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SYSTEMS ANALYSIS AND SIMULATION OF UPLAND RICE-BASED CROPPING SYSTEMS IN THE PHILIPPINES

by

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ABSTRACT

SYSTEMS ANALYSIS AND SIMULATION OF UPLAND RICE-BASED CROPPING SYSTEMS IN THE PHILIPPINES

By

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Current research in multiple cropping is done mostly through field experiments and socio-economic surveys. While these types of research are important, testing alternative cropping patterns for economic and biological stability is expensive and time-consuming. Hence, the possibility of simulating the effects of varying economic and environmental conditions on the performance of cropping systems was examined. This would enable testing of a large number of cropping patterns at various management levels and under varying economic and environmental conditions within a short period of time.

This study was conducted (1) to develop a systems model for simulating upland rice-based multiple cropping systems, and (2) to evaluate by means of the computer simulation model effects of environmental and economic influences and alternative cropping patterns on the performance of cropping systems.

The computer simulation model, written in FORTRAN language, was designed for an upland area with data obtained mostly from the barrio Cale in Tanauan, Batangas, Philippines. Eight upland crops are included, namely, rice, corn, sorghum, mungbean, cowpea, peanut, soybean, and sweet potato.

The simulation model includes components for land allocation, rainfall generation, production, price generation, labor utilization,

and income accounting. Land allocation is largely pre-determined with the user specifying the land area and planting dates of each crop in the pattern. Rainfall is generated weekly either synthetically using an incomplete gamma or lognormal distribution function or through the use of historical rainfall data. The production component estimates crop yield based on user-specified fertilizer, weed control, and insect control levels and drought stress during the various stages of crop growth. Yield is predicted using the reduction rates approach where potential yield is subjected to a series of reduction factors for input levels and environmental conditions which are sub-optimal. The price generator, which determines the price of a crop at any given week of the year, employs price indices and average annual prices and can be used stochastically. The labor component accounts for the use of labor in the production process as well as determines labor hiring. Finally, the crop accounting component keeps track of all farm income and expenses.

Several experiments were done with the computer simulation model primarily to show its usefulness, capabilities, and flexibility. These were of the following types: yield response to various levels of inptus, performance of specific cropping patterns with respect to variations in rainfall and prices; comparison of performance of crops between favorable and unfavorable conditions; comparison between intensive and non-intensive cropping patterns; and comparison of planting dates and yields using two strategies for choice of planting dates. The conduct of these experiments was facilitated by the availability of four different modes of running the model.

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The model appears to be useful in evaluating the profitability of a cropping pattern and in determining the most profitable levels of inputs; for evaluating the stability of economic returns of a cropping pattern to rainfall and price variations; for determining the biological viability of a cropping pattern; and for determining detailed labor utilization of a cropping pattern. With appropriate changes in the relevant parameters and structure, it can be adapted to other upland areas and other farm situations in the Philippines.

The model developed thus far is still tentative in view of certain limitations in the model which are attributed to the lack of reliable data and some weaknesses in the model structure. Suggestions for overcoming the limitations are outlined. In view of the preliminary nature of the model, no definitive recommendations are suggested for Cale, Batangas. It is pointed out, however, that the various experiments have shown that rice in combination with legumes show considerable potential in the study area.

To Thelma and Ivan

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INTRODUCTION

1.1 Background

Multiple cropping is usually defined as the practice of growing two or more crops, either simultaneously or in sequence, on a given piece of land in one year. While it is an ancient technique, only recently has it gained emphasis and popularity in the Philippines and other underdeveloped countries. Prior to the 1960s, the idea of multiple cropping had scarcely been mentioned in national development plans. With rapidly increasing population pressure in the face of limited land resources, however, the need to increase agricultural production other than by bringing new land into production has been recognized. While increased agricultural productivity as a development goal is primarily approached through the improvement of the technological and management package for farmers such as high yielding varieties, irrigation, fertilizer and other purchased inputs, and secondarily through the improvement of agricultural institutions supporting agriculture such as agrarian reform, credit, cooperatives, etc., multiple cropping is also recognized as an important means of increasing agricultural production. It is also cited as a means of increasing farm employment and supply of agricultural crops especially cash crops and vegetables.

Agricultural research institutions have added to their list of priorities the study of multiple cropping practices, and the development of cropping systems that help improve resource utilization and farm incomes. For example, the Department of Agriculture of the

Philippines created a special program called Project ADAM (Agricultural Diversification and Markets), the main purpose of which is to identify potential areas for agricultural diversification. The Philippine Council of Agricultural and Resources Research has also listed multiple cropping as one of its priorities, and the two primary agricultural research institutions in the Philippines, the University of the Philippines at Los Baños (UPLB), and the International Rice Research Institute (IRRI), have added the so-called "multiple cropping projects" to their basic research programs.

The primary benefits from the practice of multiple cropping are as follows: it increases total production per unit of land; it improves land and labor utilization; it increases employment on the farm; it increases family income; and it provides more variety of food to the farm family and consumers.

There are, however, some difficulties in the change from monoculture to multiple cropping.[1] First, it involves more expenditures to the farmer in terms of increased purchased and labor inputs. Although additional returns may be greater than additional costs, there are problems of obtaining the credit for increased expenditures. Secondly, the farmer may not possess the necessary technical knowledge to grow new crops, thus requiring some technical assistance from the public sector. Third, the farmer may not know what combination of crops, sequences, and timings would give stable returns under

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[1]For a comprehensive treatment of the policy issues in multiple cropping, see D. E. Dalrymple, Survey of Multiple Cropping in Less Developed Nations, Foreign Economic Development Service, U. S. Department of Agriculture, Oct. 1971, pp. 101-105.

the climatic conditions of the area. Finally, the new crops grown by the farmer may not have a ready market and necessary infrastructure like irrigation facilities. If one of the objectives of the agricultural policy is to promote multiple cropping, then, some means of overcoming the difficulties have to be devised.

1.2 Multiple Cropping in the Philippines

The extent to which multiple cropping is practiced in the Philippines is low compared to some other countries particularly Taiwan and Japan. On the national level, the multiple cropping index[2] of the Philippines was 127 in 1938, 126 in 1948, and 136 in 1960.[3] In contrast, the multiple cropping indexes for Taiwan are 134, 153 and 180 respectively for the same years.

Multiple cropping patterns in the Philippines usually take the form of double cropping of rice and corn. Double cropping is possible only in areas where irrigation facilities are available. Multiple cropping is also practiced in upland areas in the form of intercropping and relay interplanting.[4] In addition, vegetable crops with short maturity periods are grown in sequence mostly in the upland areas. However, multiple cropping indexes, vary from one region to another. In Central Luzon where irrigation facilities are available, farmers are able to plant about two crops of rice per year. In

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[2]The index is derived by dividing total land area planted during the year by the amount of cultivated land physically available and in use (D. G. Dalrymple, op. cit., p. 6).

[3]C. M. Crisostomo, et.al., The New Rice Technology and Labor Absorption in Philippine Agriculture, Malayan Economic Review, 16:2, 117-158 (1971).

[4]Relay interplanting involves the sowing or planting of a second crop between the rows of the first crop before it is harvested.

contrast, sugar producing provinces like Negros have multiple cropping indexes close to unity because sugar cane can be grown only once a year.

On the whole, multiple cropping is still not a widespread practice in the Philippines, mostly for the reasons cited above. It will take considerable effort from the government to overcome the difficulties limiting multiple cropping in terms of research, extension and the provisions of markets, infrastructure, and credit.

1.3 Multiple Cropping Research

Research institutions have only recently started to deal with multiple cropping research in a systematic fashion. At IRRI, Harwood laid down the research program of the multiple cropping project.[5] The philosophy behind their research programs is the so-called cropping system approach. The main objective is to integrate knowledge about farm resources (physical and socio-economic) and production technology through systems approach to find alternative cropping patterns which will result in improved farmer welfare. The resources which are recognized to have some effects on the cropping patterns are (1) natural resources - land, sunlight, and water, and (2) socio-economic resources - labor, credit, markets, and power source. The biological factors in cropping system design and production are varietal selection, weed control, insect management, disease control, tillage, soil facility, and interplant

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[5] R. R. Harwood, "The concepts of multiple cropping: an introduction to the principles of cropping systems design," Training Lecture, IRRI, June 1973 (mimeo.).

relations. These factors are interrelated to one another. The IRRI approach is to study each of the factors as well as their inter-relationships. Most of the research at IRRI on multiple cropping is within the framework described above.

The research at the University of the Philippines is more or less similar to that of IRRI. Both the IRRI and the UPLB research organizations are using the multi-disciplinary approach wherein the research staff is composed of agronomists, entomologists, weed specialists, and economists.

Examples of specific research are (1) variety trials, (2) alternative cropping pattern trials, (3) intercropping and relay cropping experiments, (4) socio-economic studies of old and new cropping patterns, (5) effects of various management levels, (6) weed control, and (7) insect control, and others.

Current research is being done mostly through field experiments and socio-economic surveys. While these types of research are important, the main limitation is that it takes years and years of continued testing and re-testing alternative cropping patterns before definitive conclusions can be reached regarding their economic and biological stability due to varying economic and weather conditions. In addition, the time-consuming experiments are expensive. Hence, if it is possible to simulate the effects of varying economic and environmental conditions on the performance of a cropping system and consequently on farmer welfare, then considerable time and financial resources can be saved. Many alternative cropping patterns can be tested at various management levels and varying economic and environmental conditions within a short period of time when simulation is aided by a digital computer.

Another limitation of current research in multiple cropping is that very little economic analysis, if any, is done on the newly tested cropping patterns. With computer simulation, economic analysis can be facilitated.

1.4 Objectives of the Study

There are two primary objectives of the study:

(1) to develop a systems model for simulating upland rice-based multiple cropping systems, and

(2) to evaluate by means of the computer simulation model the effects of environmental and economic influences on the economic performance of alternative cropping patterns.

