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TOWARD A WORKABLE MANAGEMENT TOOL FOR RESOURCE ALLOCATION IN APPLIED AGRICULTURAL RESEARCH IN DEVELOPING COUNTRIES

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ABSTRACT

It is argued in this paper that the contribution of applied agricultural research to achieving social goals in developing countries can be greatly increased if a more formal approach is utilized in research resource allocation As an attempt to promote such an approach, a conceptual model is developed and the data requirements are discussed It is suggested that additional research be initiated to develop and test a workable model for research resource allocation on the basis of the preliminary work presented in this paper

CONTENT

Rapid and extensive adoption of new technology in wheat and rice during 1966-71 resulted in large production increases in a number of developing countries The new technology was developed through intensive national and international agricultural research efforts The previous pessimistic viewpoint on the ability to provide sufficient food for the world population was gradually replaced by optimism, and great faith was placed on agricultural research and the resulting new technology as the factors that would help save the world from famine Increasing amounts of funds were allocated to agricultural research and a number of new international agricultural research institutes were created

However, optimism did not reign for long Poor weather conditions and a reduced rate of adoption of new technology brought the trend of increased rice and wheat production to a halt in most of the developing countries that had benefitted from the previous production increases The Malthusian predictions were brought back as being the only valid long run predictions Furthermore, a strong belief developed that the technology brought about through agricultural research tended to benefit the higher income groups in society, hence aggravating the skewed income distribution currently found in most developing countries

Although we still have a number of years to prove that agricultural research can in fact continue to provide for large production increases in such a way as to improve current income distribution, one must not forget that funding agencies, whether national governments or private foundations, tend to place their funds where expected benefits are highest Agricultural research is still benefitting from the breakthroughs in wheat and rice, but an increasing suspicion is developing that these breakthroughs were short-lived one-time occurences and that even if something similar would occur in other crops, the benefits would be obtained by the high income groups of society This suspicion

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can only be removed if research produces new technology capable of increasing food production rapidly with the mayor benefits obtained by the low income groups

Hence, there is now a greater urgency in agricultural research than ever before Expectations are high, and as a result, more research funds are available. To meet expectations, large social benefits from research per dollar invested must be realized If this does not happen, research funds will gradually be reduced as will the opportunity to prove that Malthus was wrong in his predictions

How do we assure a high social benefit-cost ratio in agricultural research? Two criteria must be met 1) We must assure the best possible scientists for the particular type of research to be done and provide them with the necessary resources and 2) we must be capable of chosing the research that is expected to have the highest social benefit-cost ratio It is to this second criteria the present paper is addressed

The paper is based on three hypotheses

1 The agricultural research manager in developing countries does not presently have at his disposal a workable and sufficiently accurate method for predicting social benefits and cost from alternative research efforts

2 Even if such a method were available, scarcity of information on the key variables would prohibit its efficient utilization

3 Availability of information on the key variables and a workable and accurate method for its utilization would greatly increase the social benefits of applied agricultural research per research dollar spent in developing countries

No attempt will be made in this paper to test these hypotheses However, based on personal observations, interaction with a large number of researchers and research managers in Latin America and elsewhere together with literature reviews, the author is convinced of their general validity

The purpose of this paper is to discuss how the information base for decision-making on resource allocation in applied agricultural research in developing countries may be improved, and to suggest a conceptual model for analyzing the information The development of a complete, workable and sufficiently accurate model is beyond the scope of this paper It is hoped that additional resources will be obtained to develop and test such a model in the near future

Following this section, past efforts aimed at estimating benefits and costs from agricultural research are briefly reviewed Then follows a dicussion of how to develop an efficient model and improve the information base and the paper terminates with a set of recommendations for future research to facilitate an increase in the social benefit-cost ratio related to applied agricultural research in developing countries

PAST EFFORTS TO EVALUATE AGRICULTURAL RESEARCH

This section discusses past research efforts in the area of research evaluation and resource allocation in applied agricultural research A complete review of literature was not attempted However, an extensive list of references is provided to facilitate further study of the issues involved

The discussion is divided into three parts 1) Ex post evaluation of agricultural research, 2) ex ante methods for research resource allocation, and 3) a critical review of the usefulness of presently available information and methodology for the agricultural research manager in establishing research priorities

Ex post evaluation

The pioneering work in quantitative methods of evaluating the returns to investment in agricultural research must be credited to Schultz and Griliches (50) Two general approaches have been utilized to evaluate agricultural research a) The so-called index number approach (50) and b) the production function approach

Index number approach This approach is based on the methodology developed by Griliches (33) A number of other studies have been carried out on the basis of this methodology

