer will tend to make these production decisions jointly and intuitively. However, the three have been separately identified for discussion purposes because although the farmer determines the cropping pattern and density of the component crops, to a large extent, the benefits from other inputs applied to the intercrop (e.g., fertilizer, weeding) are internally allocated to the component crops, not by the farmer, per se.

The “best” combination of crops to grow and inputs to use will depend on the objective(s) the farmer seeks to achieve by growing the crops, the resources available and the constraints that limit his choices and freedom in meeting his production objectives. In production, there are gains (the output produced) and losses (the inputs used to produce the crops), the net gain from the intercrop being the differences between gains and losses. Normally, the “best” combination of inputs is that which maximizes net gain, appreciating the limitations imposed on the farmer’s freedom of choice. To estimate a meaningful net gain requires that both output (gains) and inputs (losses) are measured in the same units.

The unit of measure used to assess the productivity of a cropping system must satisfy several criteria (Hildebrand 1976, p. 349):

(a) it must be common to all products and inputs and provide a means of comparing different cropping systems;
(b) it must be relatively easy to measure;
(c) it must be capable of reflecting quality differences between the products; and
(d) the unit of measurement must be meaningful to the farmer in such a way that it helps him allocate his resources between competing uses.

In addition to the criteria prepared by Hildebrand:
(e) the unit of measurement must be meaningful to the researcher so he can compare new innovations with existing ones.

For convenience, indices of productivity may be classified as physical measures and economic measures.9 The most commonly used physical units of productivity are energy, protein, and dry matter. These indices are extremely useful when measuring the gross physical output of a production process. However, problems arise when measures of net gains are required in these units as it is difficult to measure many inputs in the same physical units. Thus, while physical indices enable the gross output of intercropping systems to be compared over space and time, they are less useful when measuring net outputs. The most robust of the physical measures — for the low resource farm situation in particular — is energy, as both the food output of a cropping system and the major input under the farmer’s control, i.e., his labour, can be reasonably measured in energy terms. As a result, the productivity of various agricultural systems have been compared in these terms (e.g., Makhiyani 1975).

However, the only index that meets all five criteria is the economic indicator of price or value, as reflected in the market price of the goods produced, and inputs or services used in production. For this reason, the measurement of gains and losses of cropping patterns used in this paper are in economic terms.

One weakness of the market price criteria, as previously mentioned, is that they may not always reflect the true values to the decision-maker of products and scarce resources. In these instances, opportunity costs or values should be used (this point will be revisited). What may be regarded as a further weakness of market prices is that prices differ between locations and change over time, thus making comparisons over space and time of cropping systems more involved.10 Although this is true, it is also a strength of the market price criteria in the sense that it enables the economic combinations of inputs used and crops produced to be tailored to specific and changing economic conditions.

The theory that provides the basis for identifying the economically optimal combination of crops to grow and inputs to use is presented in several excellent texts (e.g., Dillon 1977; Heady 1952; Heady and Dillon 1961). These texts focus on the situation where crops are grown as sole crops, and where the manager can control the inputs allocated to the various production processes. However, the conditions for allocating resources in an intercrop where the farmer has little control of the allocation of inputs between crop components are not explicitly covered in these texts.

9Excluding physical indicators such as land equivalent ratio, multiple cropping index, etc.
10Economists have means of adjusting values to remove time and space effects (e.g., Thomsen and Foote 1952).
Identifying the economically efficient combination of resources to use in an intercrop is conceptually straightforward; the decision-maker should keep using additional units of a productive input as long as the use of the added input earns or saves more money than it costs. That is, for the intercrop, it pays to add inputs so long as

$$\Sigma p_i \Delta Y_i > p_X \Delta X$$

where $$\Delta Y_i$$ is the increment in output of the $$i^{th}$$ crop component of the intercrop brought about by an increase in input use of $$\Delta X$$; $$p_i$$ is the field price per unit of crop $$Y_i$$; and $$p_X$$ is the field price of the input $$X$$.