The first objective was accomplished by constructing a systems model of a typical upland farm, trimming it down to a manageable size, and expressing the various interrelationships in quantitative terms. The simulation model developed was initially designed to answer the following questions: What crop combinations are biologically feasible and economically profitable given the climatic and economic environment? What are the expected yields, net returns and labor requirements of the combination? What are the effects of various levels of management on the performance of alternative cropping systems?

The second objective was achieved by using the crop, climatic, and economic data of a Philippine village, Barrio Cale, Tanauan, Batangas in the simulation model.

The development of the simulation model was considered a major task in itself owing to the complexity of the farm system and the range of decisions which the farmer faces. Because of the complex nature of the system, it was necessary to focus only on important components and leave out numerous details simply to make the problem manageable. Thus, it should be recognized at the very outset that this study is a preliminary effort. It is hoped, however, that it will lay the foundations for more comprehensive models.

1.5 The Study Area

Most of the data used in this study were obtained from agronomic experiments and economic surveys conducted in Barrio Cale in Tanauan, Batangas. The choice of the area of study was necessitated by the fact that Cale is an area which has been studied intensively by the Multiple Cropping Project of IRRI since 1973, and the studies are still going on at the time of this writing. Benchmark economic data were collected in 1973 and a daily record of all the farm and non-farm operations, input use, income and expenses were collected weekly from 1973 to date. In addition, agronomic experiments were conducted in Cale since 1973.

Barrio Cale is in the northeastern part of Batangas province and is about forty kilometers southwest of Los Baños, Laguna - the site of IRRI. The main crops of Cale are rice and corn, but it is considered a leading barrio in the production of vegetables. It is located seven kilometers northwest of the town proper. It has a population of 3,000 and 400 households, mostly farmers. It has a third class road mostly feeder roads covered with gravel and stones.

Cale has no electricity and transportation is by jeepneys and by tricycles that ply from Tanauan town to the barrio. Water supply for the barrio comes mainly from artesian wells installed by the government, although some households dug their own wells.[6]

Farm sizes in Cale range from 0.09 hectare to 3.0 hectares with an average of 0.93 hectares. The majority of farmers own or rent several parcels of land located in different parts of the barrio. In general, farmers till one to six parcels of land with the majority of the farmers having three parcels which are generally within 12 minutes walking distance from the farmhouse. Most of the farmers have a trellis in addition to the open fields they are working.

The average farmer is about 45 years old. The average educational attainment of the farmer and his wife is four years each. The size of households range from 2 to 12 with an average of 6.4 persons per family.

Share tenants comprise the largest group in Cale (36 percent), followed by the part-owners (32 percent), and the full owners (20 percent), the rest being the share-lease tenants.

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[6]E. V. Antonio and G. Banta, "Multiple Cropping in a Batangas barrio," IRRI Saturday Seminar, June 29, 1974.

Upland rice and corn are major crops grown in the area, with various vegetables being planted in smaller scale. The rice is broadcast in unpuddled soil in May-June and harvested in September-October while the corn is planted in October-November and harvested in January-February. Based on the sequence of planting of the major crops, 8 cropping patterns were found to exist in the area (Table 1.1). Fifty percent of the total study area is planted to rice followed by corn (green or dry grain) and others. Sugarcane growing is the next widely used pattern (13 percent). The average farm is growing nearly two crops per year. The barrio has a multiple cropping index of 181 making it one of the most intensive in the Philippines.

1.6 Plan of the Study

This study is composed of 11 chapters. Chapter 1 deals with the introductory part of the study. Chapter 2 provides a brief exposition on the methodology of systems analysis and simulation. Chapter 3 is devoted to the development of a conceptual model of a family farm. In this chapter, the major components of a farming system are defined and the ones actually used in the study are identified. Chapters 4 to 8 are detailed discussion on specific components namely, land allocation component, rainfall generator, production component, price generator, and the labor component, respectively. Chapter 9 is a description of the features and options available on the computer simulation model. Chapter 10 discusses the various experiments done with the model and the results of experimentation. Finally, Chapter 11 presents the summary and conclusions of the study and some suggestions for further research.

Table 1.1. Types of cropping patterns in study area of 50 farmer cooperators, Cale, Tanauan, Batangas, 1974-75.

Pattern	Total area of study farms under pattern (hectares)	Percent of total study area[a]
Rice-corn and others	16	25
Rice-corn	16	25
Sugarcane	8	13
Rice-garlic	6	10
Trellis	6	10
Vegetables-vegetables	5	8
Rice-vegetables[b]	3	5
Corn-corn and vegetables	3	4
Total	63	100

[a]Percent in sugarcane may be bigger for the entire barrio if the less intensive farms excluded from the study were included.

[b]Except garlic.

Source: Antonio, E. V. and G. Banta, "Multiple Cropping in a Batangas barrio," IRRI Saturday Seminar, June 29, 1974.

CHAPTER 2

METHODOLOGY OF SYSTEMS ANALYSIS AND SIMULATION IN AGRICULTURAL MANAGEMENT

2.1 Introduction

This chapter deals with the conceptual and theoretical aspects of systems analysis and simulation. The general steps in undertaking such analysis are outlined and the methodology of systems analysis and simulation are described. Finally, the advantages and disadvantages of systems analysis are cited.

2.2 The Systems Concept

The term "system" has been defined in various ways in the literature. Park and Manetsch[1] define a system as a set of interconnected elements organized toward a goal or a set of goals. Dent and Anderson[2] state that a system implies a complex of factors that are interrelated; it implies interaction between these factors and it implies that a conceptual boundary may be erected around the complex as a limit to its organization autonomy. McMillan and Gonzales[3] define a system as a set of objectives together with relationships between the objectives and their interrelationships. There is not a complete agreement as to the definition of the term system. However, all definitions contain the concept of interaction.

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[1]G. L. Park and T. J. Manetsch, Systems Analysis and Simulation with Applications to Economic and Social Systems, Preliminary ed., Part I and II, Michigan State U., January 1973.

[2]Dent, J. B. and J. R. Anderson, (eds), System Analysis in Agricultural Management, Sydney: John Wiley & Sons, Australasia Pty.Ltd.,1971.

[3]C. McMillan and R. F. Gonzales, System Analysis: A Computer Approach to Decision Models, R. D. Irwin, Homewood, 1965.

Systems analysis can then best be defined as a method of analysis in which the interaction of the various components of a system are considered of paramount importance. It implies that an isolated study of parts of the system is not adequate to understand the complete system. The systems approach is thus a problem solving methodology which begins with a tentatively identified set of needs and has as a result, an operating system for efficiently satisfying a perhaps redefined set of needs which are acceptable or "good" in the light of tradeoffs among needs and resource limitations that are accepted as constraints in a given setting.[4]

Figure 2.1 shows the flow chart of the systems approach. The major phases of the approach are (1) feasibility evaluation, (2) abstract modeling, (3) implementation design, (4) implementation, and (5) system operation.

It should be emphasized that in the systems approach each process phase is iterative. The outcome of each phase is to be tested for adequacy, completeness, and validity. If a process phase fails the test then it has to be repeated. Each process phase requires either positive or normative information or both. Positive information are those which do not have any reference to good or bad and right or wrong. Normative information are those which set value judgements as to whether an action or goal is good or bad.

Feasibility evaluation has as its goal the generation of a set of feasible system alternatives capable of satisfying needs which have

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[4]G. L. Park and T. J. Manetsch, _op. cit._

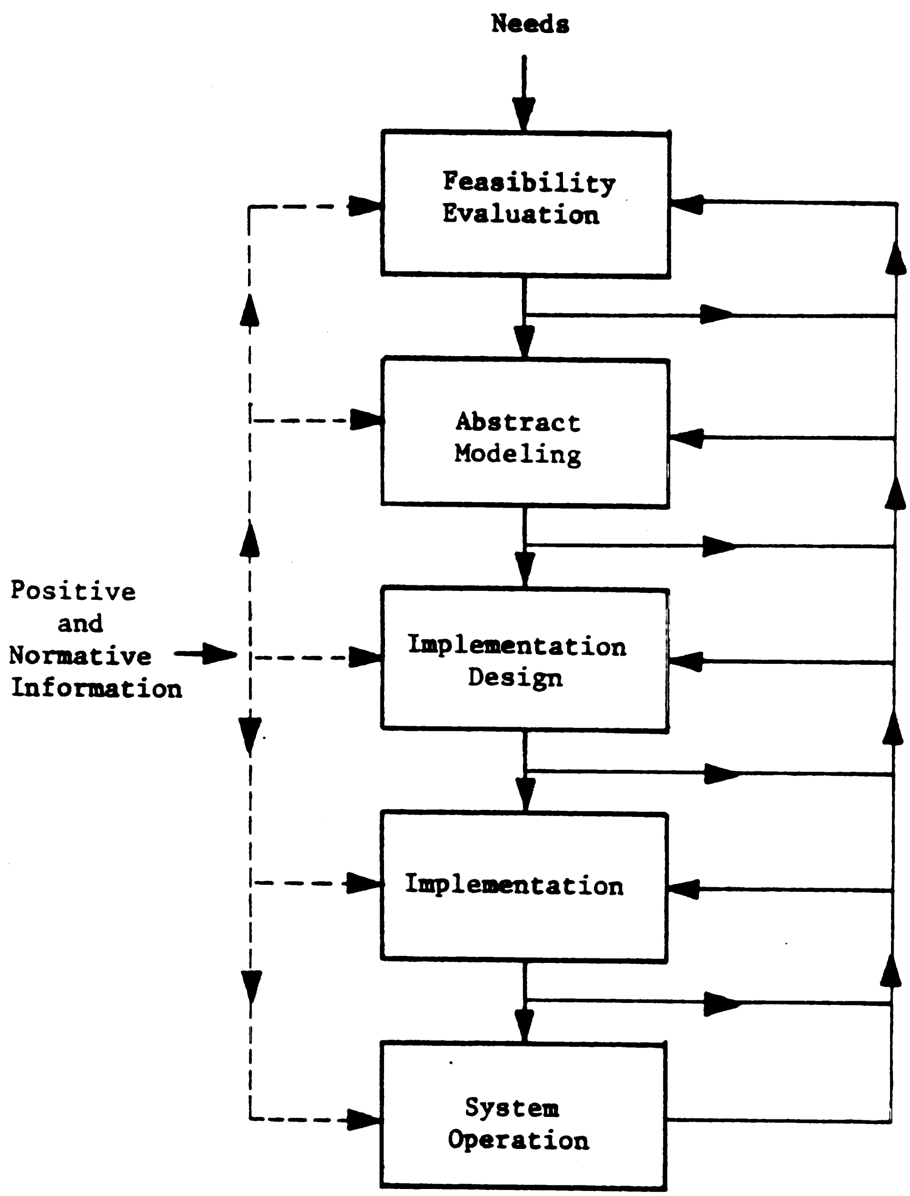

Figure 2.1. Flow Diagram of the Systems Approach as a Problem Solving Methodology

been identified and selected for satisfaction. A system alternative is a particular system, structural configuration, or management strategy devised as a means of satisfying existing needs. Figure 2.2 shows the flow diagram of feasibility evaluation phase.