(2, 5, 7, 9, 46, 51, 56, 59) Although slight modifications have been introduced, the basic approach used in these studies is the same However, considerable differences exist in the procedures for estimating the parameters used These differences will be discussed later

The index number approach estimates the change in the quality of inputs due to agricultural research to obtain a measure of resources saved in production Net benefits from research and their distribution between consumer and producer sectors are estimated as the change in consumer and producer surpluses less the estimated costs of the research [1/]

Gross benefits are generally estimated as follows

$$B = PQK\ ((1 + K/2\ E_D)\ (1 - ((1-E_D)^2\ E_S)\ /\ (E_D - E_S)\ ))$$

where

B = gross benefits

P = price of the product

Q = quantity of the product

K = shift in supply curve due to research

E_D = elasticity of product demand

E_S = elasticity of product supply

The research costs are estimated as

$$C_T = \sum_i C_i$$

where C_i is the cost of research resource i used in the research process Some of the above studies include the cost of applied as well as basic research related to the new technology being evaluated, while other exclude the cost of basic research

Research contributions are realized as streams of benefits over time A considerable time lag is likely to exist between the investment in research and the realization of the major benefits Hence, present value of benefits and costs are estimated using

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1/ The estimation of consumer and producer surpluses is illustrated in most of the studies referred to above and will not be re[illegible] ordinary discounting formulas and the internal rate of return is estimated as the rate of return that equates present values of benefits and costs incurred during the period under consideration

$$\sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t}$$

where

B_t = gross benefits obtained in year t

C_t = research costs in year t

r = internal rate of return

n = last year of research benefits

t= 1 first year of research cost

One of the most serious difficulties in estimating net returns from research using the index number approach is related to obtaining a measure of productivity gain that reflects only the contribution of research (50) Hence the procedure for estimating the parameter K in the above equation, i e the shift in the supply curve due to the adoption of input saving research results varies somewhat among the above mentioned studies In the classical work on hybrid maize, Griliches merely assumed a 15 percent yield increase due to the hybrid He then proceeded to estimate K on the basis of the yield increase and the rate of adoption of hybrid maize (33) Other studies have used time series data in order to estimate the productivity gain due to the research results as opposed to the gains obtained from increasing quantities of inputs

The index number approach is primarily aimed at estimating the contribution of agricultural research to efficiency, although the distribution of gains between producers and consumers is usually estimated A few attempts have been made in the above cited studies to include an estimation of the contribution to equity goals Ayer and Schuh (7) attempted to estimate the distribution of benefits from the cotton breeding program in Sao Paulo, Brazil between producers and consumers, the distribution of producer benefits among the factors of production, and the effects of the new technology on labor adjustment problems However, the analysis of the benefit distribution was limited by lack of information on the resource saving effects of the new technology and lack of knowledge on the structure of the parameters of the factor supply curve (7) Schmits and Seckler (59) estimated the impact of mechanized tomato harvesting in California on labor demands. They further estimated the extent to which the labor displaced by the mechanized tomato harvester could be compensated from the benefits obtained from the mechanical technology

However, in general, the ability of the methodology, as it presently stands, to estimate the contributions to equity goals is very limited

Production Function Approach The production function approach involves fitting a production function to historical input and output data with agricultural research being included as a separate independent variable This approach attempts to measure the marginal product of the research carried out on the particular commodity or group of commodities being analyzed In order to convert the marginal product into an internal rate of return a certain time lag is assumed between research investment and the benefits obtained from the research results Evenson reports that the mean time lag between expenditures on research andeffect on production in the U S is between 6 and 7 5 years (23)

A number of studies have been carried out using the production fuction approach (22,34) These studies have all been focused on specific commodity or country research programs Recently, efforts have been made to evaluate agricultural research on an international basis using regression analysis (21, 34) The major difficulty in carrying out this type of work is the lack of reliable data

Ex ante methods for research resource allocation

While it may be interesting and useful to know the magnitude of the pay-off from past investment in research, the real challenge with which we are faced is that of providing management tools that will assure an efficient allocation of limited resources to an almost unlimited number of research possibilities Information on relative pay-off to different research efforts in the past is obviously of some value for establis-ing future research priorities However, a much better framework is needed to assure efficient research resource allocation

A number of attempts have been made to develop such framerwork This discussion will be limited to efforts focused on applied agricultural research A discussion of systems related to project selection in industrial and military research may be found in (10, 12, 40, 63)

A planning, programming and budgeting system (PPBS) was initiated in civilian agencies of the U S Federal Government in 1965 In addition to other federal programs, agricultural research within the U S Department of Agriculture became subject to the PPB system

