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A SYSTEMS APPROACH TO AGRICULTURAL RESEARCH

RESOURCE ALLOCATION IN DEVELOPING COUNTRIES

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Effective agricultural development requires the interaction of farmers and rural institutions working within constraints imposed by their socio-economic and ecological environments. For the effective allocation of their scarce human and financial resources, institutions such as those involved in public agricultural research must take into consideration the needs of farmers as well as overall national social and economic goals. Whereas farmer decision-making has received considerable attention, decision-making on agricultural research resource allocation has received less attention, and as a consequence, theee is a shortage of useful data and of effective techniques for their analysis.

While improved productivity and increased production may be the immediate goals of applied agricultural production research, they are at the same time means to reach some final goals such as improved human nutrition, a more equitable income distribution, increased foreign exchange earning, etc. Agricultural research institutions are presumed to seek ways to produce more and/or better food, feed and fiber at a reduced per unit cost and in such a way as to maximize the contribution to the achievement of the final social and economic goals. Hence, there is a need for effective means to assist in predicting the relative contributions and costs of alternative research activities in order to establish research priorities and allocate available research resources.

This paper suggests a systems approach to the collection and analysis

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of information expected to be useful for establishing such means.[1/] The first part of the paper is dedicated to a brief discussion of means and ends in agricultural research. Then follows an outline of a scheme for data collection and analysis and the paper terminates with a discussion of some of the information gerating efforts currently under way in CIAT.

MEANS AND ENDS IN AGRICULTURAL RESEARCH

A clear understanding of the distinction between final and immediate goals on the one hand and means to reach these goals on the other is essential to fully appreciate the need for improved management tools for research management and to assure that such tools are relevant for establishing research priorities. For example, while increased production may be an immediate research objective, it is not a final goals of agricultural research but rather a means to reach some final goals such as improved income distribution or improved nutrition. In a similar fashion, improved income distribution, although it may be a final development goal, does not serve as working objective for the agricultural scientist.

1/ A discussion of the systems approach in general may be found in a number of books including: Stanford L. Opner (Editor), Systems Analysis, Penguin Modern Management Readings, Middlesex, England, 1973, C. W. Churchman, R.L. Achoff and E. L. Arnoff, Introduction to Operations Research. John Wiley & Sons, New York, 1957; A W. Wymore, Systems Engineering Methodology for Interdisciplinary Teams. To be published by John Wiley & Sons, New York, 1974. Preston C. Hammer, (Editor), Advances in Mathematical Systems Theory, Penn. State University Press, College Park, 1969. The usefulness of this approach for research resource allocation is discussed in: John L. Dillon, The Economics of Systems Research. Paper presented to Agricultural Systems Research Conference, Massey University, 20-22 November, 1973.

To help clarify the distinction between means and goals, figure 1 outlines the process by which applied agricultural production research may contribute to final social and economic goals. Successful applied agricultural research produces knowledge and/or improved material, e.g. seed. The knowledge and improved material may be fed back into the research process for further work, or it may be released to the farmers as new technology. There are three, and only three, potential direct contributions of such technology: (1) increasing technical efficiency of at least one resource;[2/] (2) changing characteristics and composition of products and developing new products;[3/] and (3) reducing production risk. Any other contribution will be indirect - it must come about as a consequence of one or more of the three direct contributions. There are three potential results of the above direct contributions: (1) changing the composition and quantity of the aggregate supply of food, feed and fiber; (2) changing the composition and quantity of the aggregate resource demand, e.g. increased or decreased employment, and (3) changing the composition and quantity of aggregate domestic farm consumption. Any of these results may contribute to the achievement of national development goals through changes in elements such as: (1) farm income and its distribution among groups of farmers, (2) relative resource earnings, (3) consumer real income and its distribution among consumer groups,

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2/ Technical efficiency is a measure of output per unit of input where both output and input are expressed in physical terms, e.g. production/ha.

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

(4) foreign exchange earnings and (5) human nutrition.

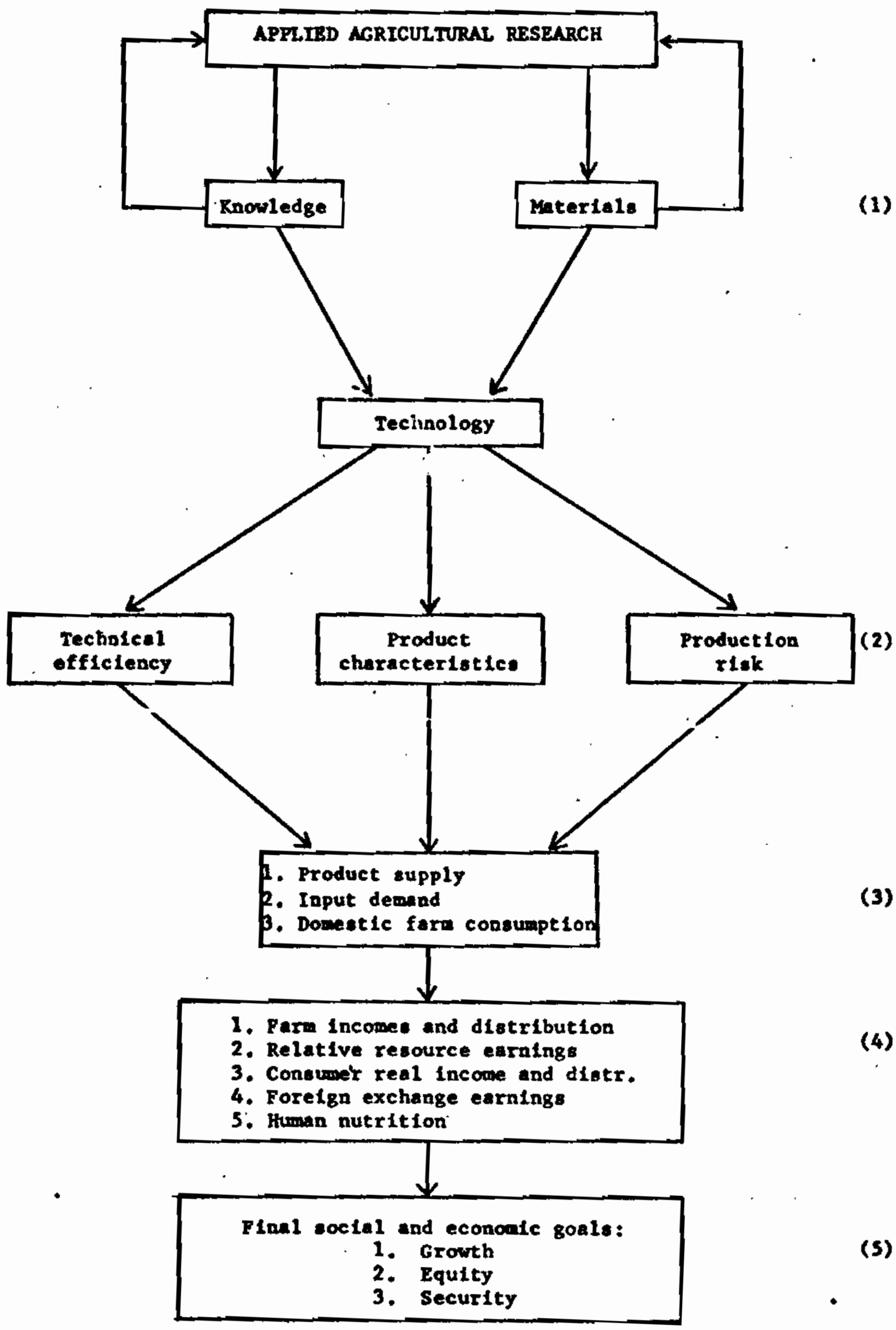
In viewing agricultural research and its potential outcomes and implications as a process, the confusion on means and ends may be reduced. The first level of outcomes (marked by (1) in Fig. 1) is clearly a set of means, except when research is carried out for its own sake. The second level represents the working objectives for the agricultural production scientist. For research management and society as a whole, however, this level expresses alternative approaches to reach the goals shown in the fourth level. The third level shown in Figure 1 represents the vehicle by which activities meeting the scientist's working objectives are influencing the achievement of the final goals. Changes in product supply, input demand and domestic farm consumption are not themselves goals but means to reach some final goals.