Because agricultural production is usually subject to diminishing returns to variable inputs (i.e., for additional and similar increases in $$X$$, smaller and smaller, and eventually negative increments in $$Y$$ occur), the inequality in equation 1 will continually diminish until:

$$\Sigma p_i \Delta Y_i = p_X \Delta X,$$

and if excessive quantities of inputs are used,

$$\Sigma p_i \Delta Y_i < p_X \Delta X,$$

which implies that the added cost of the input exceeds the added value of output.

Equation 2, which identifies the economical level of an input to use, can be rearranged as:

$$\Sigma p_i \frac{\Delta Y_i}{\Delta X} = p_X,$$

where $$\frac{\Delta Y_i}{\Delta X}$$ is referred to as the “marginal product” of $$X$$. When the marginal product of an input as multiplied by the product price (i.e., the left-hand side of the equation), the term is referred to as the “marginal value product.”

If there are many variable inputs in the production process, denote the $$i^{th}$$ input by $$X_i$$; equation 4 is then generalized to:

$$\Sigma p_i \frac{\partial Y_2}{\partial X_i} = p_X,$$

From the above, it is apparent that the optimal combination of inputs to use in an intercrop will depend on:

(a) the prices of inputs and products; and
(b) the biological relationships that prevail between the output of the crop components of the intercrop and the inputs applied to the cropping pattern.

The algebraic function used to describe the relationship between inputs used and the resulting physical crop production are referred to as “response” or “production” functions and may be empirically approximated from experimental and farm-based data (Dillon 1977, chap. 5).

In those situations where estimates of the underlying production function exist along with prices, the optimal levels of inputs to use in the intercrop can be quantitatively derived. To restate the necessary condition, it is beneficial to increase the levels of inputs to a production process until the value of their marginal product to the intercrop equals their prices. The conditions, referred to as the “equi-marginal principle,” provide the underpinning to guide decision-makers on the optimal level of inputs to use and crop densities to establish, and a procedure to assess whether farmers are using inputs at economically optimal levels (e.g., Mandac 1978; Sahota 1968; Shapiro 1976; Welsch 1965).

Although the production function approach provides the conceptual underpinning for efficient resource allocation, the author is unaware of examples of its successful empirical application to cassava-based cropping systems. Difficulties encountered when applying production function analysis to this rather complicated type of production process include the following:

(a) Normally, there are many products of value produced in the intercrop that may be harvested over an extended time period. For cassava, there may be roots, leaves, and stems. It is difficult to estimate production functions (and their interrelationships) for each of these products and crops;

(b) Some of the costs and benefits (e.g., soil depletion and conservation aspects) of alternative management strategies cannot be easily included in the analysis;

(c) Experiments designed to provide the necessary data to generate the response relationships are extremely expensive and time consuming to conduct (even if there are no statistical problems in estimating the response functions);

(d) The complexity of the experiments normally will require that they be conducted under experimental conditions, under the control of a researcher, not a farmer. Thus, the results obtained and inferences drawn are unlikely to be applicable to the farm situation; and

(e) Farmers are operating in an uncertain environment. Their preferred use of inputs will usually be less than identified as desirable in a riskless situation.

11Unlike the sole crop situation, the marginal value product of an input in an intercrop situation is the sum of the marginal products of the component crops relative to that input.

12For an extensive and current bibliography of the application of these principles to resource allocation in agriculture, see Dillon (1977).
Budgeting

Although the concept of marginality provides the intuitive logic for designing what are hoped to be efficient combinations of input levels to apply and crop combinations to grow in the cropping pattern, researchers tend to rank the attractiveness of a discrete number of patterns and associated cultural techniques using the more direct budgeting technique. In this way, the net benefits of alternative technologies are ranked in relation to a number of choice criteria, where the appropriate criterion is that which maximizes the productivity of the system in relation to the most limiting factor(s) in the production process. The most commonly used numerator is economic benefit, while commonly used denominators are land, labour, capital and, in some areas, water.