The major steps of the feasibility evaluation phase are (1) needs analysis, (2) system identification, (3) problem formulation, (4) system definition, (5) generation of system alternatives, (6) determination of physical, social and political realizability, and (7) determination of economic and financial feasibility.

2.3 System Identification

System identification forms a link between the statement of needs and the specific statement of problems that must be solved in order to satisfy these needs. In this process, the proposed system is viewed as a "black box." In other words, every effort is exerted to determine the attributes that the system must possess if it is to satisfy the specified needs.

More specifically, we seek information about system input variables, system output variables, and parameters which define aspects of system structure (Fig. 2.3). System input variables are of two classes: (1) the exogenous or environmental input which refer to those which affect the system but are not, in turn, significantly influenced by it, for example, weather, and (2) the overt inputs referring to variables which are necessary for the system to carry out its intended functions. Overt inputs can either be controllable such as the amount of fertilizer applied to crops or non-controllable such as the amount of land area in the short run.

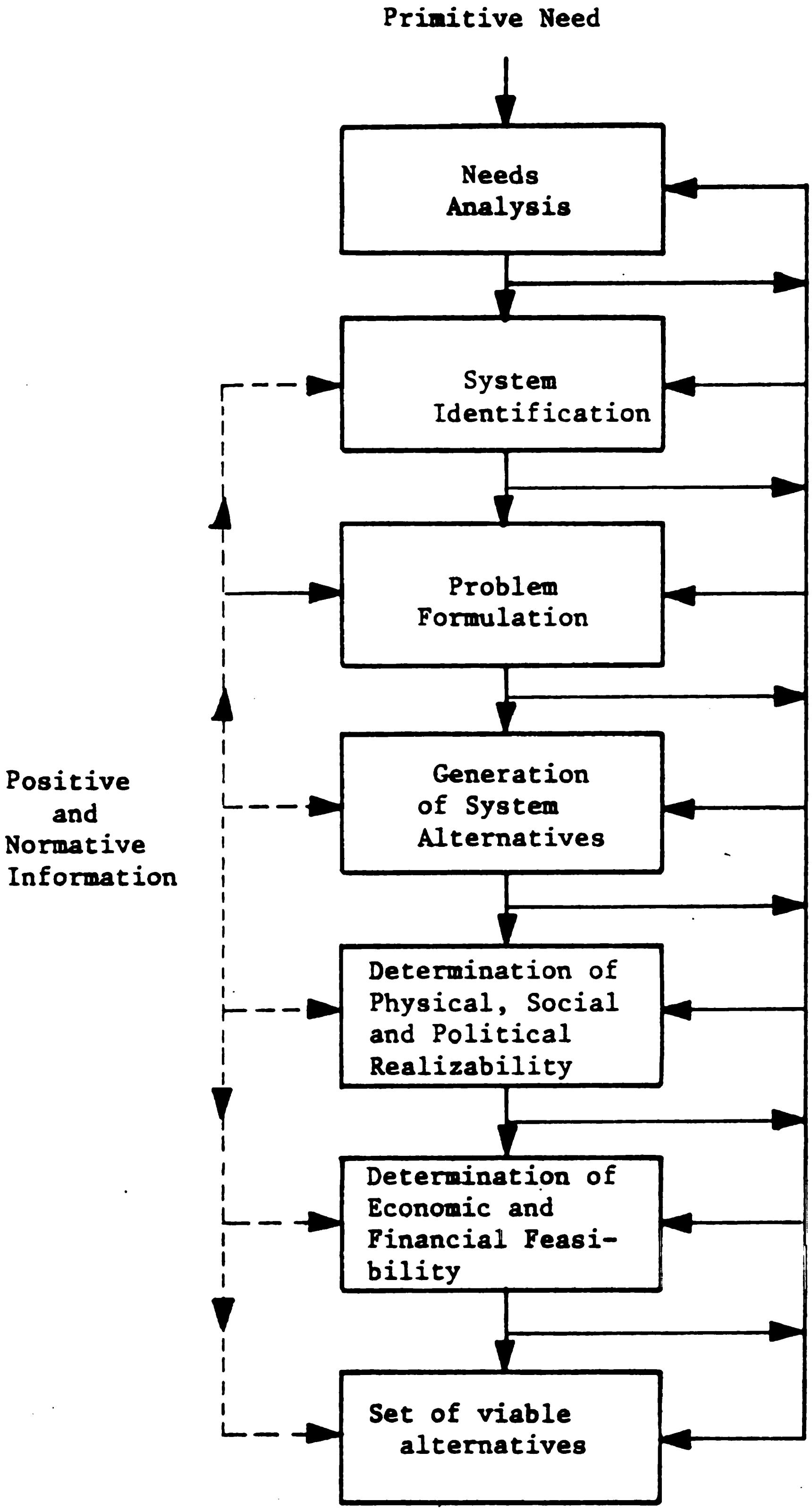

Figure 2.2 Flow Diagram of Feasibility Evaluation

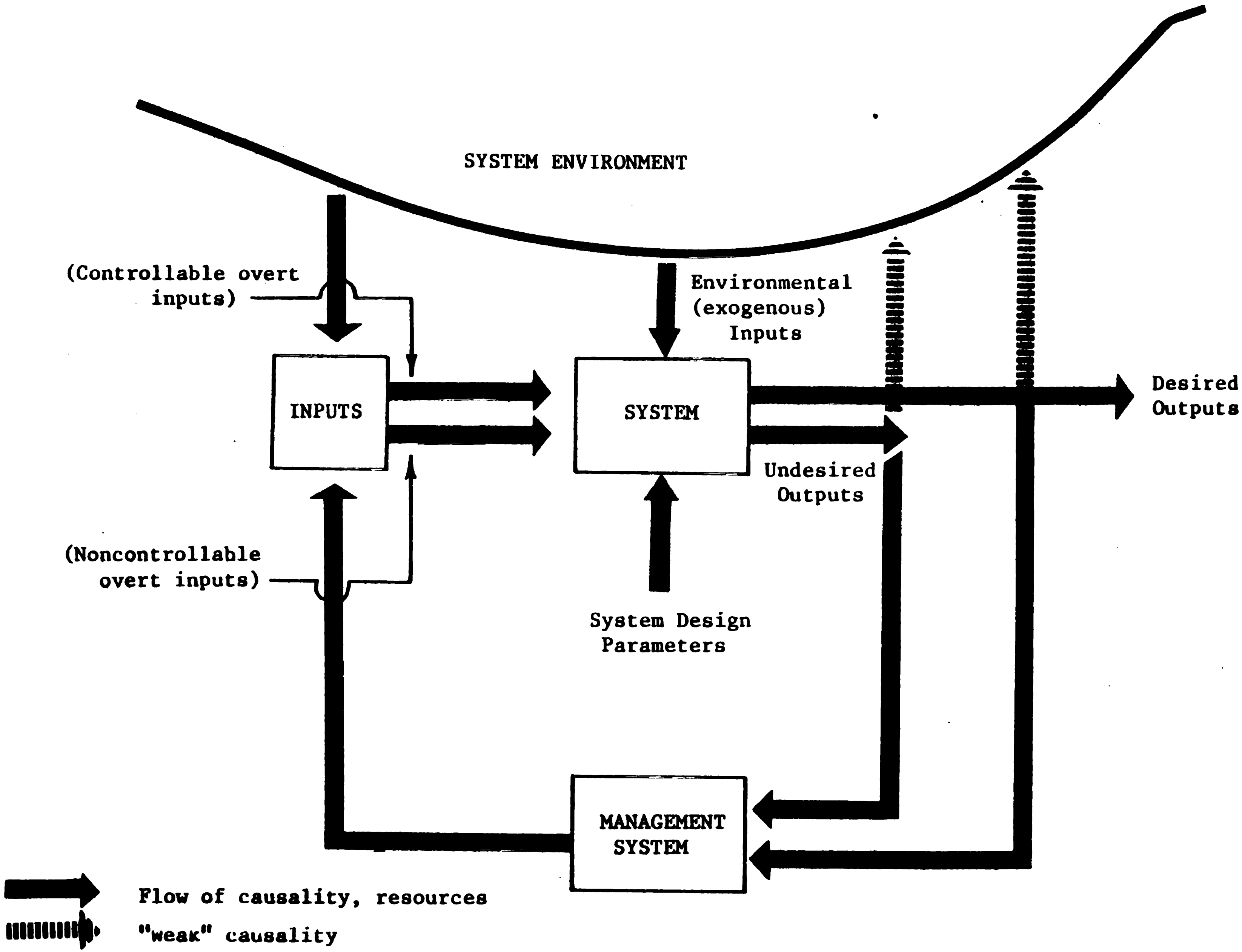

Figure 2.3 System Identification as Part of the Systems Approach

System output variables can either take the form of outputs which are need fulfilling or undesired outputs which are unavoidable by-products. System design parameters are variables which serve to specify the structure of the system. Examples might include the physical location of the system, physical dimensions, and the number and types of components.

The system identification concludes with the determination of performance criteria which can aid in the evaluation of the system alternatives.