Two conclusiones may be drawn from the above discussion:

1. The working objectives for the agricultural production scientist must be expressed in terms of technical efficiency, desired product characteristics and/or production risk. The specific working objectives and the most effective technology to reach these objectives should be determined on the basis of national development goals. Concurrence between the technology specification received by the scientist and the technology which results in maximum contribution to the achievement of social goals is the responsibility of research management.

2. Research management needs information for research resource allocation capable of (a) translating national development goals into working objectives for the agricultural production scientist and (b) helping the production scientist select the most effective technology to reach the working objectives.

Figure 1. Illustration of the potential outcomes and implications of agricultural research



A SUGGESTED INFORMATION SYSTEM

An effective information system for allocation of resources in applied agricultural production research must be capable of providing research management with reliable information that will enable the establishment and periodic review of research priorities in such a way as to maximize the expected contribution from research to the achievement of national development goals. The system should provide a frame of reference within which project priorities can be established and individual projects can be accepted or rejected without large time delays. Extreme care must be taken to avoid a system that imposes heavy bureaucratic procedures on the production scientists.

The system should be sufficiently comprehensive to improve presently available methods. However, the decision as to how much should be spent on achieving such a system must be based on the same principles as those used to allocate resources among alternative agricultural research activities.

Before the data requirements and the conceptual model are discussed it may be useful to illustrate a series of steps necessary to translate national development goals into working objectives for the scientist and technology specifications. Such illustration is shown in figure 2.

It is essential that the development goals be clearly specified. The changes in product supply, input demand and domestic farm consumption expected to meet some or all of these goals should be identified. Then the researchable problems, the solution of which is expected to accomplish such changes must be identified. [4/] Assume as an example, that one of society's

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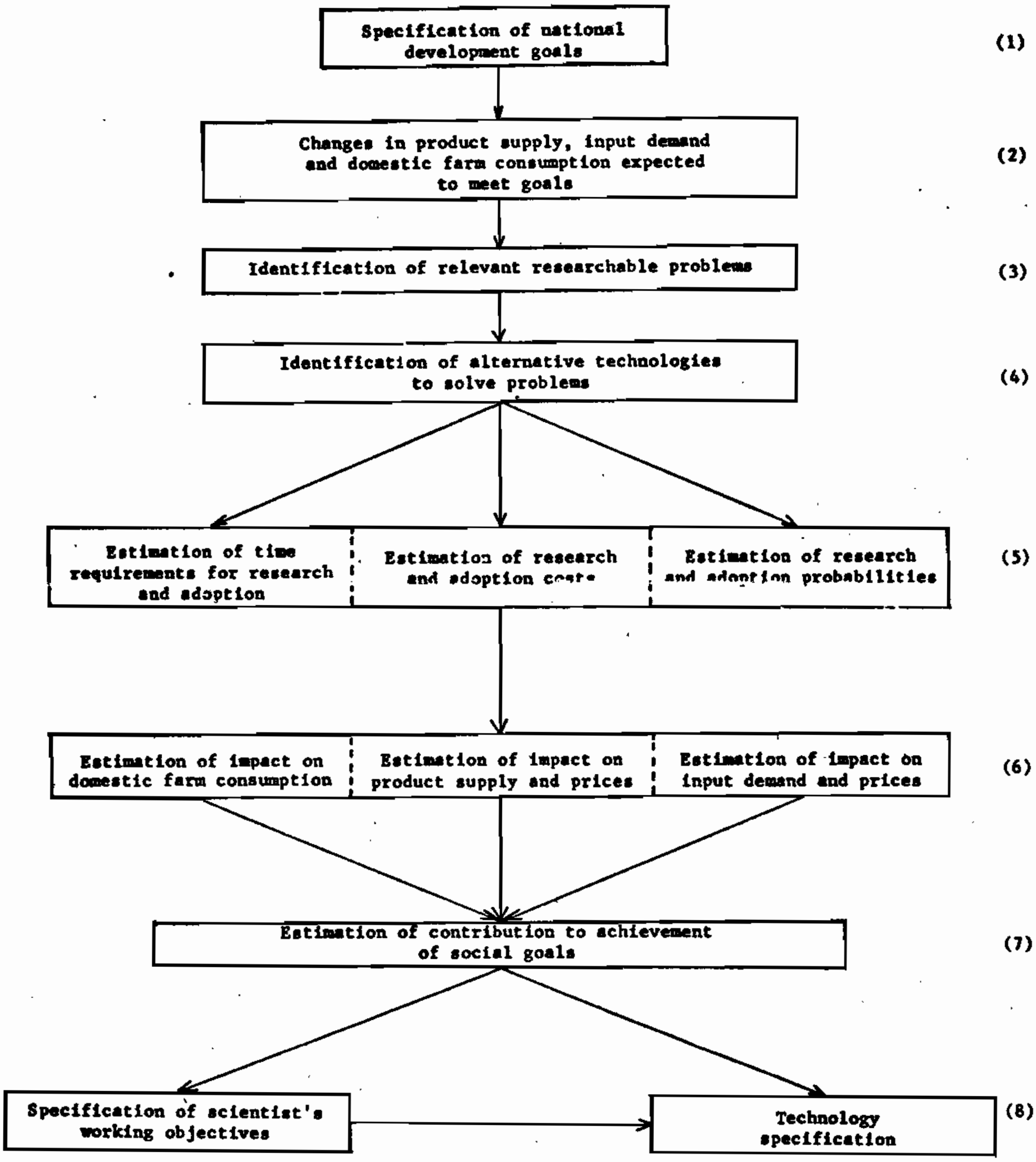
4/ At this point no attempt should be made to quantify the expected contributions to development goals.

Figure 2. Outline of a series of steps needed to translate national development goals into working objectives and technology specification



goals is to increase protein intake among protein deficient groups of the population.

It may be expected that - among other activities - increased production of grain legumes, animal products and high protein cassava may make a contribution. The reseachable problems limiting production of these commodities, e.g. a certain disease in field beans, the non-availability of a high protein cassava variety, etc., should then be identified.

It is important that the problems limiting the achievement of established objectives be identified independently of possible solutions, i.e. a "technology free specification of the problem". For example, if the problem is one of low yields, it should be expressed in terms of the factors causing low yields, e.g. lack of insect resistance, rather than specifying the problem as one of developing an insect resistant variety, because there exist alternative solutions to the problem of lack of resistance. As such, the technology free specification of the problem implicitly provides a measure of the potential value of assembling technology to solve a particular problem. The technology free specification of the problem has to identify the farmer's needs, and convert these needs into a specification of the parameters and constraints that must be satisfied by the technological innovations.

When the relevant researchable problems are identified, the alternative technologies expected to solve the problems should be specified. Then the cost, probability and time requirements of research and farm adoption should be estimated for each proposed technlogy. Based on these estimates as well as the nature of the problem, the structure and performance of the production sedtor and the input and product market relationships it is now possible to estimate the impact of solving each of the problems on product supply, input demand and domestic consumption. The last step before specifying the scientist's working objectives and the technology to be developed refers to a quantitative estimation of the contribution of alternative research efforts to the achievement of national development goals.

Data Requirements and Sources

Based on the broad framework presented above it is now possible to specify the data requirements and the possible sources of these data. An exact specification of data requirements is not attempted.[5/] Four sources of data are discussed: (1) the farm sector, (2) the market sector, (3) the research sector, and (4) the government.