A procedure for evaluating the benefits of cassava-based intercropping systems is shown in Table 2. In the format provided, the choice criterion is return per unit of land. The direct benefits from a cropping pattern will normally include the value of the primary components harvested, and probably a number of secondary products. The cassava yield used in the analysis, incidentally, should be that component of the total yield the farmer would be expected to harvest, not the total physiological production of roots as often reported in experimental work.

In most low resource farmer situations, labour costs dominate in terms of money costs and opportunity costs. Correctly estimating the opportunity cost of family (and exchange) labour is difficult. For family labour, the opportunity cost usually used for budgeting purposes is the wage that the person could earn in off-farm employment, the value of time if spent on another farm activity, and the value that the worker places on leisure. The last three values are difficult to measure in a partial context. As a rule of thumb, Perrin et al. (1976) assumed the opportunity cost of labour was 125% of the going agricultural wage in seasons when farmers were expected to be very busy, and between 50 and 75% of that rate in slack seasons. Of course, the opportunity cost of different members of the farm household may vary considerably, depending on the work alternatives available to them.

The budget in Table 2 generates net benefits per unit of land. Often this is not the most limiting factor in the production process. As a result, returns are normally computed per unit of land, labour, and capital. The outline in Table 3 provides a means of evaluating and comparing intercropping patterns in a nontime-discounted situation, in terms of various scarce resources, both as total inputs, and the return to selected resources during the period of greatest expected scarcity. These ratios enable the suitability of selected cropping patterns and management techniques to be evaluated and ranked under wide variations in factor supplies, and the most appropriate cropping patterns identified for specific situations.

The "timeless" procedure outlined above becomes limited when the elapsed time from planting to harvest is other than short term, or when different cropping patterns or management practices have input costs and revenues occurring at different points in time. Both these situations are typical of cassava-based cropping patterns, and when comparing cropping patterns that include cassava with ones that do not. Thus, it is appropriate to discount gains and cost to a common point in time to enable alternative cropping patterns to be compared on the same basis. There has been considerable discussion but little agreement in the literature as to what are appropriate discount rates to apply to the small farm situation (e.g., Lim 1975; O'Mara 1971). Each individual's discount rate will vary according to his time preference for consumption, his opportunity cost of capital, and his level of risk aversion; also, the appropriate discount rate may vary over time and for different decisions. These factors are difficult to quantify, but as a general guide it is likely that:

(a) poor farmers have higher discount rates than rich farmers;
(b) farmers with profitable investment alternatives, or stringent necessities, have higher discount rates than others; and
(c) farmers who live in a natural environment that imposes high risks on them will have greater discount rates than others.

Perrin et al. (1976, p. 33) used a 40% discount rate in their analysis of (maize-based) cropping systems; the components were 20% riskless time rate of discount, and a risk premium of a further 20%. This (or most any other) discount rate can only be justified on intuitive grounds; many would claim the 40% is low and that the riskless time rate of discount to use for the low resource farmer should be closer to 50 or 100%. Further, although the riskless time rate of discount (often equated with the cost of borrowing capital) faced by different groups of farmers may be relatively easily estimated, the "risk premiums" may differ markedly between investment alternatives (i.e., cropping patterns) and farmers. However, the point is that the appropriate discount...
### Table 2. Structure of budget to assess the benefits of alternative cassava-based cropping systems.

#### A. Benefits

<table>
<thead>
<tr>
<th>Activity</th>
<th>Unit</th>
<th>Harvested primary</th>
<th>Components secondary</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crop 1: Cassava (for example)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Anticipated market or opportunity price (recognizing quality)</td>
<td>$/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Harvest costs of labour&lt;sup&gt;a&lt;/sup&gt;</td>
<td>$/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Transport costs</td>
<td>$/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Marketing costs</td>
<td>$/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Other postharvest costs (specify)</td>
<td>$/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Hired labour&lt;sup&gt;b&lt;/sup&gt;</td>
<td>$/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Family labour</td>
<td>$/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Net unit value of cassava</td>
<td>$/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Average field yield of cassava</td>
<td>tonnes/ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Harvester's/owner's share</td>
<td>kg/tonne</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Transport and storage losses</td>
<td>kg/tonne</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Net field harvest to cultivator</td>
<td>tonnes/ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Total value of net harvest, cassava</td>
<td>$/ha</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Crop 2: Maize (for example)**