2.4 Abstract Modeling

Although some systems are more amenable to abstract modeling than others, it is safe to say that some form of modeling or abstract representation can be useful in almost every situation. Figure 2.4 shows the flow diagram of abstract modeling. The main steps are (1) alternative selection, (2) modeling of a particular alternative, (3) computer implementation, (4) validation, (5) sensitivity analysis, and (6) model application. The final outcome of abstract modeling is the specification of good or best plans and policies.

Models may be classified in two ways: (a) static or dynamic and (b) microscopic or macroscopic. While a static model provides information about model variables only at a single point in time a dynamic model is capable of generating time paths of model variables. Likewise, a microscopic model deals with individual units such as an individual farm while a macroscopic model looks at aggregates of units such as the whole agricultural sector.

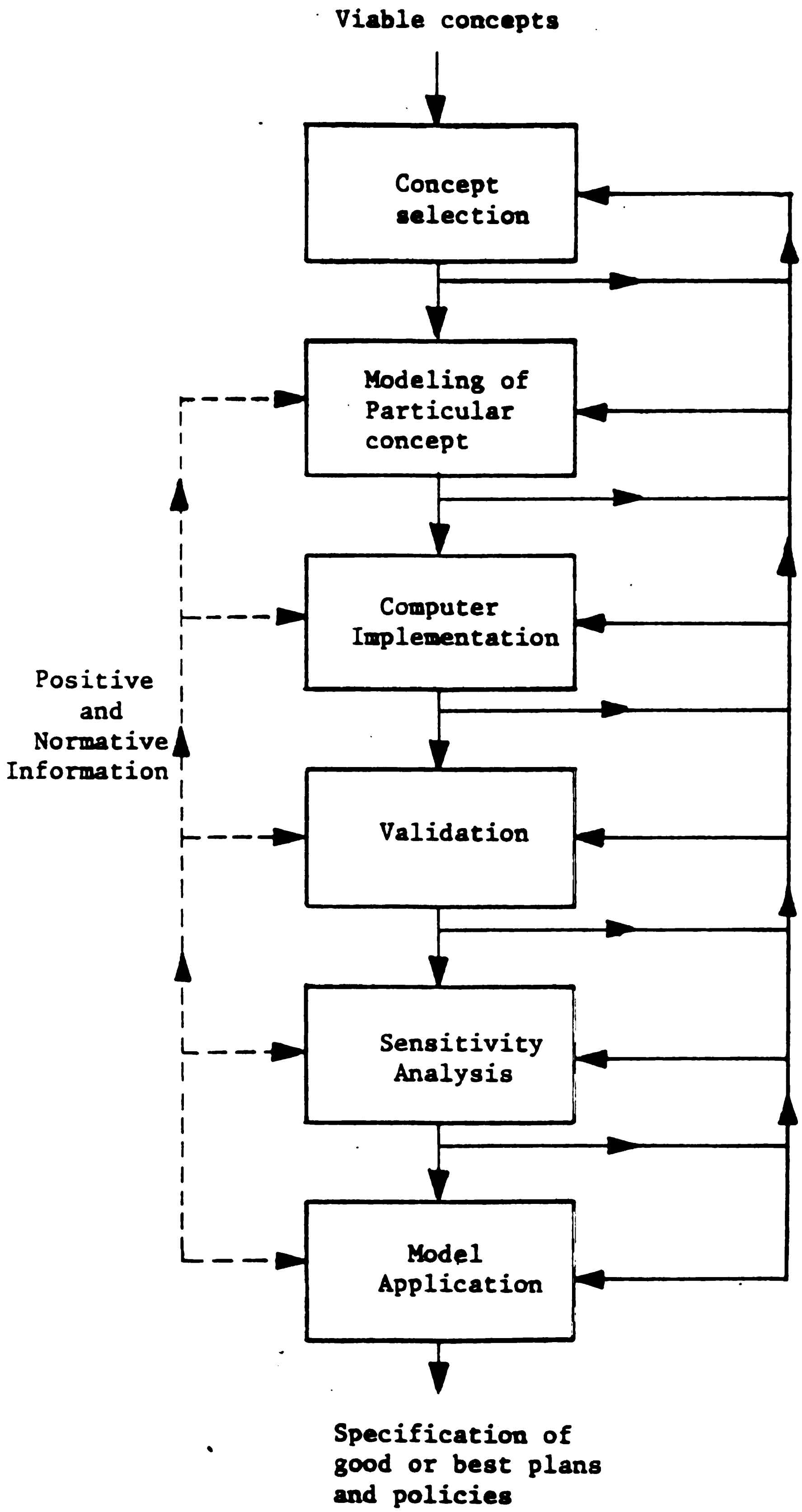

Figure 2.4 Flow Diagram of Abstract Modeling

2.5 Systems Simulation

As stated earlier, a system has important dynamic elements which make the state of the system time dependent. Moreover, the stage of the system is also influenced by uncontrollable elements which make it difficult to study and understand the system. However, with the use of simulation methods, considerable insight into both their operation and control can be achieved.

Simulation may be defined as a step by step process of working out particular time paths of variables, starting from a given set of system inputs and specific values for model parameters. It also may be considered to embrace two distinct operations: (1) development or synthesis that adequately represents the system under study, and (2) examination of the behavior of the model in relation to changes in its structure or in managerial policies.

Basically, simulation includes four iterative steps: (1) problem definition, (2) mathematical modeling, (3) model refinement and testing, and (4) model application. As shown in Fig. 2.5 each step has to be repeated if more information is obtained either within the model or outside of the model.

The main uses of the simulation model are (1) to determine what policies are appropriate for good management, (2) to attempt to locate an improved basic organization, and (3) to determine points in the organization that are sensitive to managerial interference.

Simulation can be done simply with paper and pen "seat of the pants" methods. However, this is limited by the amount of time required to carry the calculation through hand methods. The advent

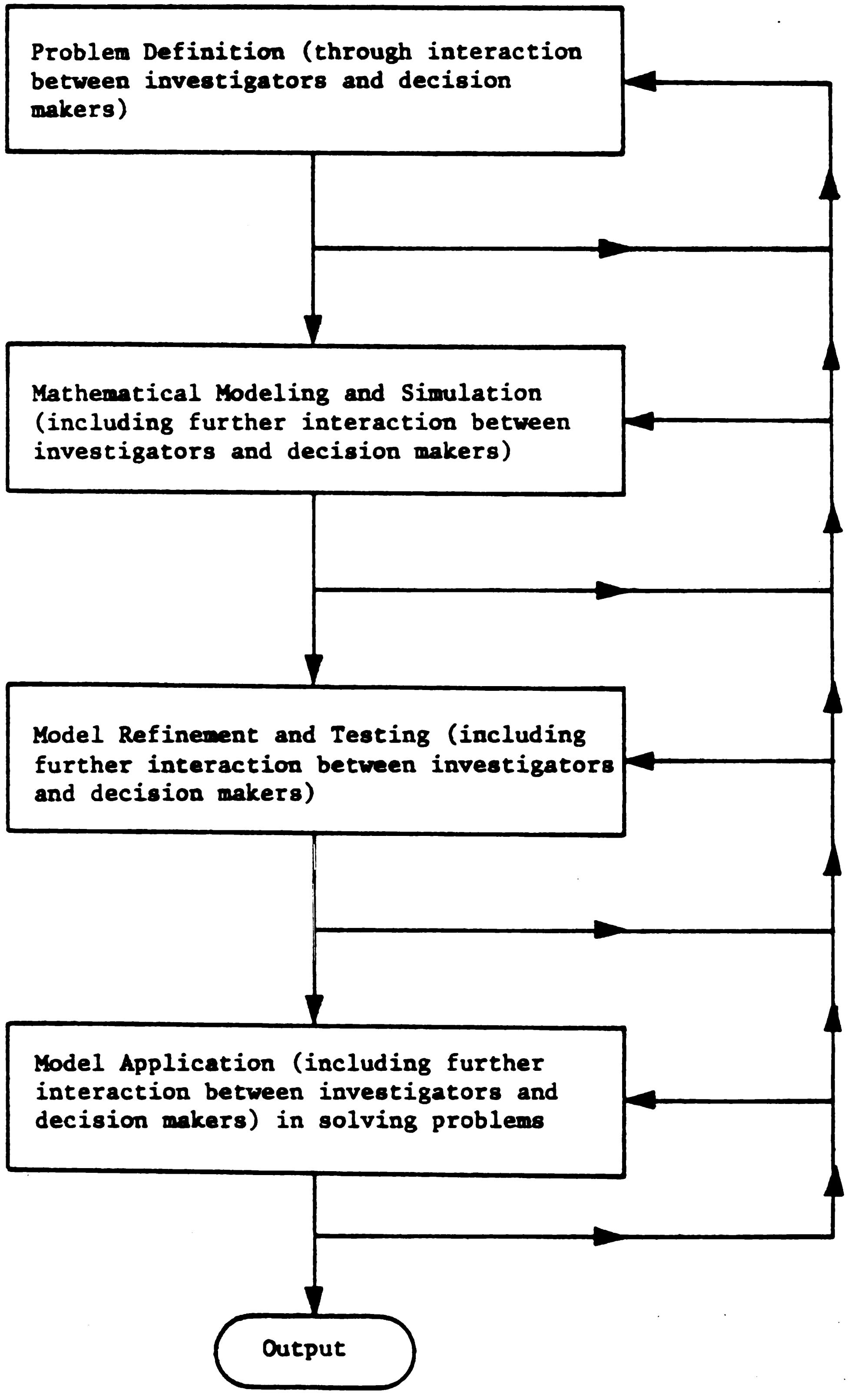

Figure 2.5 Computer Simulation as an Iterative Problem Investigating Process

of large scale electronic computers has made it possible to undertake simulation very rapidly thus saving time and money. Moreover, the computer provides for the possibility of increasing the number of alternative policies and programs that can be evaluated.