Farm Sector Data

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 may not be well known by the researchers.

Farmers in most developing countries, maybe with the exception of large

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5/ A more complete discussion of data requirements may be found in: Per Pinstrup-Andersen Toward a Workable Management Tool for Resource Allocation in Applied Agricultural Research in Developing Countries. Revised version of paper presented at the Ford Foundation Meeting for Program Advisors in Agriculture, Ibadan, Nigeria, April 29-May 4, 1974.

commercial ones and members of efficient producer associations, tend to have severe difficulties in communicating their research needs to the research institutes because of institutional and social barriers. Because of that situation, some research may be irrelevant to the actual farm problems and research results may not be adopted.

A system is urgently needed that will provide a continuous flow of information to the production scientists and others involved in research decisions, on the potential gains in production, productivity and risk obtainable from such research activities as (1) developing resistance to specific diseases and insects, (2) improving cultural practices, (3) improving plant types, and (4) changing plant response to nutrients. Furthermore, information is needed on the farmers' preferences with respect to new technology and how these preferences may be changed, in order to focus on the development of technology with a high probability of adoption.

Such a system might be built on a continuous feed back of information from the farmer through the extension service to the research agency. Unfortunately, such an information feed back usually does not exist in developing countries.

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, (pests, climate, etc.) and the resulting yield variance.

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 this regard, demand elasticities are needed to estimate expected impact on prices and distribution of benefits between producers and consumers. 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 less acceptable than the original product. A 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

Data are needed to estimate research costs and time requirements and the likelihood of achieving the desired results. Although the outcome of research usually cannot be predicted with great precision because of the very nature of research, it is argued here that efforts to utilize the prior knowledge of the scientists in a formal manner to make some, at least crude, preditions as to outcomes is likely to greatly improve the efficiency of the allocation of resources in applied agricultural research.

Government sector data

Development goals may be classified under three general headings: 1) growth, 2) equity, and 3) security. Although the specific development goals may differ considerably among countries, all three of these types of goals are usually found.

The development goals must be clearly defined and, if possible, the socially acceptable trade-offs among them should be specified.

At present, research management tends to have very limited information on these issues, and research priorities are - at best - based exclusively on the objectives of increasing production and productivity.

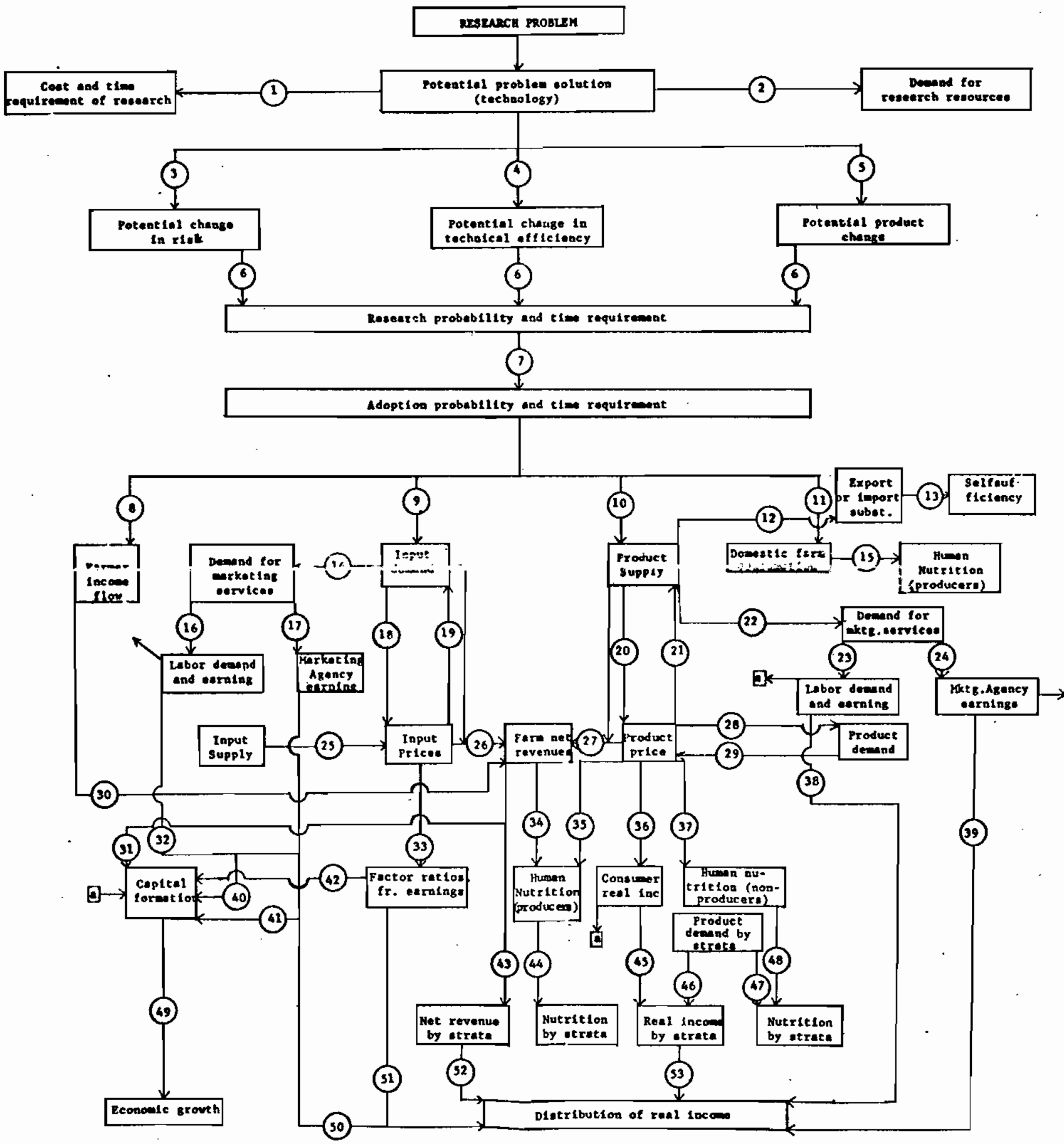
The Conceptual Model

Figure 3 outlines a conceptual model for an information system for resource allocation in applied agricultural research. The figure outlines the relationships determining the expected contribution of alternative research efforts to the achievement of selected development goals. The model outlines some of the implicit relationships we believe should be considered in decision-making on resource allocation in applied agricultural research. It is not suggested here that a quantitative model incorporating all these relationships be constructed. Rather, what is intended by presenting the model is to make explicit the range of relationships so that when a particular sub-set of relationships is analyzed, the assumptions on the excluded relationships are made explicit.

The following social goals are considered 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.

Figure 3. Flow diagram for analytical model for an information system for resource allocation in applied agricultural research



○ = reference numbers to assist in the subsequent discussion

6. Improved human nutrition.

7. Higher degree of self sufficiency in basic foods.

8. Increased foreign exchange earning.

The model may be changed to accomodate a different set of goals.

Implicit in each numbered line is a causal effect relating change in one variable to change in another. The contribution of new technology to the achievement of development goals depends heavily on existing public policy. Hence, existing policy should be clearly specified and it may be useful to apply the model to allow for alternative policy measure.

SELECTED CIAT ACTIVITIES

The remainder of the paper discusses some of the current CIAT efforts aimed at developing and field testing simple methodologies for gerating the information discussed above. While the information obtained from these efforts is expected to be useful for CIAT and the national research agencies in the countries where the empirical testing is carried out, the primary purpose of the work is to develop simple methodologies for use by national research agencies in Latin America.