(Repeat elements 1 to 12)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Unit</th>
<th>Harvested primary</th>
<th>Components secondary</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crop 2: Maize (for example)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Total value of net harvest, maize</td>
<td>$/ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Total field value of cropping pattern</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### B. Costs that vary between technologies<sup>c</sup>

<table>
<thead>
<tr>
<th>Activity</th>
<th>Unit</th>
<th>Price $/kg</th>
<th>Cost</th>
<th>Net money</th>
<th>Net opportunity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land preparation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family labour</td>
<td>man-d/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hired labour</td>
<td>$/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment use</td>
<td>$/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Planting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassava sticks</td>
<td>$/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize seed</td>
<td>$/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family labour</td>
<td>man-d/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hired labour</td>
<td>$/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesticide (specify)</td>
<td>$/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (specify)</td>
<td>$/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Repeat the above for other field activities, e.g. weeding, cultivation, thinning, fertilizer, plant protection.)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Unit</th>
<th>Price $/kg</th>
<th>Cost</th>
<th>Net money</th>
<th>Net opportunity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. Total variable cost of cropping pattern</td>
<td>$/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Net benefit of pattern</td>
<td>$/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Harvest and related cost usually related to harvest volume, and may vary by cropping pattern.

<sup>b</sup>The real cost of hired labour will often include a wage cost and an imputed cost representing the value of meals provided to the labourer by the farmer.

<sup>c</sup>The dash (–) indicates whether the field cost will more likely be a money or an opportunity cost.

<sup>d</sup>Net field costs are market price plus credit/interest charges, transport storage, costs, etc. The net field cost may be budgeted as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Price $/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Market price of input</td>
<td>$/kg</td>
<td></td>
</tr>
<tr>
<td>2. Less price discounts</td>
<td>$/kg</td>
<td></td>
</tr>
<tr>
<td>3. Transport charges</td>
<td>$/kg</td>
<td></td>
</tr>
<tr>
<td>4. Credit/interest</td>
<td>$/kg</td>
<td></td>
</tr>
<tr>
<td>5. Storage</td>
<td>$/kg</td>
<td></td>
</tr>
<tr>
<td>6. Other</td>
<td>$/kg</td>
<td></td>
</tr>
<tr>
<td><strong>Net unit price/cost</strong></td>
<td>$/kg</td>
<td>1-2+3+4+5+6</td>
</tr>
</tbody>
</table>

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Table 3. Estimating returns to factors of production.a

<table>
<thead>
<tr>
<th>Factor</th>
<th>Specific return</th>
<th>Method of calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>$/ha</td>
<td>As per Table 3 (GM)</td>
</tr>
<tr>
<td></td>
<td>$/s land</td>
<td>(GM)/land rent</td>
</tr>
<tr>
<td>Labour</td>
<td>$/man-day</td>
<td>(GM + total labour cost)/total man-day</td>
</tr>
<tr>
<td></td>
<td>$/family labour man-day</td>
<td>(GM + family labour cost)/family labour</td>
</tr>
<tr>
<td></td>
<td>$/man-day of peak lotb</td>
<td>(GM + labour cost in nonpeak period)/total man-days in period</td>
</tr>
<tr>
<td>Cash</td>
<td>$/$ cost</td>
<td>(GM + variable costs)/variable costs</td>
</tr>
<tr>
<td></td>
<td>$/$ money cost</td>
<td>(GM + money costs)/money costs</td>
</tr>
<tr>
<td></td>
<td>$/$, cost constraintc</td>
<td>(GM/total cost) cost in period</td>
</tr>
</tbody>
</table>

*aAfter Norman and Palmer-Jones (1976, p. 252).
*bPeriod when labour limits output.
*cCash constraint by supply and demand.

rate for low resource farmers is certainly higher than the 5–10% often used in budget analysis.