It should be emphasized that the systems approach is not limited to any particular methodology in systems analysis. It is also not synonymous to simulation. But regardless of the methodology involved, it is necessary for the analysis of a system to give attention to the interdependence of its components.

Other techniques and methods of analysis are widely used in systems analysis. However, there are several characteristics of systems which make computer simulation a good and often the best technique to use in systems analysis.

In the first place, it may be impossible or extremely costly to observe certain systems in the real world. The system may be so complex or so large in terms of the number of variables, parameters, relationships and events to which the system is responsive to, that it becomes almost impossible to analyze it mathematically. It also contains relationships between the system's entities and attributes which are not well behaved or mathematically tractable.

Another reason for using simulation in systems analysis is that there may be insufficient numerical data available about a system to allow verification of a mathematical model and its solution, or such data may be extremely costly to obtain. Moreover, many systems, particularly social systems, cannot be manipulated or experimented with to determine the impact of changes in the system or its environment. In this case, simulation can serve as a systems laboratory.

A further reason for using simulation is when a system contains random variables which are difficult or impossible to handle expeditiously with other types of mathematical models. Finally, real time for many systems may be either too slow or too fast to allow meaningful analysis of the system. Simulation can be used to expand or compress time to the analyst's specifications. The presence of any of the above characteristics of a system can justify the use of simulation as a method of analysis.

2.6 Advantages of Systems Analysis and Simulation

There are many advantages to be gained from systems analysis: (1) it allows exploration of alternative solutions to problems for which an optimum does not exist or cannot be found with optimizing methods; (2) a large number of heterogenous variables can be handled in a consistent manner; (3) the criteria of analysis as decision criteria can be broadened or increased in number; (4) the complex interrelationships between problem elements and the objectives of numerous functional units may necessitate the use of objective analysis of decision problems; and (5) it provides a method of reducing complex relationships to paper.

There are also several advantages of simulation for system analysis. First, it is possible to handle multiple goals with simulation. Mathematical programming models usually imply optimization with respect to one variable. If more variables are involved, a great deal of ingenuity will be required to obtain the appropriate relationships.

Simulation has also the ability to handle sequential decisions within the planning period using different criteria. Decision rules within the model can depend on a number of variables, each of which may reflect different goals. Any type of function or relationship can be included in the simulation model. It does not require that relationships can be continuous or linear. A simulation model has also the ability to handle stochastic variables and action delays.

Since there is no restriction to a formal algorithm in systems simulation the model can be as complex and as realistic as desired within the confines of available data and detailed structure of the real system being modeled. No matter how complicated the finally constructed mathematical representation, it is possible, usually with the aid of a computer, to follow the detailed workings of the system and to trace the implications of input and decision changes on the output from the model.

There are, however, some limitations of systems analysis and simulation. Park and Manetsch[5] state that this problem solving methodology is not applicable when (1) the aims or goals of the system are not well-defined and recognizable if not quantifiable; (2) the decision-making process is not centralized; and (3) long-range planning is not possible.

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[5] G. L. Park and T. J. Manetsch, _op_. _cit_.

2.7 Summary

This chapter discussed the conceptual as theoretical aspects of systems analysis and simulation. First, the system concept was clarified and the steps of the systems approach as a problem solving methodology were outlined. Some basic steps of the approach such as feasibility evaluation and abstract modeling were also elucidated. Finally, the use of computer simulation as a technique in systems analysis was discussed. Its advantages and disadvantages were also pointed out.

CHAPTER 3

CONCEPTUAL MODEL OF A FAMILY FARM

3.1 Introduction

This chapter presents the structural framework of the simulation model. First, a comprehensive, idealized structure of a farm system is developed. The major components and their respective roles in the farm system are discussed. Second, a simpler version of the structural model for the purpose at hand is justified. This was done by eliminating components and variables which are not important for the purpose at hand, those for which data are not available or are too difficult to obtain, and those components which are complicated and extremely difficult to develop conceptually and represent mathematically.

3.2 Gross Structure of a Farm System

Figure 3.1 shows a conceptualized structure of a farm system. The major components of the system are (1) production component, (2) land allocation component, (3) labor utilization component, (4) output disposal component, (5) storage and sales component, (6) investment funds allocation component, (7) cost and income accounting component, (8) product and input markets, (9) income allocation component, and (10) exogenous factors.

Production component

The production component determines the level of physical output of each crop, given the level of inputs and the underlying

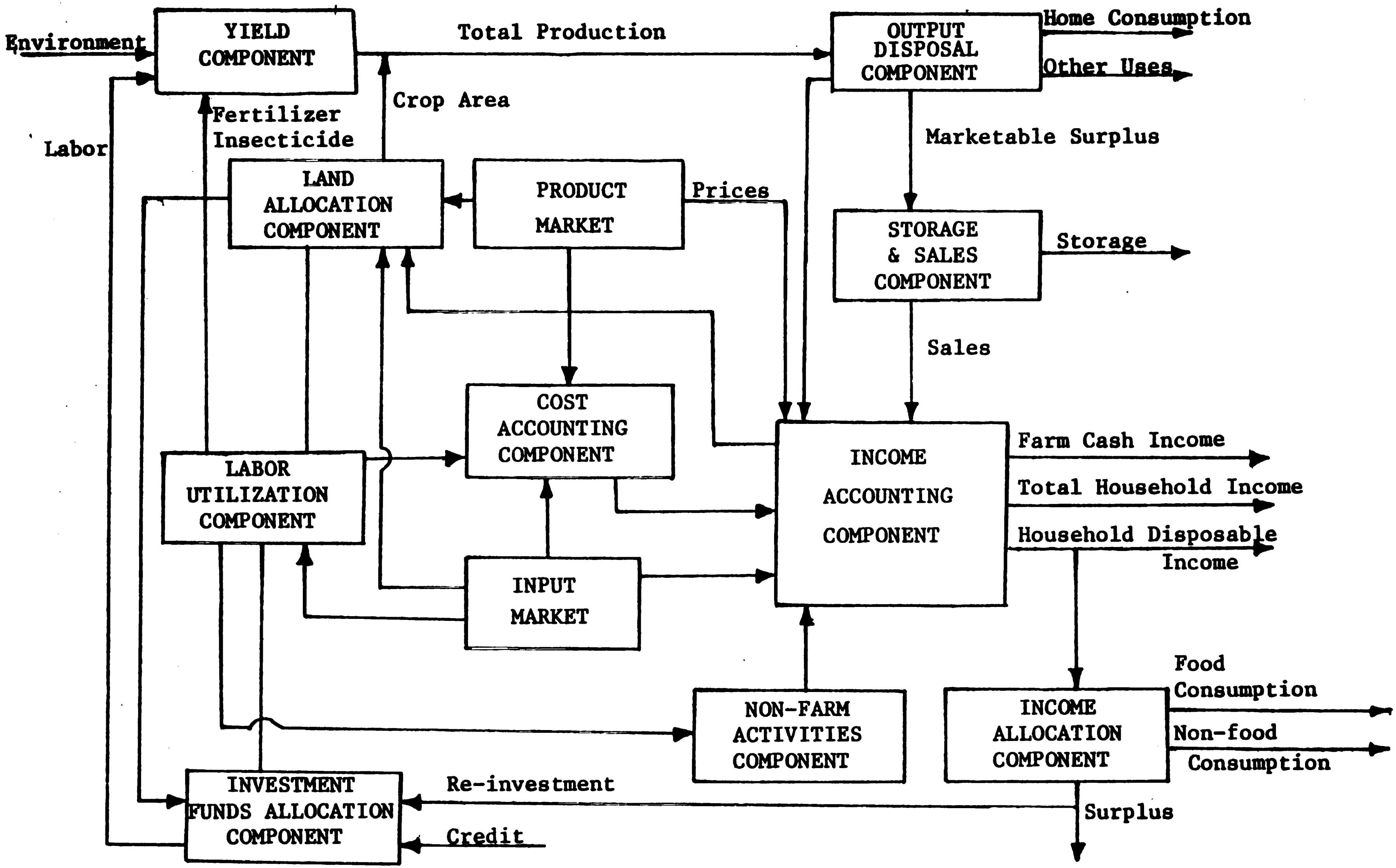

Figure 3.1. Gross Structure of a Farm System

environment. Yield depends on a great number of factors including soil type, variety of crop, water availability, type and level of fertilizer, degree of insect and pest attack and control, environmental factors such as rainfall, wind, temperature, solar radiation, and so forth. For the purposes of yield prediction, the effect of each of the above factors must be accounted for. A difficulty that arises in modeling the production component is the fact that numerous factors are interrelated. For example, weed population may increase as more fertilizer is applied. Also, the yield of rice is more responsive to nitrogenous fertilizer when the degree of solar radiation is greater.

Land allocation component

The main purpose of the land allocation component is to determine how land is to be utilized during the entire year. The role of a land allocator in a farm simulation model depends on how the model is to be ultimately used. If it is to be used as a "laboratory" wherein alternative land allocation schemes are tested to determine their effects on the performance of the system, then a model of a land allocation sub-system is not necessary. It would suffice to predetermine the desired land utilization scheme at the start of each simulation run. On the other hand, if the model is to be applied in an optimizing mode wherein land is to be allocated in such a way as to maximize net returns, then a more sophisticated land allocator is desired.

Labor utilization component

The labor utilization component determine the periodic labor use on each crop, the total labor use of the farm, and the amount of outside labor hired by the farm. Family labor availability depends on family size and the age distribution of the children. Labor availability affects land allocation which in turn affects labor utilization. Total labor utilization is dependent not only on labor requirements of each crop but also on the level of output. It is also affected by the degree of mechanization which is labor displacing. Labor is hired generally if family labor is less than labor requirements but it is also affected by wage rates.

Output disposal component

The output disposal component apportions the physical output of each crop among the farmer, the landlord if the farmer is a tenant, and to the harvesters and threshers if they are paid in kind. Additionally, this component apportions the net share of the farmer to (1) home consumption, (2) marketable surplus, (3) losses, and (4) other uses.

Storage and sales component

The marketable surplus can either be stored for sale at a later date or can be sold immediately. The storage and sales component determines how much of the total amount in storage is to be sold at a given time period. This may depend on prevailing prices, cash needs, and other factors.

