Setting Research Priorities:

Concepts and Applications to On-Farm Adaptive Research[1]

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1. Presented at the "Training Course in Agricultural Research Operations", Department of Agriculture, Bangkok, Thailand, 3 to 10 July, 1991.

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Introduction and Objectives

Setting research priorities for agriculture is an eternal problem. Even well-endowed and well-funded programs typically find themselves compelled to choose among research alternatives. Funds are rarely adequate to explore all interesting research themes in full detail. As has been said, "There are many interesting problems: some are important.".[1]

The real question, then, is one of method. How can research managers effectively distinguish the more important from the less important research themes? The objective of this paper is to review some methods that have been used for research resource allocation; briefly describe the underlying economics principles; and then discuss in some detail methods of research resource allocation (based on these principles) that have been developed by CIMMYT especially for use in on-farm adaptive research.[2]

Methods for Research Resource Allocation

There is a substantial literature on the economics of setting priorities for agricultural research, e.g., Anderson and Parton (1983), Scobie (1984), Contant and Bottomley (1988), etc.. This literature describes "economic" approaches to priority-

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1. Often attributed to Richard Bradfield.

2. In this paper, "on-farm adaptive research" or "OFR" is meant to be equivalent to "farming systems research", "FSRE", or any problem-solving, multidisciplinary, site-specific research activity that consciously seeks to use a farming systems perspective.

setting, and typically suggests making use of such criteria as the following:[1]

Congruence: Allocate research resources in proportion to the "size" of a crop (or enterprise). That is, allocate more resources to those crops or enterprises that cover a larger area, or are more important sources of income to farmers.

Expected Changes in Demand: Allocate research resources in proportion to expected changes in demand. That is, allocate more resources to crops or enterprises where demand is expected to grow most rapidly.

Equity: Allocate research resources in ways that tend to promote a fair distribution of income and well-being, e.g., give priority to those crops or enterprises that help overcome nutritional deficiencies, promote employment, or tend to be cultivated by low-income farmers.

Foreign Exchange Savings: Allocate research resources towards crops or enterprises that may help reduce imports or expand exports. This is sometimes (incorrectly) taken for an economically efficient criterion (Monke and Pearson, 1989).

Comparative Advantage: Allocate research resources in accord with national comparative advantage, i.e., give priority to those crops or enterprises in which the nation is already a low-cost producer. In other words, focus on enterprises where few domestic resources are used to save or earn a unit of foreign exchange.[2]

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1. It should be noted that are also methods that pay no attention to economics, e.g., setting research priorities by means of political criteria; in accord with past research expenditure; in proportion to the number of scientists working in a particular problem area; etc.

2. See Morris (1990) for a summary of CIMMYT's experience with assessing comparative advantage and applying this to questions of research resource allocation.

Returns to Research Investment: Allocate research resources in ways that lead to high economic returns to funds invested in agricultural research. This is nothing more than benefit - cost analysis, with special attention given to the uncertainties associated with agricultural research -- will the research investment lead to new technology? will farmers adopt this new technology? if so, to what extent, and over what time period? (Scobie, 1984)

Economic Surplus: This is a more general version of the "returns to research investment" criterion, in which net returns are measured as changes in consumer and producer surplus resulting from the supply shift caused by the research, allowing for differing degrees of research spillover between countries or regions and different rates of adoption of technologies (Davis and Ryan, 1987).

Multiple Criteria: The criterion of economic returns to research investment (or its more general cousin, the criterion of economic surplus) is fundamental to economic approaches to setting research priorities. Some analysts feel uncomfortable with any single criterion, however. Multiple criteria can be introduced by means of weighted scoring models (Contant and Bottomley, 1988) in which several factors are assessed for each alternative research theme. Factors might include all of the above, as well as others[1]. In practice, such models quickly become cumbersome and unwieldy.

The Basics: Economic Returns to Research Investment

Most of the "alternatives" described above have a common ingredient: they are, by and large, approximations of the "fundamental" criterion: "economic returns to

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1. Additional alternatives might include creating employment, achieving food self-sufficiency, improving rural incomes, reducing rural to urban migration, etc.

research investment".