The example in Table 4 illustrates the impact of different discount rates on the present net benefit of two hypothetical cropping patterns. The first cropping pattern may be based on a three-crop sequence (e.g., maize–legume–maize), the second on a maize–cassava intercrop. The differing occurrences of revenues and costs reflect different time sequences of activities. In the example, cropping pattern B has a higher net benefit than cropping pattern A up to a discount rate of about 40%; at discount rates higher than this, pattern A has the higher net present value.

Normally, a number of choice criteria (as listed in Table 3, which should be discounted to present values) are used to evaluate the potential of new cropping patterns. In addition to these, Banta (1978) argues that for a cropping pattern to have a clear advantage over existing systems it should:

(a) have a (discounted) net benefit at least 30% higher than the present pattern;

(b) the return per unit of labour must exceed its opportunity cost; and

(c) the (discounted) net benefit of the pattern should be sufficient to pay the cash costs of another cycle of that pattern.

Perrin et al. (1976, p. 19) also argue that before a new technology can be judged superior to existing ones it should also have:

(d) a marginal rate of return on capital, in relation to the current practice, of at least 40%.15

Variability of Net Benefits

Average yields (adjusted for harvest and storage reductions) are normally used to evaluate the ben-

Table 4. Discounted values ($/ha) of two hypothetical cropping patterns.

<table>
<thead>
<tr>
<th>Time period (months)</th>
<th>Stream of benefits and costs</th>
<th>Pattern A</th>
<th>Pattern B</th>
<th>Pattern B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Benefits</td>
<td>Costs</td>
<td>Net benefit</td>
<td>Benefits</td>
</tr>
<tr>
<td>1-3</td>
<td>120</td>
<td>-120</td>
<td>-120</td>
<td>120</td>
</tr>
<tr>
<td>4-6</td>
<td>300</td>
<td>150</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>7-9</td>
<td>350</td>
<td>-350</td>
<td>-350</td>
<td>350</td>
</tr>
<tr>
<td>10-12</td>
<td>90</td>
<td>-90</td>
<td>-90</td>
<td>90</td>
</tr>
<tr>
<td>13-15</td>
<td>300</td>
<td>30</td>
<td>270</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>390</td>
<td>560</td>
<td>560</td>
<td>390</td>
</tr>
<tr>
<td>0</td>
<td>950</td>
<td>800</td>
<td>200</td>
<td>950</td>
</tr>
<tr>
<td>20</td>
<td>809</td>
<td>663</td>
<td>188</td>
<td>809</td>
</tr>
<tr>
<td>40</td>
<td>697</td>
<td>558</td>
<td>178</td>
<td>697</td>
</tr>
<tr>
<td>60</td>
<td>606</td>
<td>475</td>
<td>168</td>
<td>606</td>
</tr>
</tbody>
</table>

15The marginal rate of return on capital is

\[
\frac{(\text{net benefits of new technology} - \text{net benefit of old technology}) \times 100}{\text{variable costs of old technology}}
\]

or

\[
\frac{\text{incremental benefits} \times 100}{\text{incremental costs}}
\]
enefits of alternative intercropping systems, thereby ignoring the yield variability of the practice resulting from differences in weather year to year, differences in response over space (sites), and differences due to farmer management. The most rudimentary way of accounting for the adverse effect of uncertain yields, as mentioned, is to add a risk premium to the cost of capital used in the budget analysis to ensure a conservative estimate of benefits. This approach is not selective when examining the riskiness of economic returns between cropping patterns.

The usual way that output variability of cropping practices is compared is in terms of their means, and some measures of dispersion of the means. From these statistics, it is possible to calculate (among others):

(a) the minimum level of net benefits for guaranteed levels of probability;
(b) the probability of achieving minimum defined levels of net benefits;
(c) the probability of losses of given magnitudes, for each cropping pattern being evaluated. If the distributions can be reasonably approximated by normal distributions then the above estimates can be derived directly using standard probability tables. If the distributions of net benefits are skewed, which seems to be the more common case (Day 1965; Roumasset 1976) then it may be easiest to plot out the frequency distributions of the observations and to derive the probabilities from these figures.