Investment funds allocation component

The investment funds allocation component determines how investment funds available to the farmer, either through credit or from surplus farm returns are allocated either to purchase current inputs, to hire labor, or to acquire fixed capital. This component also keeps track borrowing and loan repayment activities.

Cost and income accounting component

The cost and income accounting component keeps track of all farm income and expenses. It determines total production, value of production, cost of production, and net returns of each crop planted and for the whole farm.

Product and input markets

In the product and input markets, prices of each crop and costs of production inputs are determined. Prices and costs play important roles in determining the relative profitability of each crop. In this study, an effort was made to simulate the price movement of each crop. This was achieved by allowing price to vary both seasonally and randomly around its mean. Price could also be made to vary secularly by incorporating into the model trend lines of either linear or exponential farm. In this study, prices are exogenous to the farm. That is, a farm by itself cannot influence the movements of product and input prices.

Income allocation component

The function of the income allocation component is to allocate household disposable income to consumption (food and non-food) and to savings. This component depends on a number of factors which includes family size, age distribution of children, and cash needs for farm operations.

Exogenous factors

In this conceptual model of a family farm, the factors considered as exogenous are the crop environment and the product and input markets discussed above.

In an upland setting, rainfall is considered to be the most important factor affecting crop yields. Since rainfall is the only source of moisture for the plants, the simulation of rainfall is of prime importance. Other environmental influences such as solar radiation, temperature and relative humidity are also important and must be included if data are available.

3.3 A Modified Model for the Study

It is apparent from the above discussion and from Figure 3.1 that a farm system is indeed complex owing to the many components variables, and interrelationships involved. Not only are physical processes involved but also behavioral and decision processes. For the purposes of the study, it was therefore necessary to simplify the concept of a farming system in order to make the mathematical modeling and subsequent computer implementation manageable.

In the model developed below the major components that were included are: land allocation component, a rainfall generator, production component, labor utilization component, price and cost generator, and crop accounting component. Figure 3.2 shows the interrelationships of the above components.

The structure of each component, the variables included, the mathematical relationships, sources of data and the validation of each component are discussed in the next four chapters.

In brief, the model as implemented in the computer works as follows: The policy variables are area, planting date, and current input levels (nitrogenous fertilizer), insect control, and weed control. The land allocation component determines the crops to be planted and their respective areas. The rainfall generator determines the rainfall pattern for the simulated year. Given the rainfall pattern, the areas, the planting dates and the current input levels, yield is determined in the production component. The labor component determines labor utilization of each crop and of the whole cropping system. It also determines the amount of labor hired on the basis of total labor requirements and available family labor. The price and cost generator determines the prices of each crop and the cost of inputs. All the above information are then passed on to the crop accounting component where the performance variables, namely yield of each crop, gross returns, net returns, labor utilization and effective crop area, are computed.

3.4 Summary

In this chapter, the structural framework of the simulation model was developed. The major components of a comprehensive farm system model are the production component, the land allocation

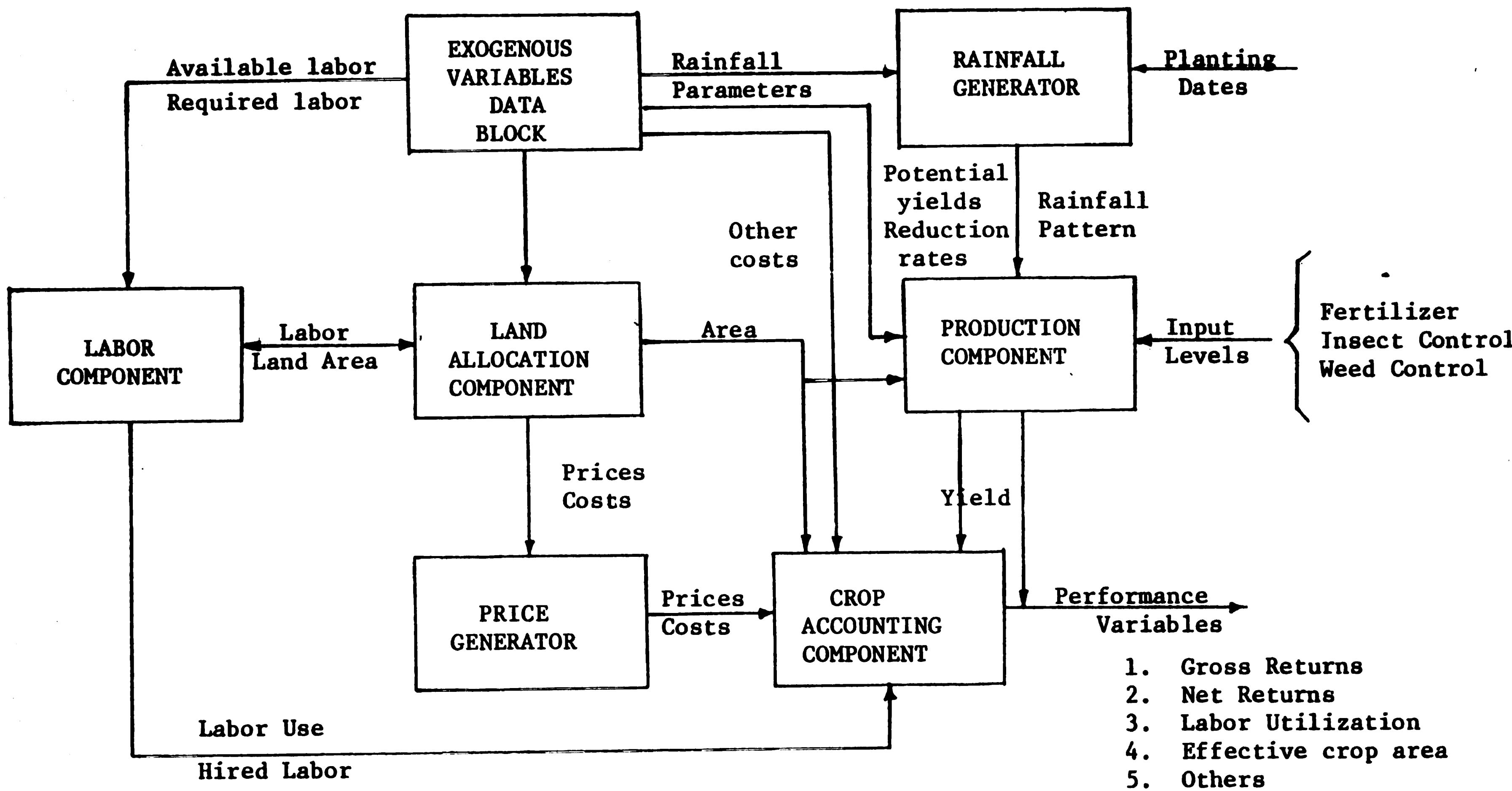

Fig. 3.2. Major Components and Interrelationships of the Simulation Model.

component, labor utilization component, output disposal component, storage and sales component, investment funds allocation component, cost and income accounting component, product and input markets, income allocation component, and exogenous factors. Each of these components and their interrelationships were discussed.

Because of the complexity of the system, it was deemed necessary to adopt a simpler conceptual model of a farm to make the mathematical modeling and computer implementation manageable. Thus, for the purpcses of the study, only the following components were included: land allocation component, rainfall generator, production component, labor utilization component, price and cost generator, and crop accounting component.

CHAPTER 4

LAND ALLOCATION COMPONENT

4.1 Introduction

The purpose of the land allocation component in the simulation model is to determine how total land area is to be utilized during the crop year. Land utilization is concerned with the determination of the proportion of total available land brought to cultivation, the kind of crops and area planted to each crop during the year, and the planting dates of each crop.

The land allocation component can take many forms within a simulation model. It can be set as predetermined variables (area of each crop, planting dates, etc.) or it can be determined endogenously within the model. Dong Min Kim's model[1] handled the land allocation as a policy variable and the consequences of alternatives land allocation schemes were determined. This framework is compatible with one of the objectives of the study, which is, to determine the performance of alternative cropping schemes. If determined endogenously, the range of complexity varies from simple look-up functions to complex mathematical programming models. Prantilla,[2] and Thodey

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[1] Dong Ming Kim, "Korean family farm simulation model," unpubl. paper, Michigan State University, 1975.

[2] E.B. Prantilla, Economic optimization models of multiple cropping system: applied to the Philippines," Ph.D. thesis, Iowa State University, 1972 (unpublished).

and Sektheera[3] both used linear programming models to find the optimum combination of crop that can maximize net return of farms.

The problem of land allocation is important in multiple cropping because the farmer must decide from among a number of choices as to what crops to plant at a particular time, their relative hectarage, and sequencing. The decision usually takes into consideration a large number of factors including total land area, subsistence requirements, household cash needs, weather and other environmental variables, labor availability, prevailing crop prices, input prices, and many others. The final land allocation may depend on the particular decision criterion adopted. Some possible decision criteria are maximum net returns, minimum operating costs, minimum hired labor costs, and others.

4.2 Method of Land Allocation

A fundamental question that was dealt with in the development of the model was whether land allocation can be achieved by optimization or simply by setting land allocation as a predetermined set of variables and observing the values of certain performance variables. It is obvious that the two divergent approaches imply a great difference in tasks, data requirements, and ease of computer implementation. An optimizing routine such as linear programming model of land allocation can be very complicated depending on the nature of constraints and objective function employed. On the other hand, pre-determining the land allocation simply entails specifying the land area of each crop and their respective planting dates.

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[3] A. Thodey and R. Sektheera, "Optimal multiple cropping systems for the Chiang Mai Valley," Agricultural Economics Report No. 1, Faculty of Agriculture, Chiang Mai University, July 1974.

Notwithstanding the ease with which it can be done, a more basic question has to be considered as to which methodology is appropriate for the problem at hand. The main objective of developing the simulation model, at least in this study, is to determine the cropping patterns which are appropriate for a particular locality or area. Appropriateness is not only concerned with the level of economic returns but also with economic, biological and environmental viability.