In the congruence approach, for example, the "size" of an enterprise (e.g., the harvested area of a crop) is assumed to be highly correlated with returns likely to be gained from investing in research for that enterprise. For a "large" enterprise, benefits from new technology would be spread over an extensive area, producing sizable total net benefits -- as long other factors are held constant. Similar arguments may be made for most of the other criteria described above.

Given the conceptual importance of the "economic returns to investment in research" as a criterion, then, it is useful to list its underlying elements.

Research benefits can be shown to depend on:

- The net productivity gain (after subtracting the cost of associated inputs) attributable to the new technology.
- The length of time between the initiation of research and the production of technology that can be adopted.
- The probability that <u>any</u> suitable technology will be developed within a reasonable time period.
- The length of time between the initial release of the new technology and the maximum level of adoption.
- The length of time in which the new technology continues to contribute to output.
- The area under the new technology for each time period.

Research costs, in turn, are a combination of investment cost and maintenance cost. Extension costs may also be logically included. Costs are sensitive to the complexity of research, the selection of research designs, etc.

Estimating the economic returns to research investment, however, requires one more piece of information: the discount rate. For each time period -- from the commencement of research until the last period in which the resulting new technology produces tangible benefits -- net returns (benefits minus research costs) must be estimated, and these must be <u>discounted</u> to a common time period. In this way, indictors of economic returns to research investment -- net present values, benefit-cost ratios, or annual average returns -- may be estimated.

Getting Practical -- Applications to OFR

In theory, the above approach works nicely. In practice, however, it has shortcomings. One of the most serious is that it requires information (e.g., future adoption rates) that research managers simply don't have.[1] Another is that it allows no room for research managers' judgment: it is excessively "mechanistic". As Scobie (1984) eloquently notes,

> "... while a vast array of quantitative armor has been developed, it neither can nor should be a substitute for the creativity and judgment of informed participants. A formula, however rigorous in a mathematical sense, may give an impression of pseudo-objectivity. It cannot,however, disguise the fact that certain important elements are inevitably subjective." (p. 16)

The Case of OFR:

These concerns take on special importance when priorities need to be set for on-farm adaptive research. The likelihood of producing adoptable technology

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1. Another area where uncertainty prevails is in the selection of an appropriate discount rate.

becomes less certain; the onset of farmer adoption is harder to predict; the maximum area of coverage (extrapolation) is more difficult to ascertain; and the role of researchers' judgment[1] becomes supremely important.

The increased role of judgment is largely due to the need to incorporate an understanding of farming system interactions in the design and assessment of new technology. The arithmetic of cost-benefit analysis is capable of capturing this feature only in very indirect ways -- through estimates of the probability of research resulting in suitable new technology.

Procedures for Setting Priorities in OFR

Scientists from CIMMYT and CIAT have developed a set of procedures specifically devoted to helping set research priorities for OFR programs (Tripp and Woolley, 1989). These procedures -- which are divided into discrete steps -- are based conceptually on the economics principles described above, yet allow ample room for judgment, and explicitly take account of system interactions. These procedures have been taken and developed into training materials by Harrington (1989). The rest of this paper will be devoted to describing these procedures.

Step One -- List and Define Problems

"Problems" are defined, rather arbitrarily, as taking one of four forms: (1) Factors that directly reduce enterprise yields; (2) Factors that reduce the efficiency of purchased inputs, regardless of whether yields are affected; (3) Inefficient use of farmers' resources, e.g., inefficient enterprise or cropping pattern selection; (4) Prac-

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1. Tempered by the judgement of farmers and extension workers, of course.

tices that are not sustainable. Problems, then, may be specific to a crop or livestock enterprise, or common to the system, e.g., resource quality. (Figure 1)

The important thing in this approach is to clearly distinguish between problems and causes. Farmers may not apply fertilizer to a crop because "marketing problems" raise the price of inputs and reduce the price of the crop. However, "marketing" is not a problem (technically defined), but rather a cause (one of several) of a nutrient deficiency problem. If there were no nutrient deficiency problem, fertilizer application would be irrelevant.