Table 5 provides an example of an analysis of the net benefits of three hypothetical cropping patterns in terms of the variability criteria. Cropping pattern A for example, may be the farmer’s current practice, with B and C two proposed patterns. Both B and C appear attractive when compared to A from a net benefit viewpoint, with C being superior to B. However, the variability of expected returns of C is higher than B, and although there is a higher probability of larger gains with C, there is also a higher probability of loss. On this basis, if the farmer is risk adverse, he may prefer pattern B to C, although it has a lower expected net benefit. The problem is, it is not clear what are individual tradeoffs between higher expected gains with the probability of being worse off on some occasions, and lower expected gains with less chance of an adverse outcome.

Indeed, Dillon (1977, p. 103) points out that although the above approaches have intuitive appeal for appraising risky outcomes and ranking alternatives, they are somewhat arbitrary and “without logical foundation in decision making.” The decision theoretic approach based on the maximization of expected utility provides the most rigorous basis for risky choice (Anderson et al. 1977). This approach, however, has not been widely applied to the evaluation of cropping innovations in developing countries partly because of difficulty and stability in estimation and a lack of understanding of the utility functions of low resource, transitional farmers.

A more general appraisal of the attractiveness of a technology vis-a-vis others that does not require a knowledge of the farmer’s utility function is possible using the rules of stochastic dominance (Anderson 1974), wherein cropping patterns are identified that have a greater probability of a higher net benefit at all levels of net benefit than alternative patterns. The first-order cumulative probabilities for the three hypothetical cropping patterns illustrated in Table 5 are shown in Fig. 3. Pattern B is “risk efficient” when compared to pattern A, because its cumulative probability distribution is always to the right of A. Thus, pattern B is always better than A, and would be preferred by decision-makers who prefer a higher net benefit to less. Pattern C, although having a higher mean net benefit to A and B, in some situations, will have lower net benefits (i.e., the curves cross over). Thus, although unqualified statements about the relative merits of C versus A or B should not be made, the probability of C being superior to the former patterns (i.e., 91% and 80% of time) can be identified, and statements made on this basis. In most situations, and as demonstrated in Fig. 3, stochastic dominance if strictly applied is

<table>
<thead>
<tr>
<th>Table 5. Comparison of hypothetical cropping patterns based on means and measures of variability.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropping pattern</td>
</tr>
<tr>
<td>Mean net benefit</td>
</tr>
<tr>
<td>Standard deviation*</td>
</tr>
<tr>
<td>Coefficient of variation</td>
</tr>
<tr>
<td>Min. benefits with probability of 90%</td>
</tr>
<tr>
<td>Min. benefits with probability of 80%</td>
</tr>
<tr>
<td>Min. benefits with probability of 70%</td>
</tr>
<tr>
<td>Probability of at least $80/ha</td>
</tr>
</tbody>
</table>

*Assuming 15 degrees of freedom for t distribution.
not a discriminating criterion, since the cumulative distributions of the alternative cropping patterns may cross more than once.

"Minimum return analysis" provides a working approximation to the concept of stochastic dominance (Perrin et al. 1976). The procedure compares the worst 25% of the net benefit of each proposed practice (and the average of the worst 25%) with the worst 25% of the outcomes from the current practice (and the mean of this quartile). If the proposed practice is worse than the current practice on either count, then its relevance and the reason for this poor performance should be examined.

Whole Farm Analysis of Cropping Alternatives

Budgeting procedures, supplemented by returns to the scarcest resources and by measures of variability, in the majority of cases provide the end point for the economic analysis and comparisons of new innovations within cropping systems-oriented programs. The procedures have the strength of being relatively simple and are usually sufficient to identify new cropping patterns and management techniques that have a real chance of being adopted.