A main concern in using linear programming is that, while it solves for the land allocation pattern that maximizes or minimizes a given objective function, it also determines the other unknowns of the system which the simulation model is designed to determine. Moreover, in linear programming it is difficult to handle multiple decision criteria at a time.

Another concern is that linear programming model assumes that the coefficients are fixed. Thus, yields, prices, costs, labor requirements, operating costs, etc., are held fixed in a particular run without regard for the fluctuations in rainfall pattern, prices, and other random variables.

Finally, there is the problem of physically linking other components of the simulation model with the linear programming land allocator. Mathematical programming problems are usually solved nowadays, with software packages which are usually available in machine language. Although it is possible to write a separate linear programming routine in the same language as that of the simulation model,[4] the task is by no means easy; moreover it is also time consuming.

To sum it up, there are several arguments against the use of a linear programming model as a land allocator for the purposes of the study: it competes with the simulation model in terms of the determination of values of other unknowns in the system; it has very rigid assumptions; and it involves difficulties in physically linking software linear programming packages with the simulation model.

An alternative is the method of leaving out the land allocation component and viewing the rest of.the system as a laboratory wherein experimentations on various land allocation schemes can be performed. This kind of experimentation tests the performance of alternative cropping patterns that is, a given set of crop combination, sequencing, relative achieved by first in putting alternative cropping patterns, making several iterations of each pattern and finally comparing the relative performance of each pattern.

In this method the user simply specifies the kind of crops included in the pattern, their respective areas, and their planting dates. Total farm area is dictated by the user. It is apportioned among the crops included under the condition that total area planted does not exceed the farm area. Two plantings of a crop are allowed. For the present purposes, the crops are rice, corn, sorghum, mungbean, cowpea, peanut, soybean, and sweet potato.

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[4]R. P. Strickland and J. D. Davis, "Interfacing the MPS/360 Linear Programming Routine with FORTRAN programs," U.S. Dept. of Agriculture, Econ. Res. Service, 1970. Also J. L. Kuester and J. H. Mize Optimization techniques with FORTRAN, McGraw-Hill Inc., 1973.

The method was preferred over other methods for the following reasons:

1. It is a very simple method.

2. It conforms with the experimental method of agronomists and thus, can supplement the results of actual experiments or predicts the outcome of a particular experiment.

3. Various levels of management input, different rainfall patterns and different market conditions are possible for a particular cropping pattern.

4. It is not restricted by a single performance criterion.

The disadvantages are as follows:

1. Numerous computer runs have to be made in order to identify the cropping patterns suitable for a particular area.

2. There is a great number of possible crop combinations and an infinite number of possible land allocation schemes (in terms of proportion of total area planted to each crop) in a given combination. However, this is not considered to be a very serious limitation because the crop combinations or cropping patterns that are specified in this model are those which agronomists are interested in which is a limited number. Cropping patterns which are obviously inferior are no longer included.

Although an optimizing method such as linear programming was not used in this study for reasons cited above, it can be of positive contribution to the simulation model. First, it helps reduce the number of possible crop combinations that are tested in the simulation model by eliminating those combinations which are obviously inferior. Second, it helps in bounding the problem to manageable limit and in improving the logic of interrelationships between farm constraints and activities.

4.4 Summary

In this chapter, alternative methods of land allocation were examined. Two methods of land allocation were examined in detail. The first simply presents the areas and planting dates of each crop. The other is an optimizing model which maximizes net returns subject to various constraints. The advantages, disadvantages and limitations of each method were discussed. In the model, the farmer method was used owing to its simplicity, flexibility and versatility.

CHAPTER 5

RAINFALL GENERATOR

5.1 Introduction

The purpose of the rainfall generator is to provide to the simulation model the rainfall pattern for the period covered in the simulation. Under upland conditions, rainfall is the only source of moisture for the crops. Indeed, as researchers have shown,[1] rainfall is considered to be the most important factor affecting rice yields under upland conditions.

In generating the rainfall pattern for the simulated period, there are two points that must be considered. They are (1) the time interval or the shortest unit of time for which rainfall is generated, and (2) the method of generating the rainfall pattern for the simulation model.

5.2 Modeling Considerations

5.2.1 Time interval of generated rainfall

In this study, rainfall is generated on a weekly basis. That is, the total rainfall for each of the 52 weeks of the year is generated and together they comprise the rainfall pattern for the simulated year. It was felt that weekly rainfall generation is a reasonable compromise between generating rainfall on a daily basis and generating rainfall on a monthly basis.

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[1] S. Yoshida, "Factors that limit the growth and yield of upland rice in IRRI," Major Researches in Upland Rice, Los Baños, Phils., 1975, pp. 46-71.

There were several reasons why a weekly rainfall generation was preferred. First, weekly time increments are employed in the other components of the simulation model. Second, the time series data for most of the other variables in the model are available only on a weekly basis. Third, when historical data are to be used as the rainfall pattern for the simulated year, fewer are required in the model resulting in less programming difficulties. Although, daily rainfall generation is not incompatible with weekly time incrementation, it is more difficult to do so mainly because of the large degree of interdependence among daily rainfall observations and hence more modeling efforts required.

On the other hand, the aggregation of daily rainfall observations into weekly totals removes to a large extent the interdependence among adjacent time observations.[2] The question of independence among weekly observations is examined below.

Since the primary purpose of the rainfall generator is to determine the rainfall pattern of the simulated year for the purpose of predicting crop yields, a daily observation would have been ideal. This is because daily soil moisture levels are better predictors of yields than weekly observations.[3] For instance, the weekly total may indicate a high level of rainfall, but if the rain fell only on

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[2]See J. B. Philipps, "Statistical Methods in Systems Analysis," in Dent and Anderson (eds), op. cit., pp. 34-52.

[3]See J. C. Flinn, "The Simulation of Crop-Irrigation Systems," in Dent and Anderson (eds), op. cit.

one day while the rest of the week was dry, the effect on the crop would be quite different than if there was rainfall every day of the week adding up to the same total.

On the other extreme, monthly rainfall totals are poor bases for predicting crop yields since the distribution of the rainfall within the month is ignored. With weekly data, some detail on distribution is still available. In terms of data handling and programming, however, monthly rainfall observations are easier to work with. They are also are more amenable to synthetic or probabilistic generation since they could easily pass tests of independence.

5.2.2 Methods of rainfall generation

The method of generating rainfall depends on two main considerations: (1) correspondence with the real world situation, and (2) purpose for which the generated rainfall data is to be used.

The first consideration is self-explanatory. The rainfall pattern that results from the generator must belong to the established patterns of a specific area. This implies that the statistical properties of a set of generated rainfall patterns must be close to the statistical characteristics of the historical data in that area.

Since the rainfall generator can be used in several modes, each mode may call for a particular method of rainfall generation. One possible mode is to generate a rainfall pattern over a given period of time for a particular area to be used in a simulation run. Here, either a synthetic generator or the historical data of a randomly selected year can be used. Another mode is to verify the validity of a component of the simulation model using the data for a specific year. In this instance, the rainfall pattern to use must be the historical rainfall data for that particular year. Hence, a facility has to be provided such that the historical rainfall data for that particular year will be used automatically and not that of another. Another possible mode of using the rainfall generator is to use a pre-determined rainfall level for a particular simulation run. For example, a high, medium, or a low rainfall year may be desired for the particular run. Although this can also be achieved with rainfall probability distributions, it would be much easier to do so with historical data. Hence, a facility for achieving this is an added convenience.

Because of the varying modes in which the rainfall generator may be used, five options were developed in this study: (1) to generate rainfall based on the parameters of a probability distribution for each week synthesized from actual data, (2) to randomly select a year between 1949 and 1975 and to use the historical rainfall data of the Ambulong Weather Station for that year as the rainfall pattern for the simulation run, (3) to use the historical rainfall data of a pre-determined year, (4) to randomly select a high, medium, or low rainfall year on the basis of annual total rainfall and to use the historical data of the selected year in the simulation run, and (5) to use the average weekly rainfall of the Ambulong Weather Station from 1949 to 1975 as rainfall pattern for the simulation run.

Note that there are two primary methods of rainfall generation namely (1) the use of probability density functions such as used in the first option, and (2) the use of historical rainfall data such as used in the other four options.

5.2.3 Historical data vs. synthetic rainfall generation

Concerning the use of historical data as opposed to generated data in simulation models, J. B. Philipps states that: "The historical data represent nothing more than a sample from a much longer-term process than has been observed, and the result is that unnecessary restrictions are placed on the generality of findings based on the performance of the simulation model."[4]

Historical data have two important roles in model building. First, it serves as a basis for the generation of a series of observations from a stochastic process. Second, it can be used as a device for testing the complete model against known historical information, and thus, assisting in the validation of the non-stochastic portions of the model.

The basic objections to the use of historical data are: (1) it forces discreteness on the variable in that the sample will always be something less than a complete coverage of all possible values of the variables; and (2) even with fairly long series of historical data, a certain lack of smoothness will usually occur.

The advantages of synthetic rainfall generation are: (1) it provides additional benefits arising from a more complete understanding obtained of the way in which the process operates, (2) it enables less cumbersome computer programming, and (3) there are real economies

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[4]J. B. Phillips, op. cit., p. 43.

obtained from using parameters of a process rather than a massive quantity of data as input.

5.3 Synthetic Rainfall Generation Methods

One of the main methods of incorporating rainfall into the simulation model is by generating rainfall patterns through independent sampling from some specified probability distribution function. This involves the estimation of the parameters of a particular probability density function for each week which are then used to generate the weekly rainfall. The generated rainfall is a random variable which belongs to the hypothesized distribution function.

Three different distributions were tried on the historical weekly rainfall data taken from the Ambulong Weather Station over the period 1949-1976. The distributions are: (1) normal distribution, (2) log-normal distribution, and (3) the incomplete gamma distribution. In each of these distributions, the parameters were estimated and tests of correspondence or goodness of fit were conducted. As it will be seen below, the incomplete gamma distribution was finally adopted as the best distribution function which fits the actual rainfall data.