The CIAT work is discussed under three headings: (1) Single commodity analyses, (2) Multi-commodity analyses, (3) A systems engineering methodology for small farms. The discussion is limited to selected illustrative projects. A description of all the CIAT activities in this area is beyond the scope of this paper.

Single Commodity Analyses

This type of work is relevant to a situation where a decision has been made to research a specific commodity either indefinitely or for a certain minimum time period. While the amount of research resources allocated to a certain commodity may be gradually increased or decreased over time, low mobility of research resources may not permit rapid and large changes in relative research emphasis among commodities. Hence, the single commodity analysis may be appropriate at least for the short run.

In the case of a single commodity, information is needed on the commodity itself as well as its interaction with other commodities both in production and consumption. The current CIAT single commodity data collection and analysis focuses on the farm sector.

The single commodity approach attempts to identify the factors associated with low productivity in a specific crop. It then proceeds to (1) identify researchable problems expected to improve productivity and production, (2) estimate the impact of solving each of the problems on productivity and production, (3) estimate the research and adoption probabilities, costs and time requirements for each problem and each technology, (4) estimate the impact of alternative research efforts on product supply, input demand, domestic farm consumption, farm sector income and its distribution on farm size. Such projects are currently under way for maize, cassava and beans. Basic data are collected from agro-economic surveys and agro-biological experiments.

Agro-economic surveys

The agro-economic survey attempts to transmit to production scientists and research management the farm level demand for applied agricultural research, through establishing a direct link between the farm and the research agency. The survey describes the production process and focuses on identifying factors limiting production and productivity and estimating their relative importance. Although highly interrelated, these factors may be classified as (1) agro - biological, (2) socio-economic, and (3) institutional. Given the purpose of the survey, emphasis is placed on agro-biological and related economic factors.

Agro-biological factors

Most of the data related to the agro-biological factors are obtained from direct observation in the farmers' fields. The occurrence and severity of disease and insect damage, and weed occurrence are noted. Furthermore, existing cropping systems, cultural practices, soil quality, availability of water, plant type and general plant development are described and yields and yield variance are estimated. The farmer's perception of the agro-biological problems are compared to the field observations and his attitudes toward solutions to the problems (New technology) are sought. 6/

Economic factors

Data are sought on (1) the use of purchased inputs such as chemical fertilizers and insecticides, (2) labor use and production costs by production activity, and (3) gross and net revenues obtained from the crop.

Institutional factors

Information is sought on certain aspects of input and product market relationships, as well as the availability and use of credit and technical assistance.

6/ Emphasis is placed on obtaining some indication of the farmer's objective function cincluding the relative importance of income, risk and home con - sumption to help identify technology with high expected rate of adoption.

Data collection mechanism

The data are collected by a small team of agronomists and economists. After having received an intensive training course in diagnosing farm level production problems, the team makes periodic visits (normally 3 - 4 visits) to a selected sample of farmers throughout a complete crop cycle. About half of the time on each farm is spent in the field collecting data on agro - biological issues while the other half is used to interview the farmer.

Training of the field team is one of the most critical issues in assuring high quality data from the agro-economic survey. Making a correct diagnosis in the field, e.g. distinguishing among the symptoms of certain diseases, insect damage, etc. in most cases requires considerable expertise. Before initiating the agro-economic survey, the agronomists on the CIAT field teams spend a certain amount of time with each disciplinary group on the relevant CIAT commodity team supplemented in some cases with training from professionals from national research and extension agencies. Most of this initial training takes place in the field.

Agro-biological experiments

The agro-economic survey provides an estimate of the area affected by each of the problems identified. Furthermore, it gives an indication of the yield depressing effect. However, it is frequently difficult to estimate the yield impact from survey data with a great deal of accuracy. Hence, controlled experiments are carried out to help quantify the impact of the problems on yields.

Results

The work described above is in its perliminary stages and although more time is needed to terminate the first round of data collection and analysis before the real value of these efforts for research resource allocation can be established, it appears that the direct participation of the CIAT agricultural production scientists in project planning and training of field agronomists as well as communication with these agronomists when they are back at the research station and the distribution of preliminary project findings have been of value to the scientists in planning their future research.

Multi-commodity Analysis

As opposed to the analysis described above, the multi-commodity approach assumes that the choice of commodities for research and the relative priority among those commodities are not determined a priori. Hence, in addition to the data collected for a single commodity, information is needed on the relative contribution to development goals of research on alternative commodities.

In this area, CIAT is currently undertaking a project which initial objective is to develop and test a methodology to estimate the impact on human nutrition of increasing the production of each of a number of foods. The empirical testing is currently being done for the city of Cali, Colombia. In addition to the impact on human nutrition, the project provides information of the impact of alternative production expansions on consumer real income by income strata and may at a later stage be extended to include the impact on farm sector incomes and distribution.

The methodology is based on a simulation model using as basic data a set of price elasticity matrices (one for each of five income strata) as well as current food prices, quantities consumed and protein and caloric intakes. The model facilitates the estimation of the impact of alternative agricultural research efforts on human nutrition. The model forms a part of the conceptual model shown in Figure 3, estimating the coefficients indicated in the figure by the numbers 20, 21, 28, 29, 36, 37, 45, 46, 47, 48 and 53.

A Systems Engineering Methodology for Small Farms

This approach centers on the farmer and is considered complementary to the commodity oriented approach discussed above. This approach is focused primarily on farmer goals. It involves the development of models for the small farm where the small farm system is defined as one in which the farm family and others living on the farm assemble individual enterprises into production, consumption, marketing systems in which biological and physical factors interact with social, political and economic systems. Such systems engineering models of the small farm help explaining the dynamic behavior of the farm system as a function of the input and output relationship with the external systems (the biological, ecological and institutional environment) and makes it possible to identify the most effective agricultural technologies required to stimulate changes in the performance of the individual farm systems. In particular, by being centered on the farm as a system, it is hoped that these models will identify the principal limitations to the generation of well-being, income and marketable agricultural surpluses in what we earlier in this paper called a technology free specification of the problem, i.e. a specification of the problem independent of possible technologies for its solution. The relationships explored by these efforts correspond to the numbers 8, 25, 26, 27, 34 in figure 3.