However, the users of budget analysis also recognize that the approach is partial and does not consider the relevance of innovations within a whole farm framework. To this extent, budgeting in the manner presented suffers from the following limitations:

(a) the correct evaluation of opportunity prices for resources that have distorted market prices — often land, labour, and capital — is difficult;

(b) the comparison of two (or more) alternative cropping patterns does not identify the most appropriate way for resources to be allocated between these and other uses; and

(c) it is difficult to judge whether the input requirements for the technology are managerially feasible, given the farmer's resource base and the alternative uses to which the family commit these resources.

One way of internalizing many of these questions is to analyze the proposed and existing production opportunities at the same time in a simulated whole farm family framework. These models are designed to reflect the resource base of the farmer, his objectives, and his commitment of resources and produce to the needs of the family, the farm, nonfarm activities, and the market. Generally speaking, there are two types of models designed to simulate the family and farm. There are those models that are essentially designed to evaluate the feasibility of selected

Fig. 3. Illustration of the principle of stochastic dominance.
new practices (e.g., Zuckerman 1973) and those that are designed to select a combination of practices that will optimize some suitably chosen (and constrained) objective function.

Linear programming is the most widely used optimizing technique in the latter regard and provides a conceptually straightforward approach for the whole farm analysis of currently used and proposed cropping systems. The direct benefits of each activity included in the programming model are derived using budgeting techniques in a manner described in the previous section. As a result, average values are used in most linear programming models when estimating the benefits of each production process. However, with ingenuity, the basic model can be modified to take account of stochastic elements, most easily in the benefit function. Arifin (1978), Barlow (1977), Benito (1976), Headly and Agrawal (1970), McCarl (1978), Schluter (1974), and Thodey and Rapeepum (1974), among others, provide examples of the application of linear programming and its extension to the low resource, multiple cropping-based farm.

Farm Level Evaluation of Technology

The framework for cassava intercropping research presented earlier in the paper recommended that improved production practices should be identified from on-farm evaluation of promising cropping patterns and cultural practices. Normally, the on-farm evaluation will include a sequence of trials, the farmer's testing of the technology, and an evaluation of the technology after it has been recommended to farmers.

Zandstra (1978) discusses the logic and conduct of on-farm trials and refers to the extremes of on-farm testing as "research managed" trials and "cropping pattern" trials. Typical experimental designs, with small plots, are used for research-managed trials that are usually designed to evaluate a wide range of management alternatives. As a next step in the assessment, farmer field trials may be conducted using the farmer's land and labour but the management input (and risks) borne still by the researcher. The number of alternatives considered in these trials should be few because it is necessary to obtain:

(a) an idea of the variation of treatment outputs that require emphasis on replication over the environment being studied;

(b) an impression of the desirable characteristics, limitations, and difficulties experienced by the farmer when implementing the proposed technique; and

(c) the farmer's impression of the technologies, which is difficult for him to do adequately if there are a large number of treatments.

The results of the farmer field trials should be carefully evaluated for economic and management relevance before the best alternatives are chosen to go forward for farmer field testing in cropping pattern trials. This evaluation in part will be a comparative one between the farmer's current cropping patterns and practices and new ones designed by the collaborating researchers. Thus, whether the results are included in budget analysis alone, or extended to a whole farm evaluation, they need to be examined for their relevance in the reality of a farm-managed situation as opposed to the somewhat stage-managed trial conditions. Thus, the analyst is faced with the challenge of deciding in particular:

(a) how much should yields be discounted to reflect that they are still "experimental" yields and not really "farmers'" yields;

(b) what should the labour coefficients be for the various production practices, as labour estimates derived from experiments normally overestimate what would be the farmer's practice;

(c) what will likely be the level of use of other inputs (e.g., fertilizer, insecticides); and

(d) what will be the equipment used, and its performance were the practice applied by farmers. Obviously, no hard and fast adjustment rules exist for these points. Sensible adjustment of these figures requires that the research is familiar with farmer practices, conditions, and performance rates, and understands how and why farmers have adapted other recommendations to suit their own conditions.