PPBS emphasizes planning, in contrast to control and management as in most other budgeting systems (45) The primary focus of PPBS in making budgeting decisions is on the expected output of programs in relation to social goals rather than on input categories, such as personnel, supplies, equipment and buildings (45) The system forces the researcher and/or research manager to estimate the likely contribution of alternative research efforts to the achievement of social goals rather than to narrow research goals It views research as a tool to solve problems, and program priorities would ideally be established in such a way as to maximize the degree of achievement of social goals per dollar invested in research

As a first step towards this end, U S D A established a list of social goals towards which its research should be aimed In order to be considered for funding, each research activity must provide information on a) the objective in terms of technology to be developed through the research activity The objective must be defined in such a way that progress towards or fulfillment of the objective can be measured, i e <u>ex post</u> evaluation of the research activity in terms of its objective should be possible b) Expected consequences of the technology to be developed, c) magnitude of potential be-

benefits in terms of social goals, d) probability of success, and e) research costs and time requirements On the basis of this information attempts are made to estimate net social benefits and cost for each research activity. A more detailed description of the application of PPBS made be found in (24, 53, 54, 55)

Based on PPBS concepts, a system somewhat similar to that used by USDA was introduced in the College of Agricultural and Environmental Sciences and the Agricultural Experiment Station of the University of California at Davis A description of this system - The California Academic- Responsive Budget System - may be found in(45)

The Iowa Review Panel technique is another attempt to increase the contribution of agricultural research to the achievement of social goals Panels of scientists in different research areas estimate potential or expected benefits and costs associated with alternative research opportunities Benefits are estimated in terms of the three goals efficiency, equity and security Panel estimations are then utilized to establish long run (5-year) research priorities on the basis of which budgets and staffing are planned The Iowa review panel technique is essentially qualitative in estimating expected benefits and the validity of the outcome of the technique depends almost exclusively on the ability of the panel members to make correct judgements For further details of this technique see (42, 49)

A common problem of these methods for establishing research priorities and selecting among research projects is the deficiency of the data base and the lack of a complete quantitative framework for analyzing available information Fishel attempted to develop a system that would overcome these two basic weaknesses The Minnesota Agricultural Research Resource Allocation Information System (MARRAIS) This system is a "computer-based, generalized structure for collecting and processing information relevant to resource allocation decisions under situations characterized by a high degree of uncertainty " (30) Primary emphasis is placed on improving the quality of information available to the research manager Individual researchers are requested to estimate average annual costs, expected time requirements and probability of success for each of a number of proposed projects These estimates are transformed into subjective probability distributions Probability distributions are generated for the present value of expected benefits and costs For a more complete discussion of MARRAIS see (25,27)

A number of other papers deal with the issue of developing improved systems for aiding the research manager in establishing research priorities However, few, if any, attempt to develop a complete and workable model

Usefulness of available methods and needs for further work

In attempting to evaluate the usefulness of existing ex ante methods it may be useful to divide the discussion into a) quality and quantity of basic information available, b) efficiency of available systems for analyzing such information and generating the information needed by the research manager and c) the ability of these systems to evaluate alternative research possibilities in terms of social objectives

Quality and quantity of information All the above systems relay on groups of scientists for basic information on potential benefits from alternative research possibilities

Unless there is continuous flow of relevant information from farmers to researchers concerning researchable problems and their magnitude, it is unlikely that the researchers are able to provide sufficiently reliable information In the case of Latin America I would argue that such an information flow does not exist Hence information must be obtained directly from the farmers Otherwise we are likely to be working on the wrong problems The systems described above do not provide a framework for a continuous collections and analysis of data from the farm sector Neither do they provide a framework for collection and analysis of data related to product demand, input supply and expected impact on input demands

Analytical efficiency of available systems In the Iowa system little quantitative analysis is performed beyond a summary of the scientist judgements The PPB and related systems attempt to estimate cost-benefit analyses of proposed projects Although the author of this paper is not sufficiently well informed of the performance of the PPB system in USDA it appears that cost-benefit analyses have been extremely difficult to carry out because of a) the large number of goals to be achieved and the lack of specification of an acceptable trade-off among them, b) the difficulty involved in estimating and quantifying expected benefits at the "research activity" level The MARRAIS seems to provide the best analytical capacity particularly with respect to handling uncertainty. However, the system can only evaluate research activities where the value of the research results can be independently determined

Ability to evaluate in terms of social objectives The MARRAIS evaluates alternative research possibilities exclusively with respect to the efficiency goal The PPBS consider a large number of social goals and the Iowa system consider the general goals of efficiency, equity and security However, given the weak information base and the lack of an efficient analytical model, the latter systems do not provide quantitative estimate of expected contribution to achieving social goals other than efficiency

Hence, to summarize, it appears that the research manager does not yet have an efficient and workable set of tools that will help him establish research priorities with the highest expected pay-off in terms of social goals The information base must be improved, at least in Latin American research agencies, and a more efficient methodology must be developed that will provide improved tools to the research manager to facilitate decision making on research priorities In particular, an analytical framework is needed for estimating expected contributions of alternative research possibilities to the achievement of goals other than increasing production.