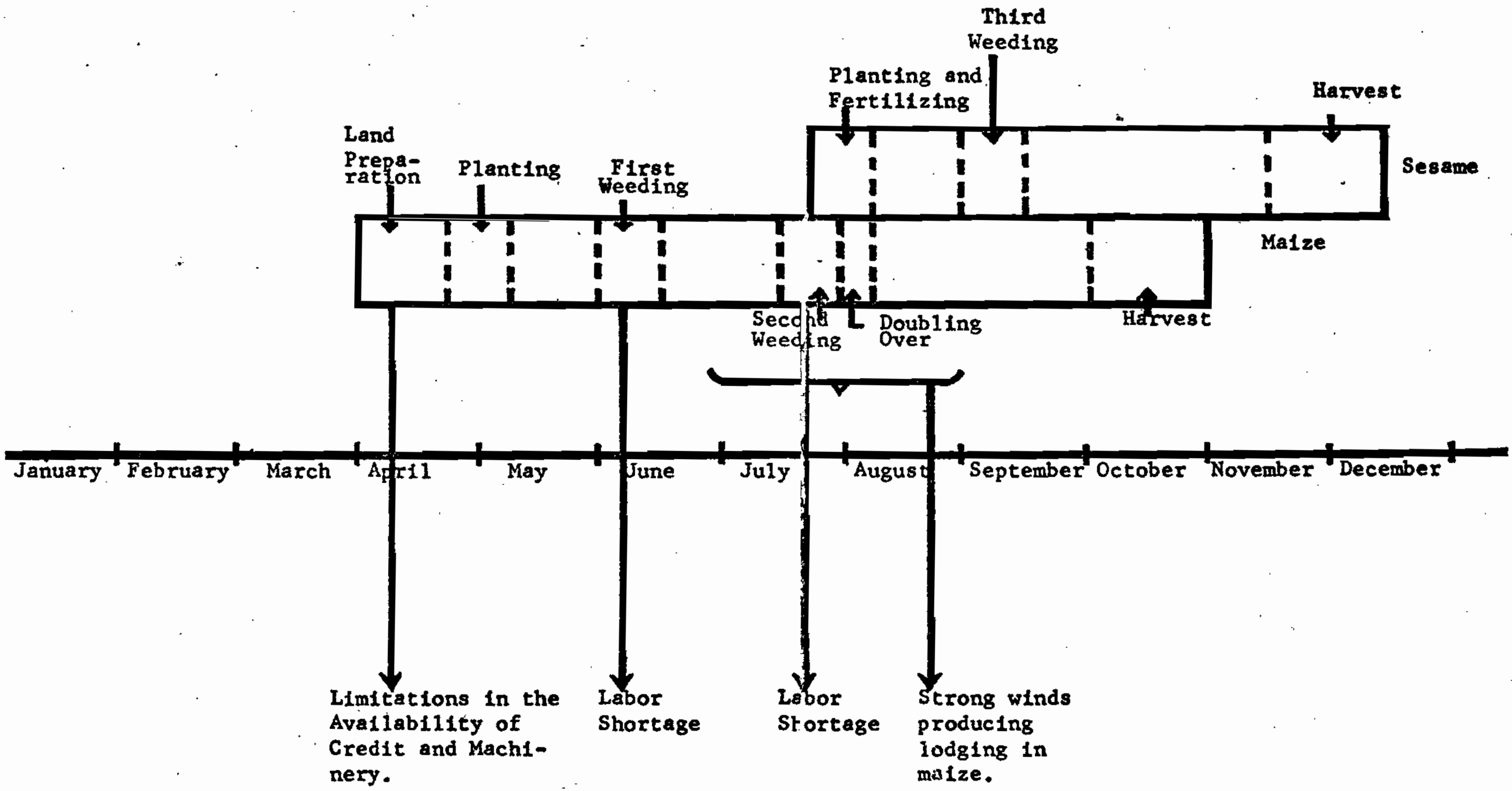
The systems engineering methodology for small farms is currently being applied by the Small Farm Systems Program of CIAT in its collaborative work with the Institute of Agricultural Sciences and Technology of Guatemala (ICTA). Before the expected utility of this methodology for research resource allocation is discussed, the overall structure of the models is briefly described.

The collaborative project is being carried out in an agrarian zone in a Southern Coastal Region of Guatemala. Figure 4 shows the principal activities of the agricultural cycle for that zone. A schematic representation of a general model for the small farm system is presented in Figure 5 while Figure 6 is a reduced version which is currently being utilized for the study of the farm system in the zone. The behavior of the small farm system is being studied as a function of the principal inputs for the system: credit, prices, availability of machinery and labor and climate. This is a limited set of input factors and the principal concern at this time is to understand the behavior of the small farm system in the presence of the climatologic risk and the interaction of this risk with other inputs.

The farmers in this zone currently utilize almost no modern factors of production and it is speculated that this situation is due primarily to risk aversion. Delays in the credit system and the lack of confidence in the support prices create a situation in which institutional factors do not help absorb the risk. There are serious delays in availability of machinery and a seasonal labor shortage exists due to competition with the large plantations. The primary purpose of the model is to analyze whether in fact the dynamic interactions of institutional and climatological factores are the principal limitations to production and farm incomes.

Sub-system Z_1 in figure 6 denominated CASH has as its principal function to account and allocate the cash flow to the different activities of the family, including the purchase of family consumption goods, factors of production and payments to credit. It is in this sub-system that farmers' decision criteria are studied.