In this step, evidence is required that a particular factor is, in fact, a problem before proceeding to the next step. This serves to separate fact from speculation.

Step Two -- Tentatively Rank Problems

Problems are given a rough ranking by means of a scoring model. This model, which can be weighted or unweighted, assesses each problem with respect to the following two criteria[1]: (1) the productivity loss associated with the problem (broadly defined to include the low productivity of a suboptimal cropping pattern, or long-term productivity losses associated with resource degradation); (2) the incidence of the problem (area affected by the problem; the frequency of occurrence of the problem; number of farmers affected; etc.).

It should be noted that the product of these two criteria -- productivity loss times incidence -- provides an estimate of total gross annual benefits from research

1. In practice these two main criteria are split into several sub-criteria. See Tripp and Wooley, 1989.

Figure 1: Some Problems in Rice-Wheat Pattern - Indian Terai

WHEAT

- Late planting
- Phalaris minor
- Waterlogging
- Delay wheat harvest
- Plant stand

RICE

- Brown planthopper
- Bacterial leaf blight
- Delayed transplanting

RICE-WHEAT

- Rats
- Inefficient N-use
- Soil pathogens
- Sheath blight

that would be earned if the problem were to be solved. This is, of course, a rough estimate of research benefits. (However, the probability, timing, and extent of adoption are not yet considered in this step -- they come into play in a subsequent step.)

The aim of this step is not to provide an exhaustive ranking of problems -- rather it is only intended to help distinguish between problems that are potentially important vs. those that are obviously trivial. Note also that this rough ranking of problems simultaneously serves to help rank crops or enterprises (recall that many problems will be strictly associated with a particular enterprise). (Figure 2)

Step Three -- List Causes for Major Problems

Typically, alternative solutions to a problem do not become apparent until its causes become understood.

In Southern Mindanao, Philippines, for example, it was found that weed competition in maize is caused by (among other things) poor tillage, open plant spacing (allowing sunlight to germinate more weed seeds), and weed control practices that allow continued production of weed seeds. As these become better understood, it became apparent that major opportunities for solving the weed problem included -- improved tillage, closer plant spacing (or leafier plants!), and adjustments in weed control strategies to reduce the production of weed seeds (Oliva, Burgos, Mate and Harrington, 1990).

Similarly, in East Java, problems of plant stand management (overplanting) in maize were found to be caused by a need to compensate for expected shootfly damage. Improvements in plant stand management were found to be contingent on the availability of shootfly control measures. Other expected causes of overplanting --

Figure 2

Ranking of near-term problems in the rice-wheat rotations, Pantnagar University, India (Preliminary scores*).

Problem	% of years	Yield loss	% of farms	Large /small	Total score	Rank
Wheat						
Late Planting	3	2	2	2	9	I
Phalaris minor	3	2	1	2	8	II
Waterlogging	3	2	1	2	8	II
Delayed wheat harvest	2	1	1	3	7	II
Plant stand	2	1	1	2	6	III
Rice						
Brown planthopper	2	2	1	2	7	II
Bacterial leaf blight	1	2	1	2	6	II
Delayed transplanting	3	1	1	1	6	II
Rice-Wheat						
Rats	3	1	2	2	8	I
Inefficient N-use	3	1	2	1	7	II
Soil pathogens	3	?	3	2	?	?
Sheath blight	1	?	?	2	?	?

* Score	year	yield	farms	size
0	0-10%	0-5%	0-5%	—
1	10-40%	5-15%	5-15%	Large
2	40-80%	15-50%	15-50%	Both
3	>80%	>50%	>50%	Small

livestock fodder needs, seed quality, etc. -- were found to be of little importance. Research, as a consequence, focused on shootfly control as a means of reducing planted density (Krisdiana, Harrington, Dahlan, Herianto and Van Santen, 1991).

Step Four -- Diagram Interactions Among Problems and Causes

This is where the understanding of system interactions comes into play. Problems can cause each other. Similarly, farming system interactions are frequently major causes of important productivity problems. Identification of viable solutions, then, can depend on understanding these interactions.