A review of the literature reveals a wide recognition of the need for additional research to facilitate efficient decision-making on resource allocation in applied agricultural research Tollini points out that many new production processes recommended by agricultural research are not presently economically feasible "In some cases the new processes seem to give poor results when compared to those now being used, even from the technical efficiency standpoint With limited resources for research and the need to rapidly increase productivity in the agricultural sector, this situation cannot possibly continue The country (Brazil) can no longer pay for research that does not have a good possibility of solving present problems" (64)

Dillon argues that such research should be carried out within a systems approach (15) and Drillon suggests that a joint research-training approach be utilized (17) We will now turn to a discussion of the more specific requirements of a workable model

TOWARD A WORKABLE MANAGEMENT TOOL

This section discusses the requirements of a workable analytical model useful for the research manager in decision-making on allocation of resources in applied agricultural research A conceptual model is suggested The development of the complete mathematical model is beyond the scope of this paper

The discussion will be based on the following premise <u>There are three, and only three, potential direct contributions of applied agricultural production research</u>

1 Increasing technical efficiency of at least one resource [2/]

2 Changing characteristics and composition of products and develop new products [3/]

3 Reducing production risk [4/]

Any additional contribution of applied agricultural research will be indirect - it must come about as a consequence of one or more of the three direct contributions As a result of applied agricultural research, production may expand, farm imcomes may increase, employment may be reduced, small farmers may be better or worse off, human nutrition may improve, etc However, none of these things will come about except as a consequence of one or more of the above three potential direct contributions Applied

2/ Technical efficiency is a measure of output per unit of input where both output and input are expressed in physical terms

3/ Developing plant types more apt for mechanization and improving amino acid composition in the protein of a certain crop are examples of this kind of research contribution

4/ Increasing available information for further research and improving research capacity may be considered a direct contribution of research However, it is indirect in the sense that it is an input into the research process itself rather than an output from agricultural production research cannot increase farm return *per se* It can facilitate such increase by increasing technical efficiency of one or more resources, by changing the characteristics or composition of products, or by reducing risk

This distinction between direct and indirect contributions of agricultural production research is essential to fully understand and appreciate the need for improved management tools for the research manager and to assure that such tools are relevant for establishing research priorities Furthermore, improved understanding on this issue among social scientists would greatly improve their ability to communicate successfully with agricultural production scientists particularly with respect to impact of new technology and research resource allocation It must be quite frustrating for, say, a plant breeder, who has been successful in developing a high yielding variety with wide farm adoption, to be told by the social scientist that he did it all wrong' He should have been more concerned about the distributional effects' The job of the plant breeder is to develop varieties that will yield more per unit of resource used in the production process, change the characteristics or composition of products and/or reduce production risks If society is concerned about some goal beyond that - and it should be - the plant breeder must be provided with information that will enable him to choose the research problems and solutions that are expected to correspond with these goals But once such priorities are established, his immediate goal must still be to increase technical productivity, change characteristics or composition of products and/or reduce risk

This brings us to the type of information needed to establish research priorities

Basically, an efficient model should help the research manager and/or individual researcher establish research priorities with respect to the following issues in such a way that the expected research output would reflect development goals to the fullest extent possible

1 Crops for which technical productivity should be increased

2 Resources for which technical productivity should be increased

3 Desired changes of product characteristics and composition

4 Specific types of risk to be reduced

5 Specific researchable problems to be attacked, the needed disciplinary research input and expected costs

6 Specific characteristics of the new technology to be developed

How extensive should the model be? Or, in other words, how many resources can be justified on efforts to improve research resource allocation? One would expect that the benefits from such efforts would be positively correlated with the amount of resources spent One would also expect that beyond a certain investment in such efforts the marginal benefits would be decreasing

An efficient model must provide reliable information for decision-making It must be relatively simple to operate The cost of collecting data for the model and the processing and analysis of the data must not be excessive The complexity of the model could range from certain gross predictions based on secondary data to a complete systems simulation model for the economy While the former is unlikely to provide sufficient reliable information the latter would probably be too costly to operate.[5/]