Figure 4. Cropping Cycle on Some Farms in Southern Guatemala



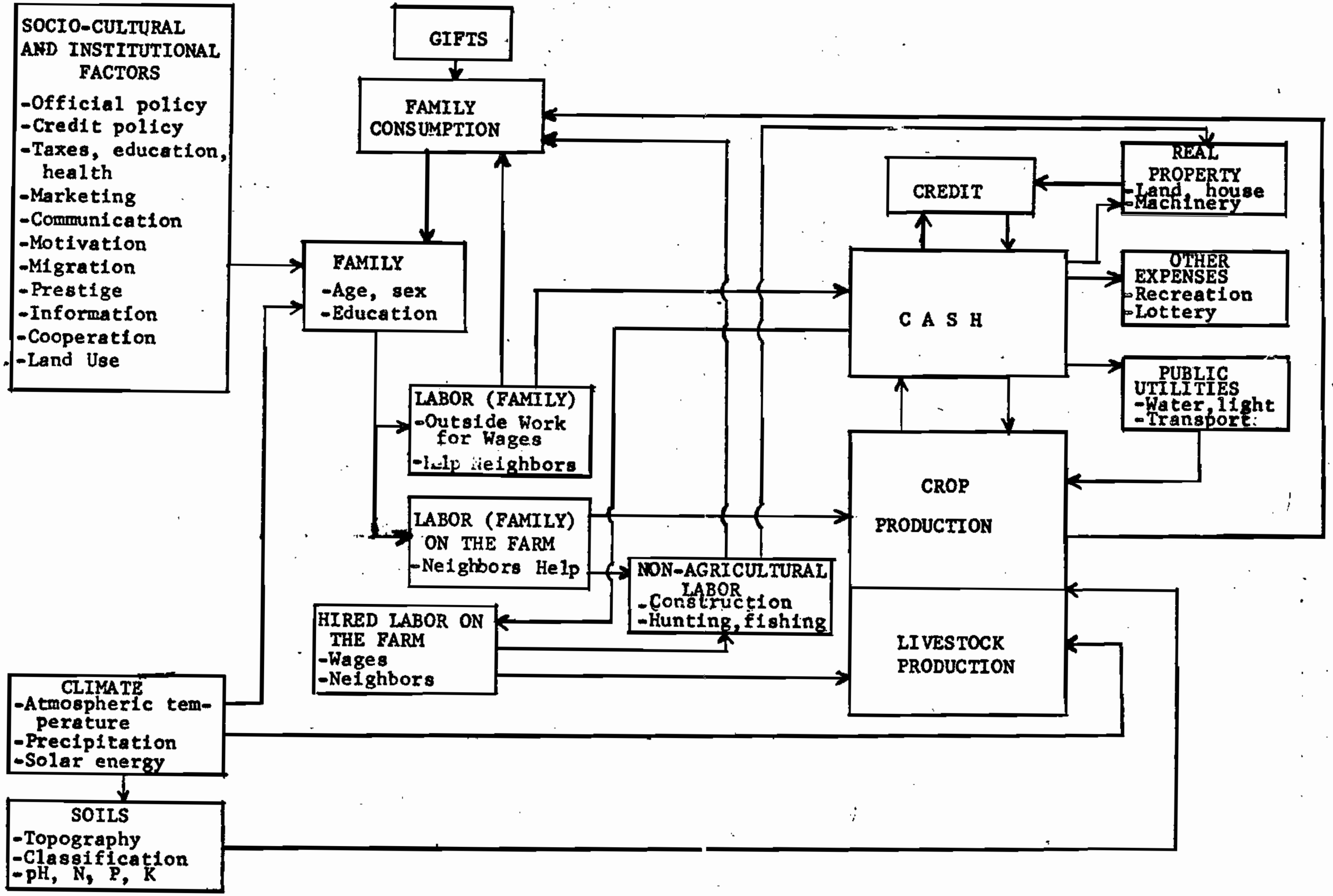


Figure 5. Schematic Diagram of "A General Model' for Small Farm Systems

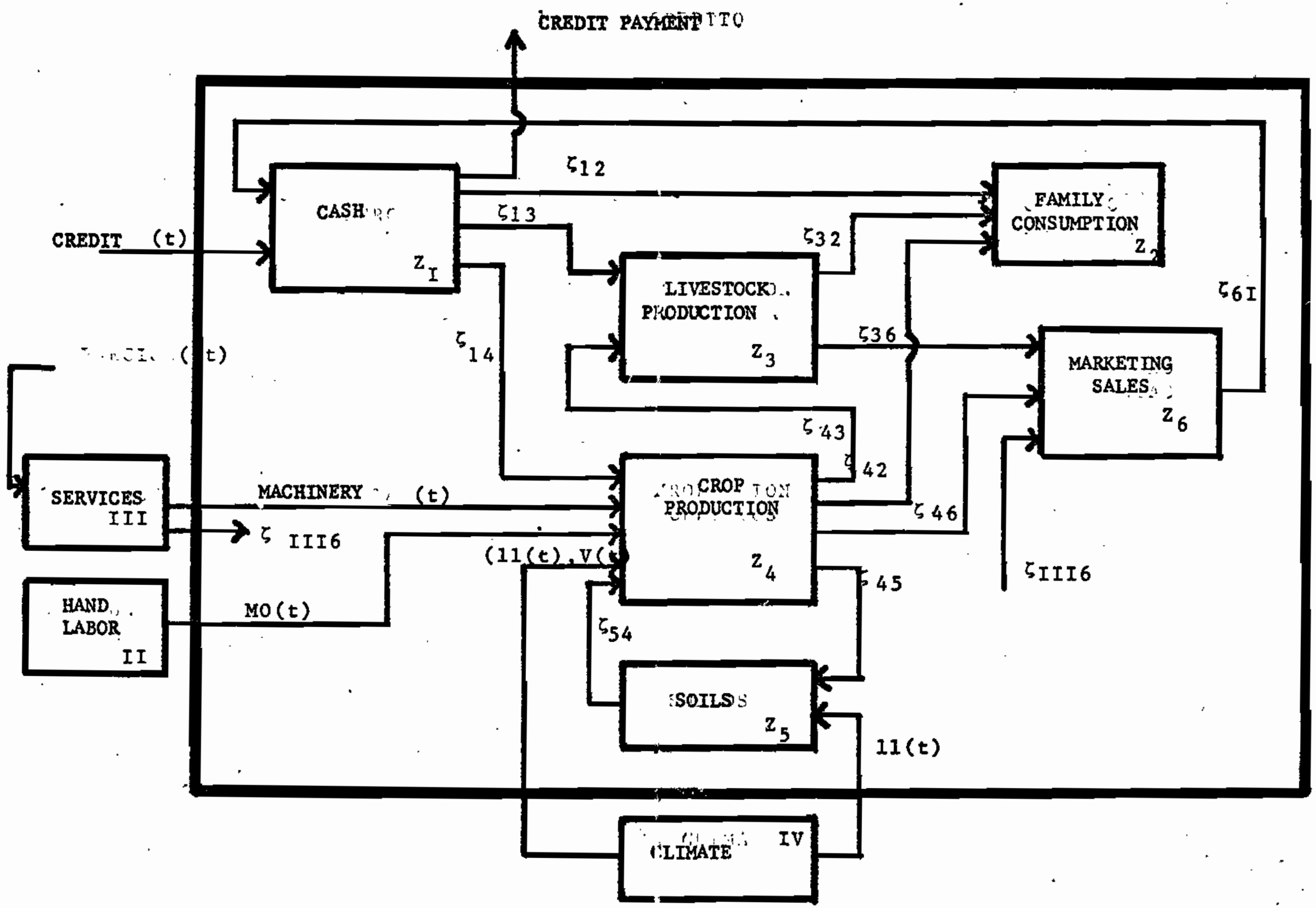


Figure 6. Reduced Model of a Farm System in Southern Guatemala

Sub-system Z_4, which is CROP PRODUCTION is linked to the external inputs of machinery and climate and to the CASH and SOIL sub-systems. The evaluation of alternative technological alternatives for production is carried out within this sub-system. The FAMILY CONSUMPTION sub-system represents the need for on-farm consumption of the various products produced on the farm as well as for the purchase of food stuffs and non-foods. This sub-system helps in estimating the family nutritional situation.

The technical coefficients used in the model are the best estimates on the behavior of each of the sub-systems as have been provided by technical experts. The structure of the model was derived from information gathered through frequent visits to the zone by the members of the CIAT Small Farm Systems Program and represents the synthesis of the insight that is available on the behavior of small farms in that zone.

A number of agronomic experiments and a socio-economic survey are presently being carried out by the CIAT Small Farm Systems Program to test the technical coefficients presently available and to test the behavior and predicting ability of the model.

It is not suggested that this model as it presently stands represents the total reality of agriculture in the zone. The purpose of developing and utilizing the model is to illustrate some of the principal structural relationships in the physical, biological and economic environment and to demonstrate the possible utility of such a model.

<u>The Model as a Research Guide</u>

It is expected that this model will be useful for estimating the likely outcomes of alternative research and public policies and institutional changes.

With specific reference to the likely outcomes of alternative extension and research policies the model evaluates a number of proposed technological packages. These packages are evaluated with respect to their expected impact on family nutrition, family income, risk (as measured by income and production variance) and labor utilization. Preliminary results from this work are shown in Figures 7, 8, 9 and 10.

Figure 7 and figure 8 present production trajectories generated by the model over a simulated five-year period. Each production trajectory is identified with the production package which was simulated. Figure 7 presents the production under the assumption that prices fluctuate between US$70 and US$120 per metric ton throughout the year as is presently the case in the zone. Figure 8 presents the production trajectories under support price. Comparison of the graphs indicates that price stability can be a means by which the adoption of technological packages is stimulated.

Figures 9 and 10 are the net family income trajectories for some of these technological packages under the two sets of price assumptions. Figure 9 is illustrative of the risk that is involved under a situation of unstable prices and unstable weather conditions. In particular two of the so called "production packages" are so costly that when risks are taken into consideration they would generate negative net income for at least one year. Traditional or subsistence farmers cannot tolerate this kind of risk. Another salient feature of the four graphs is that the traditional production package which utilizes few modern factors of production, produces the lowest yields but tends to be better in terms of net income than some of the more complicated production packages. The traditional system has the lowest income variance. A comparison of figures 9 and 10 would illustrate the potential

Figure 7. Simulated Maize Production Trajectories with Prices Varying from US$70 to US$120/ton