In the example shown in Figure 3, for example, soil fertility in rice-wheat systems in the Indian terai were found to be linked to choice of cropping pattern; timing of system intensification; crp residue management; the changing balance of use of FYM for fuel vs. feed; and declining levels of livestock, and other factors.

Step Five -- "Brainstorm" for Alternative Solutions

Once the causes of a priority problem become clear, alternative solutions often become apparent. At this point researchers can "brainstorm" -- freely speculate about possible solutions to a problem. This is a creative process and is very much dependent on the quality of information on system interactions and causes developed in previous steps.

In the example of the rice-wheat in the Indian terai, for example, the suggestions for solving long-term soil fertility problems follow directly from the causes illustrated earlier. These suggestions are summarized in Figure 4.

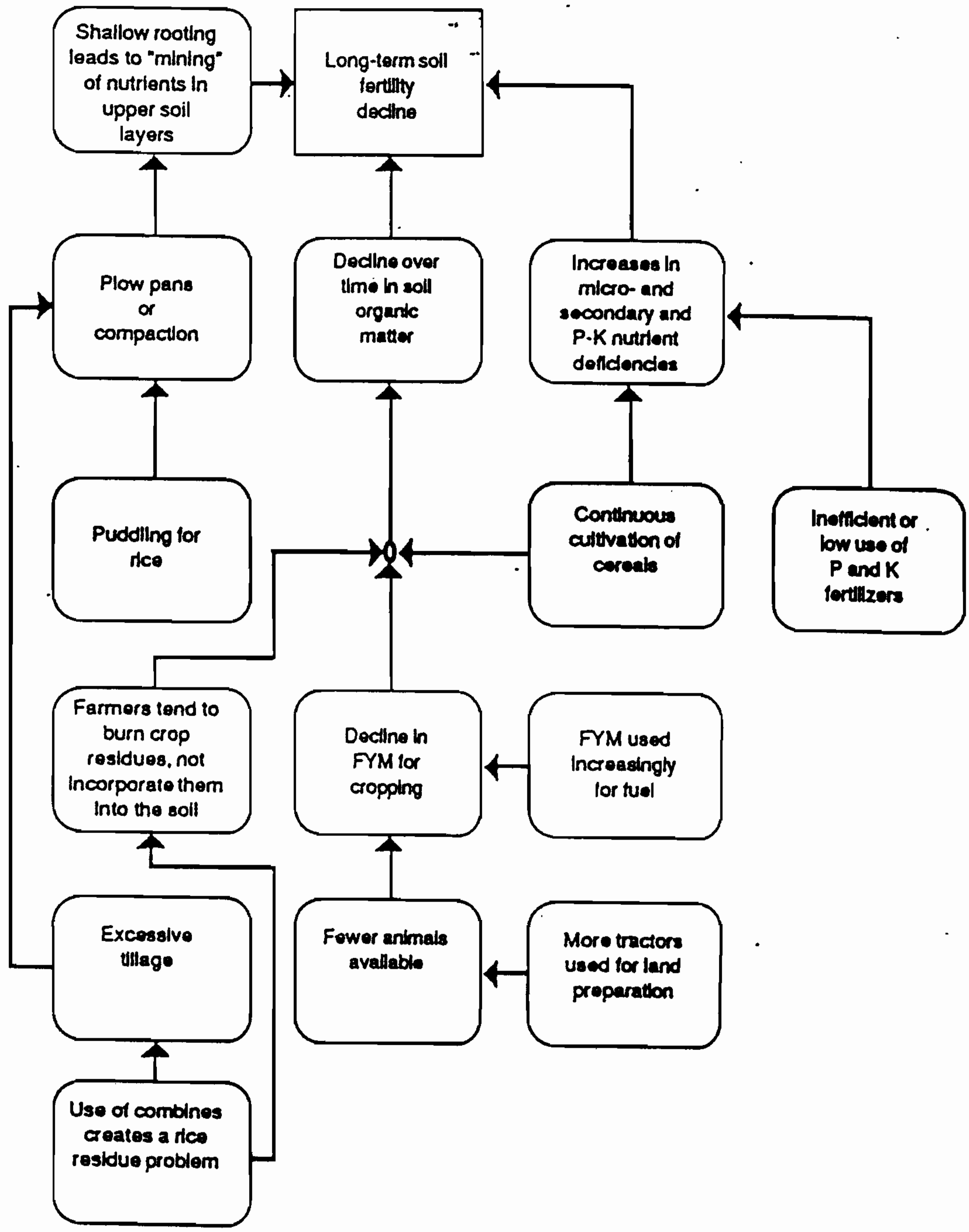

Figure 3. Causes of soil nutrient depletion.