Assuming that agricultural research and efforts to improve its contribution to the achievement of development goals complete for the same resources, the decision as to how much should be allocated to one versus the other must be based on the same principles as those used to allocate resources among alternative agricultural research activities

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5/ Although expected benefits from such a model might exceed costs, it is likely that the cost differential between a complete simulation model for the economy and a somewhat simpler and more selective model exceeds the difference in benefits, i e marginal costs exceeds marginal benefits However, if a systems simulations model of the whole economy is needed for other purposes such as public policy and planning it may be feasible to include the components necessary for our present purpose at low costs

Assume that, for any given time period, a social utility function exists with respect to applied agricultural research

$$U = \sum_{i=1}^{n} \alpha_i u_i \qquad \sum_{i=1}^{n} \alpha_i = 1.0$$

where

U = social utility from applied agricultural research

α_i = the relative importance of social goal i in the overall social objective function

u_i = a quantitative expression of the utility obtained from applied agricultural research through its contribution to social goal i

n = number of goals

Then, the overall objective of applied agricultural research would be to maximixe U subject to research resource constraints

Assume further that for any one time period there is one and only one set of research activities that maximizes U within the resource constraints

$$U(max) = \sum_{i=1}^{n} \sum_{j=1}^{m} \beta_j \alpha_i u_{ij} \qquad \sum_{i=1}^{n} \alpha_i = 1.0 \qquad \sum_{j=1}^{m} \beta_j = K$$

where

β_j = optimum amount of resources allocated to research activity j

α_i = as previously defined

u_{ij} = a quantitative expression of the contribution of research activity j to social utility through social goal i per unit of research resource

K = amount of research resources available

m = number of research activities

The utility currently obtained from research is

$$U(Cur) = \sum_{i=1}^{n} \sum_{j=1}^{m} \alpha_i b_j u_{ij} \qquad \sum_{i=1}^{n} \alpha_i = 1.0 \qquad \sum_{j=1}^{m} b_j = K$$

where

b = amount of resources currently allocated to research activity j

The extent to which research resources are currently misallocated is shown by the ratio (U (Cur)/ U (max)) Hence the smaller the ratio the greater is the need for a model to improve research resource allocation The expected benefit from such a model is estimated in terms of its ability to increase the ratio (U (cur)/ U (max)) by means of 1) predicting βj for j = 1, ,m and 2) influencing the research manager to move from bj to βj Hence, the model must provide reliable predictions and be acceptable to the research manager The amount of resources to be spent on efforts aimed at improving research resource allocation is determined by the expected marginal benefits from such efforts relative to the marginal benefits from agricultural research itself

<u>The analytical model</u>

Figure 1 outlines an analytical model for decision-making on resource allocation in applied agricultural research The diagram consists of two parts The top part illustrates the area of decision-making and the bottom part outlines the relationships determining the expected contribution of alternative research efforts to the achievement of selected social goals Only those relationships believed to be most important are included in the model