Finally, the best alternatives identified through the analysis of the field trials should be tested in cropping pattern trials using the farmer's resources and management, with the cropping pattern under test competing with other activities for the farmer's resources. The cropping pattern trials are normally field size, with one pattern per collaborator. As with the farmer field trials, replication of the cropping patterns over the region of interest is important to enable the yield variability of the practice to be estimated.

To assess their suitability as improved methods of crop production, the cropping patterns should be evaluated in terms of:

(a) their technical feasibility — if it failed at this late stage of the screening process, why?

(b) profitability and dependability when expressed in terms of the most limiting resources;
(c) the compatibility of the innovation with the farmer's overall farming system;
(d) social acceptability; and
(e) whether the innovation is realistic given the institutional and infrastructural realities in the target area.

Any alternative that is positive in relation to the above five criteria should have a reasonable chance of being adopted by farmers if extended to them. Flinn and Lagemann (1976) provide an example of the evaluation of a proposed technical innovation based on the above criteria. Their study also demonstrates the value of the appraisal being a joint one between the various scientists involved in the research project and the farmer.\(^\text{18}\)

Often, the researchers who designed the technology and the extension workers who have the responsibility of disseminating it come from different agencies of government or different departments within agencies. The collaborative design, conduct, and evaluation of the farmer field trials and cropping pattern trials provides an excellent focus for these two groups to work together and to jointly contribute to the formulation of the extension recommendations for the new technology.

During the extension of new innovations, an impression of farmer acceptance of the new technology is of value to help assess the success of the technology; who and why certain farmers and not others have adopted it; and how and why farmers have adapted recommendations to suit their individual conditions. The inferences drawn from such evaluation studies can contribute to the identification of future research objectives and designs, the modification of extension recommendations related to the practice, and the effect of institutional backup to the technology. Okali and Bortei Doku (1978) provide an example of an early evaluation of a cassava-based intercropping system, and demonstrate the importance of on-farm and off-farm factors that influence the farmer's adoption of the recommendation.

**Summary**

Research aimed at developing improved cassava-based cropping systems should be based on an understanding of why specific cassava-based cropping patterns prevail. This implies a knowledge of the reasons why farmers manage their crops in the way they do, and an appreciation of the agronomic, economic, and social advantages and disadvantages of the cropping systems it is hoped to change. Such information is best gained through the researcher having first-hand contact with the farmer and his environment. Farm-focused studies designed to generate this information should be collaborative between, for example, an agronomist, farm management economist, and pest management scientist if they are to most effectively influence research requirements and design.

The normal bioeconomic relationship that prevails in cassava-based intercrops is one of competition. That is, after some point, the yield of one crop in the mixture can only be increased at the expense of the other. The combination of inputs that will result in net benefits being maximized for the cropping pattern is when inputs are used to the point where the value of the increment in output of the intercrop is equated with the per unit value of the input.

The most usual and practical way of evaluating the relevance of proposed cropping patterns and cultural techniques is through budget analysis focusing on the return to the farmer's most limiting resources, and the variability of these returns. Often the market prices for some of the most important inputs for the low resource farmer — particularly family labour, capital, and land — poorly reflect their scarcity value to the farmer, which implies that these inputs should be valued at their opportunity costs. When resources and time permit, the alternatives may be evaluated within a whole-farm framework, which to some extent reduces the researcher's need to estimate opportunity values as they are internally generated.

The evaluation of new innovations should be derived from results that resemble farm conditions as closely as possible. Such conditions are best achieved by conducting the cropping systems research on farmer's fields. This component of technology development and assessment will ideally involve a range of activities from research-managed trials through to the joint evaluation of proposed extension recommendations by farmers, scientists, and extension workers. Postadoption studies provide links to the research and planning process to enable their activities to be more efficiently directed to the real constraints to production faced by farmers.

**Acknowledgments**

With the usual caveats, the author is grateful to Sisira Jayasuriya, R. W. Herdt, and Joyotee Smith for their comments on an earlier draft of this paper.