Figure 4

List of Possible Solutions: Nutrient Depletion in Indian Terai

- Collating available data related to yield declines.

- Monitoring farmers' fields (i.e., land use and management, livestock and FYM production, yields, OM, macro- and micro nutrients, root depth, the plow pan, and pests) over the long-term.

- Cycling nutrients from deeper soil layers, which would involve: a) reduced puddling by dry seeding or reduced tillage to reduce compaction, b) use of green manures with deeper root systems, and c) studying the effect of deeper plowing on the system's productivity.

- Increasing OM or the efficiency of OM use through:

  a) Using legumes and green manures in the rotation. Rotational studies, in general, should be conducted to see what combinations might increase productivity. The benefits of the rice-wheat-sugarcane rotation should be studied.

  b) Encouraging good residue management (compare composting with burning or incorporation) and using organic fertilizers and biofertilizers in maintaining soil fertility. Soil microbiology would play a role in this issue.

  c) Improving FYM management (better storage) and techniques to combine FYM and inorganic fertilizer for better efficiency. The use of cane mill residues should be studied.

  d) Encouraging agroforestry to help decrease FYM use for fuel. Other alternative fuel sources should be developed.

- Improving inorganic fertilizer management through:

  a) Evaluating sources of P and K, NPK mixes, and the role of different P and K fractions in the soil on providing these nutrients to plants.

  b) Conducting studies on soil testing and calibration to more easily relate tests to field responses so that farmers can be given more scientific recommendations.

  c) Studying the nutrient requirements of the rice-wheat system and develop realistic and profitable recommendations for inorganic fertilizer use, possibly including secondary elements.

Step Six -- Prescreen Alternative Solutions

In this step, scoring models are used to rank the alternative solutions identified in the previous step. Solutions are ranked with respect to such factors as technical feasibility, expected profitability, changes in riskiness, divisibility, learning costs (or complexity), farming systems compatibility, farmer safety, etc.

Note that these are all factors that can be expected to influence the probability, timing, and extent of adoption of new technology. In addition, expected research cost (broken into ranks such as "high", "medium" or "low") is included in the scoring model.

Finally, the most promising "possible solutions" for most important problems are included in an efficiently designed set of on-farm trials[1] and farm surveys.

Summary

Economic approaches to setting research priorities compare expected benefits from research with expected research costs. Returns to research investment, when worked out mathematically, they can be shown to depend on:

The net productivity gain (after subtracting the cost of associated inputs) attributable to new technology; the length of time between the initiation of research and the production of technology that can be adopted; the probability that <u>any</u> suitable technology will be developed within a reasonable time period; the length of time between the initial release of the new technology and the maximum level of adoption;

1. Efficient designs may include farmer participatory and other nonconventional designs.

the length of time in which the new technology continues to contribute to output; the area under the new technology for each time period; research investment costs; research maintenance costs; and the discount rate.

A strict mathematical formulation is exceedingly difficult to apply to programs of on-farm adaptive research because the above data is typically not available for all future time periods.

This paper has described a set of steps whereby the above analysis can be approximated qualitatively in ways that rely on researcher judgment as well as available data, and which incorporate information on farming system interactions. In these steps, priorities are set twice: once for problems (step two) and once for alternative solutions (step six). Benefits from solving problems are estimated, and the likelihood of adoption of different alternative interventions (solutions to priority problems) are both estimated at one point or another.

It is felt that these steps can help practitioners of on-farm adaptive research take informed decisions on research resource allocation -- the eternal problem of research managers.

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