The following social goals are included in the model

1 Economic growth

2 More equitable income distribution

3 Increased productive employment

4 Increased net incomes to small farmers

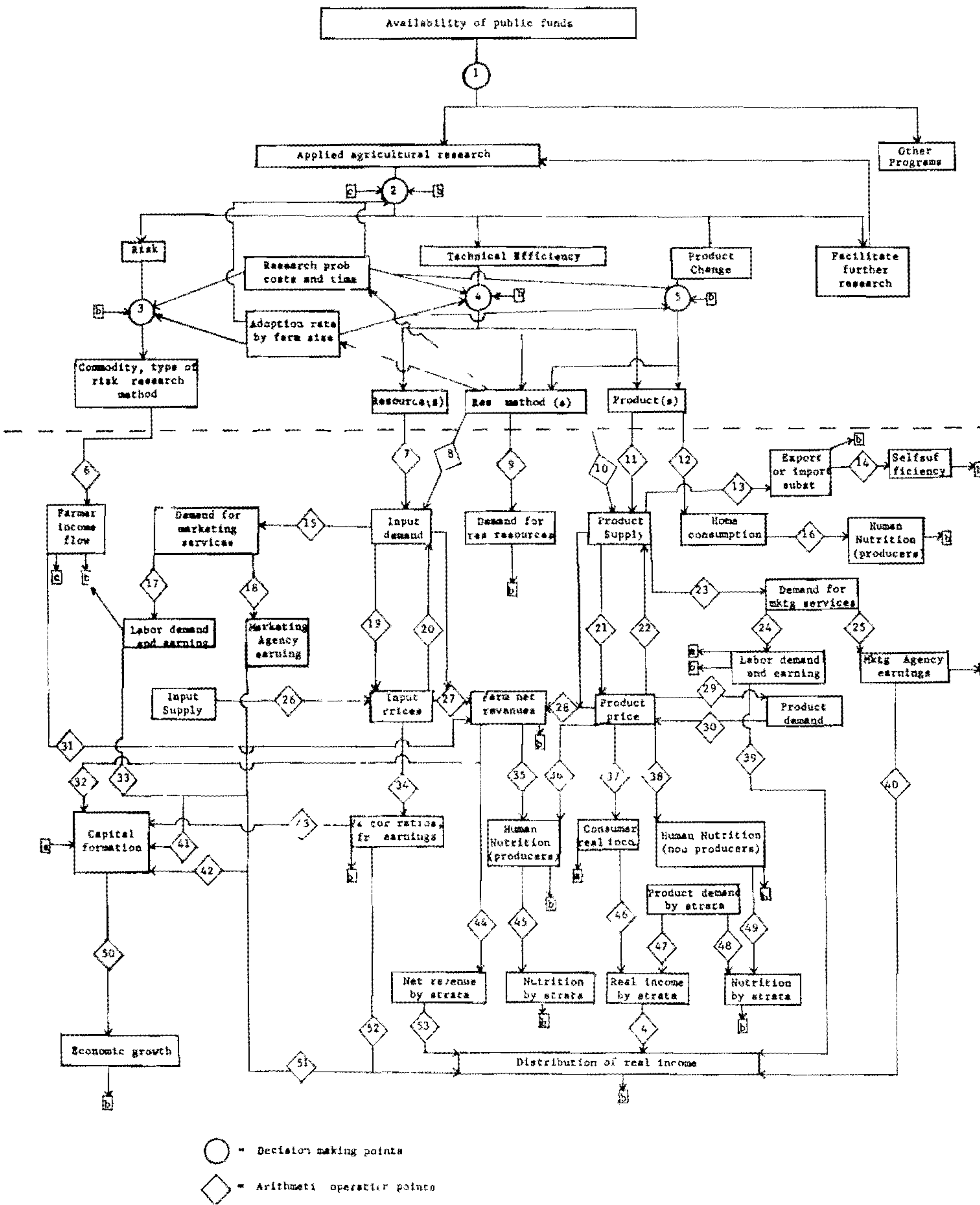
5 A more even cash flow to farmers

6 Improved human nutrition

7 Higher degree of self sufficiency in basic foods

8 Increased foreign exchange earning

Figure 1 Flow diagram for analytical model for decision making on resource allocation in applied agricultural research



Other relationships and goals may be included as needed

The contribution of new technology to the achievement of social goals depends heavily on existing public policy Hence, expected changes in this factor should be considered and the estimations may be carried out for various policy anternatives

Decision points Essentially five types of decisions must be made

1 How much public funds should be allocated to applied agricultural research versus other public programs? This decision is political in nature In the best of all cases it is based on expected relative benefits from research and other programs per dollar allocated Hence, it may be expected that improved benefits from research relative to other programs would increase the funding for research This decision is not usually made by the research manager

2 How much emphasis should be placed on research to (1) reduce risk vs (2) increase productivity vs (3) facilitate further research and research capacity (training) vs (4) changing characteristics and composition of products? In this model I assume that all applied research is problem oriented and that the impact on further research and research capacity is a by-product This does not mean that every single field experiment by itself is expected to solve a farm level problem It merely means that each research activity considered consists of the experiments expected to be necessary to solve the problem The relative emphasis on risk vs efficiency vs product change is determined on the basis of expected impact on farm income flow [c], expected impact on other goals [b], research probability, cost and time requirements and expected adoption rate of new technology

3 For what commodities should risk be reduced, what type of risk, and which research method should be used?

4 For what commodities should technical efficiency be increased, for what resources, and which research methods should be used?

5 What characteristics and/or composition of what products should be changed? Should new products be developed? If so, what should be their characteristics?

The latter three types of decisions should be based on the probability of success in alternative research efforts, cost and time requirement, expected adoption rates and expected impact on social goals [b].