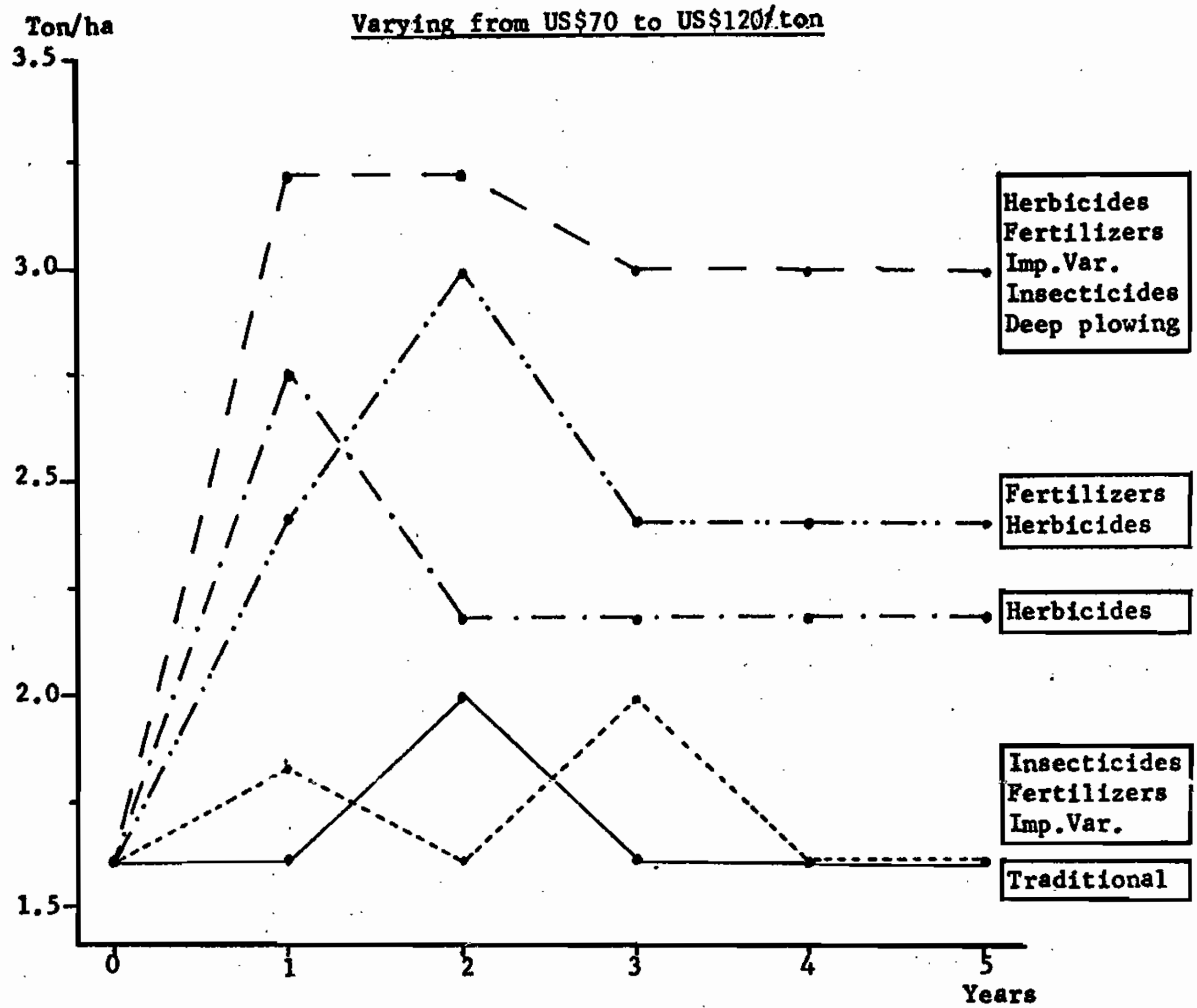


Figure 8. Simulated Maize Production Trajectories With Prices Fixed at US$120/Ton

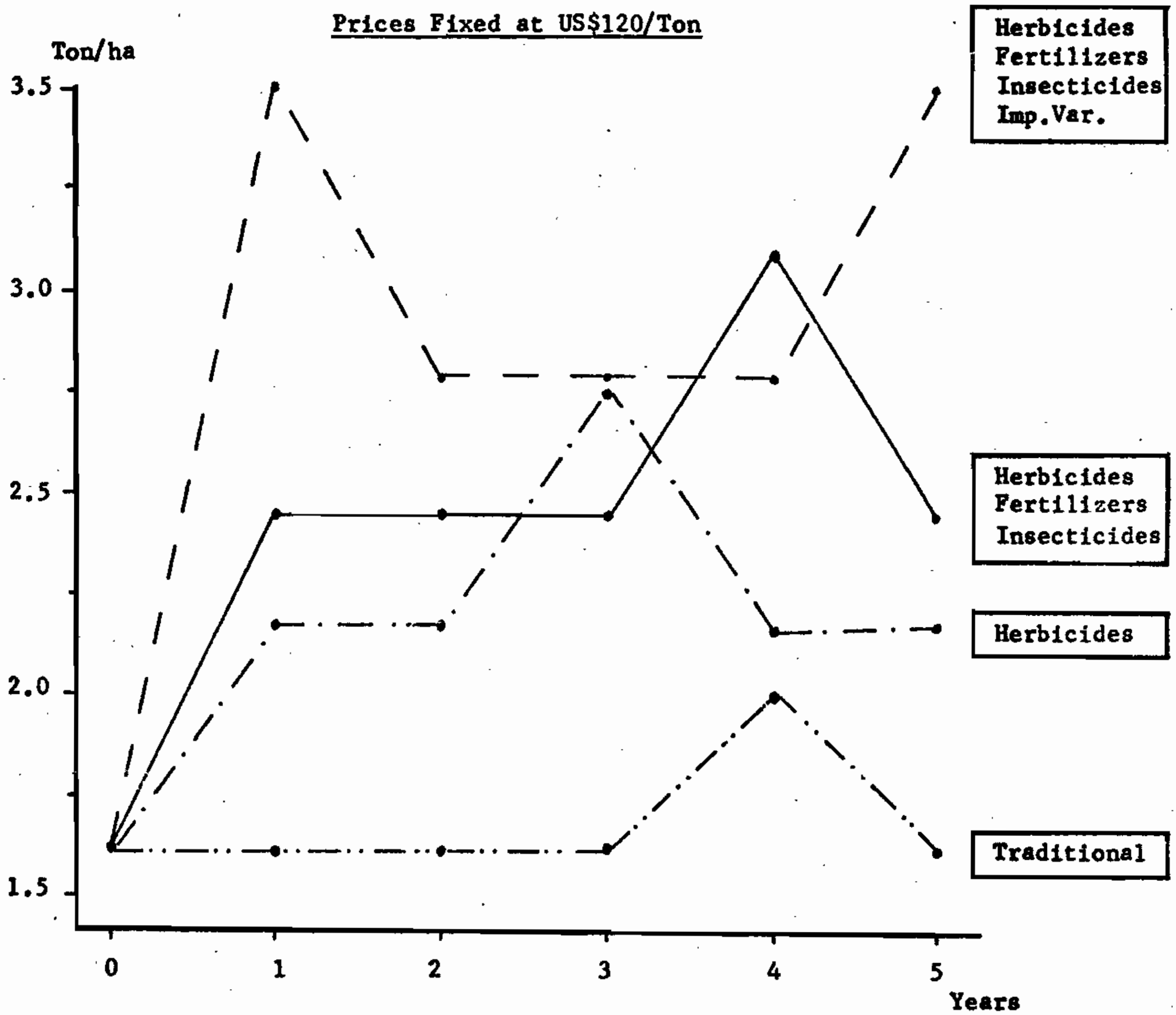


Figure 9. Simulated Annual Net Income From Maize Production With Prices Varying from US$70 to US$120/ton.