Arithmetic operation points This model included 49 arithmetic operation points Each point estimates the quantitative causal effect of a change in one variable on another In addition, the quantitative value of a number of exogenous variables must be estimated Data requirements are discussed in the following section

DATA REQUIREMENTS

An exact specification of data requirements will not be attempted here However, the information needed for the model outlined in Figure 1 focuses on four sets of variables

1 Data from the farm sector

a) A general description of the production processes with primary emphasis on (1) identifying researchable problems, (2) estimating their impact on technical efficiency, (3) risk issues and (4) level of technology

b) Estimated impact of eliminating or reducing these problems on economic efficiency, product supply, home consumption and farm family nutrition, risk and cash flow, input demand including labor, farm revenues and the distribution of additional revenues on farm size

c) Predicting rates of adoption of alternative research results (new technology) and distribution costs

2 Data from the market sector

a) Current utilization of products, foreign trade and expected future product and input prices

b) Future demand potentials for existing and potential markets

c) Price elasticities of demand for products In the human consumption market such elasticities should be estimated by income strata

d) Price elasticities of demand and supply for inputs including labor

e) Nutritional status of consumers by income strata and expected distribution of additional food supplies

f) Current utilization of marketing services and impact of expanded product supply and/or input demand on the demand for these services.

3 Data from the research sector

a) Probability of success in research, time and research resources required

b) Probability and cost of solving the problems by means other than research

4 Data from the government sector

a) The general development goals of society, and their approximate relative weights.

A brief discussion of each of the four sets of variables is presented in the following

Farm Sector Data

It is interesting to note that most efforts aimed at improving resource allocation in applied agricultural research assume that the relative importance of alternative re - research efforts w r t production and productivity is known This is probably not true in Latin America On the contrary, lack of information on the relative impact of re - searchable problems on production and productivity may well be the major reason why current benefits from most agricultural research in Latin America are below potential benefits

Allocation of resources in applied agricultural research is frequently made without sufficient knowledge about the existing problems and their relative economic importance in the production process The communication between the farm sector and the research institute is often deficient and the demands at the farm level for problem solving research frequently are not well known by the researchers

Most Latin American farmers, maybe with the exception of large commercial ones and member of efficient producer associations, are unable to communicate their research needs directly to the research institutes because of institutional arrangements and social barriers Because of that situation, research is often irrelevant to the actual farm problems and research results are not adopted

A system is urgently needed that will provide a continuous flow of information to the research manager and/or the individual researcher on the potential gains in production, productivity and risk obtainable from (1) developing resistances to existing diseases and insects, (2) improving cultural practices, (3) improving plant types, (4) changing plant response to nutrients, (5) adapting plant type to ecological conditions that are not optimal for present plant types, etc Furthermore, information is needed on the farmers' demand function for new technology and how it may be changed, in order to focus on the development of technology with a high probability of adoption

Ideally, such a system would be built on a continuous feed back of information from the farmer through the extension service to the research agency as is the case in Denmark and certain other countries Unfortunately, such an information feed back does not exist in Latin America maybe with the exception of some of the integrated rural development projects

Although such feed back may develop on a national scale, it is not likely to do so in the near future In the meantime, the necessary information may best be obtained through organized surveys including field observations In addition to these surveys it may be necessary to carry out controlled experiments on the yield reducing effect of the various researchable problems. While field surveys will provide information on area affected by each of the researchable problems and some indication of the yield depressing impact, controlled experiments on yield losses will provide more exact information on yield reducing effect and together the two data sources provide a sound basis for estimating production and productivity impact of each of the researchable problems The impact on risk would be estimated from survey data on past appearance and severity of the problems

Market sector data

Information on the structure and performance of product and input markets is essential to predict the contribution of alternative research efforts to the achievement of development goals

Existing and expected future product demand relationships may be very unfavorable to the expansion of the supply of certain commodities while favorable to the expansion of others. In the case of new products or drastic changes in traditional products it is important to predict consumer preferences either before research is initiated, or at as early a stage in the research as possible Although a certain change in a traditional product makes it "better" using some objective measure such as nutritional value, it is quite possible that the consumer finds it unacceptable A considerable number of cases could be cited where "good" products have been developed through research, only to find that they were unacceptable to the consumer Had the consumer preferences been checked out at an earlier stage, a considerable amount of research resources might have been saved

Instead of allocating research resources to fit existing product market relationships it is frequently possible to change the market relationships to fit the research results Consumer preferences may be changed, new markets may be found, etc It is important to predict how these relationships would behave in the case of supply expansions in order to recommend adequate public policy measures aimed at facilitating the necessary changes

The impact of new technology on input demand will depend on the particular technology developed Hence, before the decision is made on the type of technology to develop, information should be obtained on existing and expected future input supply relationships

Research sector data

It is very difficult to predict the outcome of most research with a high degree of precision The uncertainty is largely due to the very nature of research A number of agricultural scientists, probably a large majority, are likely to argue that it is impossible to predict research outcomes at all However, after having discussed the issue with a number of colleagues in the biological sciences I am convinced that most applied agricultural scientist have a fairly well found opinion about the degree and/or probability of success of projects in their professional field as well as the time requirements Few attempts have been made, however, to utilize this expertise in a formal way to help guide the allocation of research resources One should not overlook the fact, of course, that a large number of potential project proposals were never submitted because the researcher considered the probability of success to be too small or the time requirements too large

Although the outcome of research usually cannot be predicted with great precision it is argued here that efforts to utilize the prior knowledge of the scientists in a more formal manner to make some, at least crude, predictions as to outcomes is likely to greatly improve the efficiency of the allocation of resources in applied agricultural research An analytical framework for this purpose has been suggested by Fishel (30)

Government sector data

Development goals may be classified under three general headings 1) growth, 2) equity, and 3) security Although it may differ considerably among countries, the overall development objective usually includes all three of these types of goals

The expected contribution of alternative research efforts to society's development goals must be estimated if social benefit from agricultural research per research dollar invested is to be maximized For this purpose, the development goals must be clearly defined and, if possible, the socially acceptable trade-offs among them should be specified

At present, little information is available for the research manager on society's development goals, the acceptable trade-offs among them and the expected contribution of alternative research efforts to these goals Research priorities are - at best - based exclusively on the immediate research objectives of increasing production and productivity

NEED FOR FURTHER RESEARCH

This paper may be considered a first step to develop an efficient and workable model for improving resource allocation in applied agricultural research In order to complete the model the following additional steps must be made

1 The flow diagram must be refined and maybe reduced

2 A mathematical model must be developed on the basis of the flow diagram

3 The exact data requirements must be specified

4 An efficient method for collecting these data periodically must be specified

5 Data must be collected from one country or region to test the model

Certain aspects of the above mentioned are presently being worked on A mathematical model aimed at predicting the impact of product supply increases on consumer real income and nutrition is near completion Furthermore a considerable amount of data has been collected on the relative impact of researchable problems (disease and insect damage, etc) on production and productivity of cassava and maize in Colombia Similar work is presently being planned for field beans

Other research urgently needed include

1 An analysis of the criteria currently used for resource allocation in applied agricultural research within national agricultural research agencies in developing countries This study would focus on the research manager's decision making behaviour and how decisions are presently reached about research priorities in public agricultural research agencies.

2 An analysis of the potential gains from the utilization of a model such as the one suggested in this paper instead of presently used methods for research resource allocation Such an analysis should estimate expected pay-off from resources used to develop and use the model

These two studies may be carried out as case studies of, say, three research agencies in Latin America It appears that they provide sound topics for Ph D dissertations

CONCLUDING REMARKS

During frequent discussions with colleagues in agricultural research, research management and economics, three arguments against a more formal method for allocation of resources in applied agricultural research have evolved First, it is impossible to make any reliable predictions on relative impact of alternative research efforts on development goals because of the uncertainty involved Secondly, expanding production and improving productivity are the only responsibilities of the agricultural research agency If research activities aimed at these goals conflict with development goals it will be the responsibility of the government to introduce corrective public policy measures Thirdly, there is some concern that individual researchers will lose the freedom to choose his own research projects

A considerable body of theory has been developed on decision-making under risk and undertainty [6] While this theory is widely utilized in private enterprise it is hardly recognized in agricultural research management There is reason to believe that the application of such theory together with improved information provided by a system such as the one suggested in this paper will greatly improve the probability of successful research resource allocation However, the type of model suggested in this paper cannot - and should not - replace the judgments of the research manager or the individual researcher It merely reduces the degree of uncertainty involved in making judgments and focuses research on development goals

With respect to the second argument raised above it should be noted that interaction between research and public policy measures is needed to assure a high level of social benefit from research However, correctly established research priorities can greatly reduce the need for corrective public policy Furthermore, certain mistakes in establishing research priorities cannot be corrected by public policy

Finally, on the third argument it should be stressed that the framework suggested in this paper should not constrain the individual researcher unduly but merely help him focus on problems with the highest expected pay-off to society, something that no serious and socially conscious researchers is likely to oppose It should, however, constrain the researcher who selects his research projects for reasons other than their expected contribution to the achievement of social gaols Research for the sake of research is a luxury that few developing countries can afford

Given the urgency to accelerate food production and assure an equitable distribution of the resulting benefits, all resources involved in applied agricultural research must be employed in such a way as to produce as large a contribution as possible to the achievement of development goals

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6/ See, for example Robert Schlaifer Analysis of Decisions Under Uncertainty McGraw-Hill Company, New York, 1969

If this is not presently the case - and I argue it is not - we, the agricultural economists, can blame ourselves for having focused primarily on estimating the results from past research rather than developing guidelines for future research

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