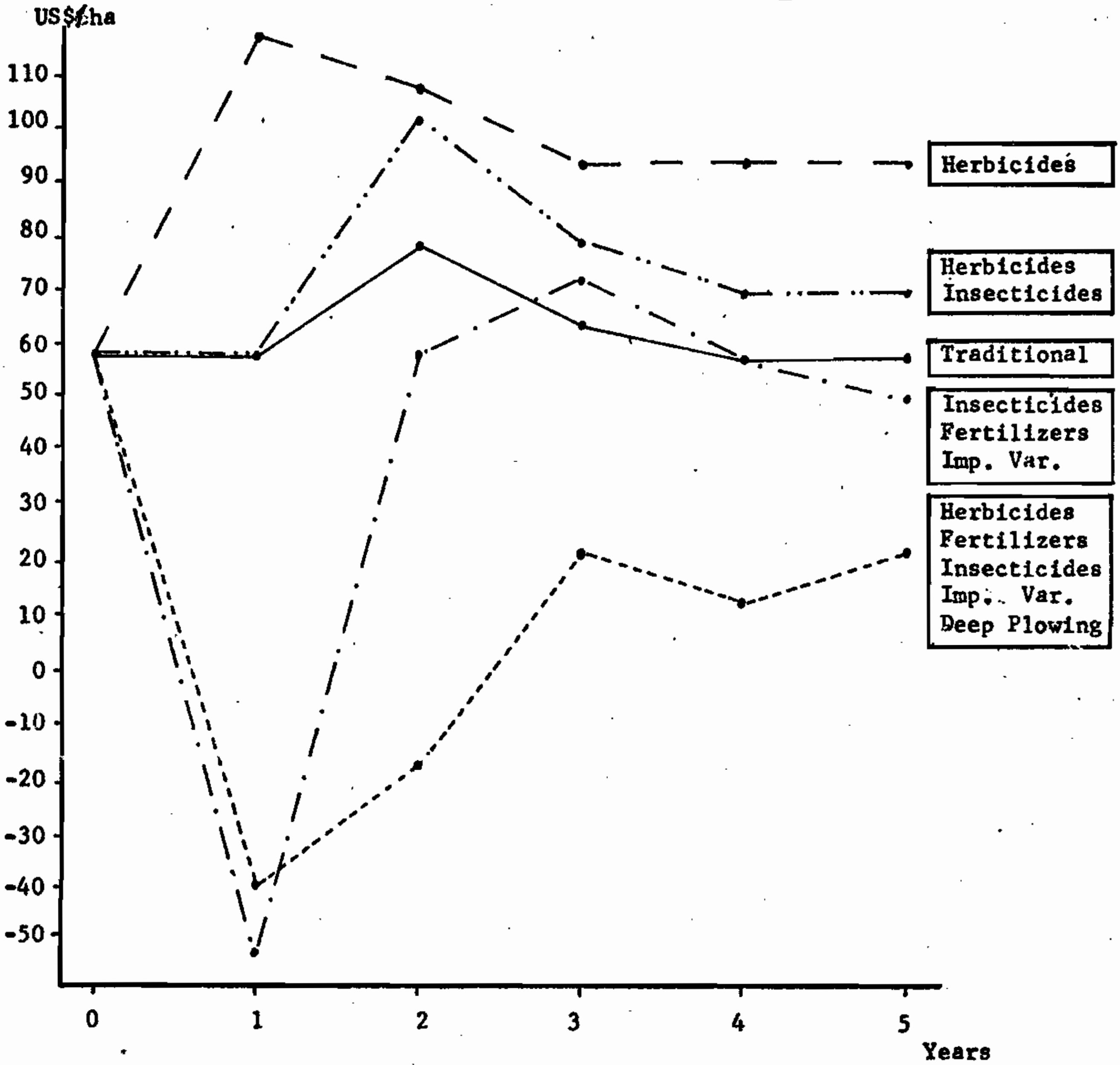
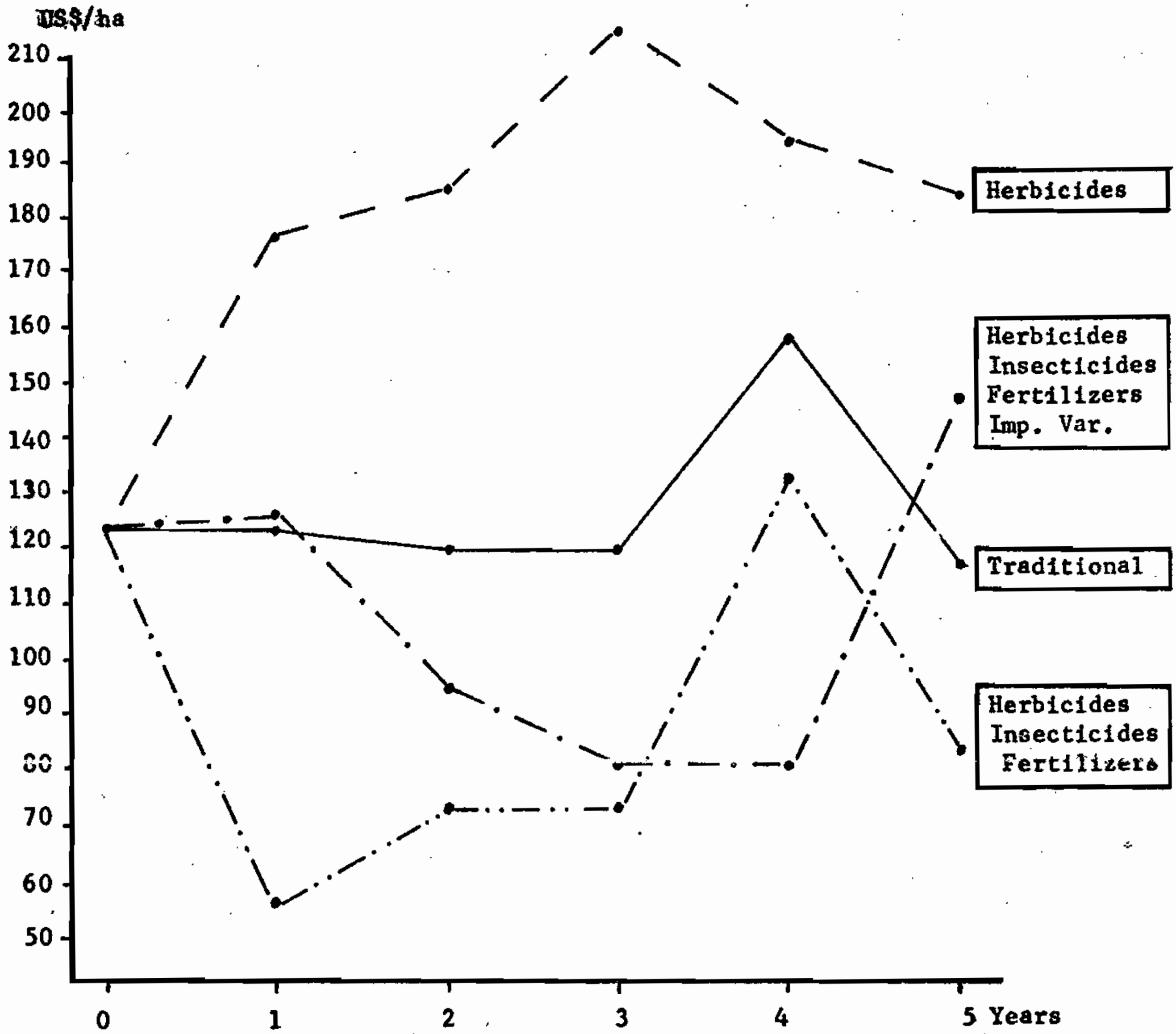


Figure 10. Simulated Annual Net Income From Maize Production With Prices Fixed At US$120/ton



value of an effectively functioning market and price support system.

It appears that the package expected to make the largest contribution to the income goal is that refering to the use of herbicides. Prior to this finding, ICTA did not have any work planned on weed control for that zone. However, as a result of the finding, a professional has now being sent for training in weed control and the collaborative CIAT-ICTA work for the coming agricultural season will involve extensive research on weed control methods and the economic evaluation of different weed control techniques.

In addition to this immediate although preliminary outcome of the model, it is expected that further utility to decision making on research resource allocation will be achieved through sensitivity analysis of the model. This involves the estimation of the response of the system to variation of the parameters and coefficient. The experimental work will be focused on measuring with precision those technical coefficients which appear to be sensitive to variation. If, for example, the model were to indicate sensitivity for insect damage, intensive research on insect control would be recommended. On the other hand, if the model is not sensitive to variation in these technical coefficients, such research would take a lower priority. Thus the model can be utilized to establish research priorities both in the farmer's field and the experiment station.

The above mentioned systems simulation efforts are expected to be utilized for the agro-economic survey results to achieve some of the analyses suggested by the conceptual model presented in this paper.

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