5.3.1 Tests of independence

The use of the above-mentioned distribution functions in the generation of weekly rainfall assumes independence between successive values. Hence, the observed data for the variable to be synthesized must be examined for the existence of relationships between successive observations (i.e., autocorrelation). A number of tests are available for testing autocorrelation of time series data which includes both parametric and non-parametric tests. A computer program incorporating five separate tests for autocorrelation of weekly rainfall was developed in this study:[5] (1) Anderson's circular autocorrelation coefficient, (2) Von-Neumann ratio, (3) Wald-Wolfowitz test of randomness, (4) theory of runs, and (5) standard chi-square test for independence.

The first two tests are parametric tests involving assumptions regarding the distribution of the parent population (usually normal). The last three tests are non-parametric requiring no assumption regarding the distribution of the parent population and thus, are much more general in their application.

In doing the tests, the rainfall data were first transformed to remove seasonal patterns that exist in the series. The seasonal influences were removed by working with deviations from the mean for each time period (week). This involved the assumption that the seasonal pattern is adequately reflected in the average values of rainfall for each week. Since rainfall distribution is markedly skewed, however, the same tests were also done using the weekly median rainfall as a reflection of seasonal pattern.

Tables 5.1 and 5.2 show the results of the tests based on deviations from the means and medians, respectively. It can be seen that in both cases, four out of the five tests indicate that the rainfall series is autocorrelated. Only the chi-square test supported the hypothesis of independence at 5 percent level. The result of the

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[5]For a detailed discussion on the use of tests for serial correlation, see J. B. Phillips, loc. cit.

Table 5.1. Results of five tests independence of weekly rainfall data, Ambulong, Tanauan, Batangas, 1949-1975 (deviation from means).

Test[a]	Computed	Expected	Variance	Significance
Anderson's	0.165	-.00074	.00074	1%
Von-Neumann	1.67	5.09	3.05	1%
Wald-Wolfowitz	682.90	-3.05	12377	1%
Theory of runs	524.00	589.00	256.67	1%
Chi-square	16.6311			n.s.[b]

[a]The null hypothesis is no autocorrelation among adjacent observations.

[b]At 5 percent level.

Table 5.2 Results of five tests of independence of weekly rainfall data, Ambulong, Tanauan, Batangas, 1949-1975 (deviation from medians).

Test[a]	Computed	Expected	Variance	Significance
Anderson's	0.168	-0.00074	0.00074	1%
Von-Neumann	1.66	5.34	3.21	1%
Wald-Wolfowitz	1055.80	321.69	13688	1%
Theory of runs	580.00	658.26	320.72	1%
Chi-square	19.32			n.s.[b]

[a]The null hypothesis is no autocorrelation among adjacent observations.

[b]At 5 percent level.

tests have to be interpreted with caution, however, since a normal distribution has been assumed for the parent populations. Rainfall data in general, and Ambulong data in particular, are not distributed normally. Phillips[6] state that if the time interval for which observations are to be generated is weekly, it will be found that for such periods successive observations of rainfall can reasonably be assumed to be independent. Consequently, synthesis of the element can be undertaken by independent sampling.

In this study, despite the fact that not all the tests indicated independence of weekly observations,[7] it was assumed that weekly rainfall series are not autocorrelated. This is mainly because developing another rainfall generating model which accounts for autocorrelation is complex and time consuming. Moreover, the extra effort it takes to obtain a more accurate generated series may not be justifiable if it is only to be used together with data which are not themselves very accurate. In the final analysis, the acceptability of the rainfall generating model will be tested by the comparison of statistical characteristics of actual versus the generated data.

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[6]Ibid., p. 39.

[7]A number of methods of varying complexity can be used in an effort to reproduce the desired relationships in the synthesized data. See for example M. M. Hufschimdt and M. B. Fiering, Simulation Techniques for Design of Water Resource System, Harvard University Press, Cambridge, 1966 and A. Pattinson, Synthesis of Rainfall Data, Civil Engineering Technique, Report 40, Stanford University, 1964.

5.3.2 Alternative probability distributions

Normal distribution

Fitting a normal distribution to a set of data is fairly straightforward. It simply involves finding the estimates of μ and σ from the density function

$$P_{\mu,\sigma}(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma^2}$$

which by maximum likelihood method or method of moments are given by

$$\hat{\mu} = \bar{X} = \Sigma x_i$$

and

$$\hat{\sigma}^2 = s^2 = \frac{\Sigma (x_i - \bar{X})^2}{n-1} .$$

Table 5.3 shows the means and standard deviations of each week based on 27 years of rainfall data gathered from the Ambulong Weather Station from 1949 to 1975.

Lognormal distribution

A variable X is lognormally distributed if Y = log X is normally distributed with mean μ and variance σ^2. Thus X has a lognormal density if and only if it has the density induced by e^Y where Y is normal with parameters μ and σ^2.[8] That is,

$$P_{\mu,\sigma}(x) = \frac{1}{x\sqrt{2\pi\sigma^2}} \exp \frac{1}{2\sigma^2}(\log x - \mu)^2 , \; x>0.$$

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[8] J. Aitchison and J.A.C. Brown, The Lognormal Distribution with Special Reference to its Use in Economic, Cambridge University Press, 1957.

Table 5.3. **Means and standard deviations of weekly rainfall data, Ambulong, Batangas, 1949-1975 (in inches)**

Week	Mean	Standard Deviation	Week	Mean	Standard Deviation
1	0.51	1.18	27	1.93	1.48
2	0.19	0.26	28	2.31	2.31
3	0.11	0.29	29	3.42	4.25
4	0.13	0.20	30	2.27	2.15
5	0.12	0.24	31	2.56	2.11
6	0.07	0.11	32	3.15	2.43
7	0.11	0.28	33	2.63	2.15
8	0.13	0.25	34	1.84	1.67
9	0.20	0.31	35	2.60	2.38
10	0.22	0.43	36	3.37	4.58
11	0.21	0.46	37	1.61	0.87
12	0.13	0.33	38	2.42	1.74
13	0.11	0.32	39	1.55	1.37
14	0.07	0.17	40	2.36	2.21
15	0.27	0.51	41	2.43	2.45
16	0.34	0.56	42	2.25	2.56
17	0.69	0.92	43	1.24	1.43
18	0.86	1.38	44	1.45	2.68
19	1.02	1.28	45	1.21	1.11
20	1.35	1.75	46	1.32	1.48
21	1.40	1.58	47	1.85	2.30
22	1.67	2.35	48	1.53	1.82
23	1.62	1.97	49	1.19	1.61
24	1.45	1.53	50	1.16	1.28
25	1.96	1.48	51	0.90	1.49
26	2.81	3.27	52	1.16	1.71

Source of basic data: Ambulong Weather Station, Tanauan, Batangas

The mean α and variance β^2 of X are given by

$$\alpha = e^{\mu + .5\sigma^2}$$

and

$$\beta^2 = e^{2\mu+\sigma^2}(e^{\sigma^2-1}) = \alpha^2\eta^2$$

where

$$\eta^2 = e^{\sigma^2-1}.$$

Note that η is the coefficient of variation of the distribution. In estimating α and β^2 , it is sufficient to estimate μ and σ^2 which are then substituted to the above relationships.

The maximum likelihood estimators m_1 and $s_1^{\ 2}$ of μ and σ^2 are given by

$$m_1 = \frac{1}{n} \Sigma \log x_i$$

and

$$s_1^{\ 2} = \frac{1}{n} \Sigma (\log x_i - m_1)^2$$

$$= \frac{n-1}{n} v_y^{\ 2}$$

where

$$v_y^{\ 2} = \frac{\Sigma (\log x_i - m_1)^2}{n-1} .$$

The estimator $s_1^{\ 2}$ is biased but consistent. If, however,

$$s_1^{\ 2} = v_y^{\ 2}$$

then m_1 and $s_1^{\ 2}$ are minimum variance estimators and unbiased estimators of μ and σ^2 , respectively.

With the method of moments, the estimators m_2 and $s_2^{\,2}$ of μ and σ^2 are obtained by equating the first two sample moments w_1 and w_2 to the expressions given by substituting m_2 and $s_2^{\,2}$ for μ and σ^2 in the equation

$$\lambda_j = e^{j\mu + .5\sigma_j^{\,2}}$$

where λ_j is the jth moment about the origin and j = 1, 2. The jth sample moment about the origin is given by

$$w_j = \frac{1}{n} \Sigma x_i{}^j \ .$$

So

$$w_1 = \exp\ (m_2 + 1/2\ s_2^{\,2})$$

and

$$w_2 = \exp\ (2m_2 + 2s_2^{\,2}) \ .$$

Therefore,

$$m_2 = 2 \log w_1 - 1/2 \log w_2$$

and

$$s_2^{\,2} = \log w_2 - 2 \log w_1 \ .$$

The estimates are both consistent.

The two methods of estimation were tried with the Ambulong rainfall data. The maximum likelihood method gave better results with respect to the fit with actual data. Thus, in later comparisons with other distribution functions, only the maximum likelihood estimators were used. Table 5.4 shows the estimates of μ and σ^2 for each week.

Table 5.4. Estimates of μ and σ parameters of a lognormal rainfall distribution by week, Ambulong, Batangas, 1949-75

Week	$\hat{\mu}$	$\hat{\sigma}$	Week	$\hat{\mu}$	$\hat{\sigma}$
1	-1.98	1.53	27	0.43	0.46
2	-2.30	1.14	28	0.52	0.67
3	-3.18	2.00	29	0.76	0.93
4	-2.83	1.09	30	0.50	0.64
5	-3.25	1.86	31	0.68	0.52
6	-3.06	1.08	32	0.91	0.47
7	-3.20	2.01	33	0.71	0.51
8	-2.75	1.50	34	0.31	0.60
9	-2.17	1.18	35	0.65	0.61
10	-2.42	1.68	36	0.69	1.05
11	-2.41	1.74	37	0.39	0.31
12	-3.14	2.11	38	0.68	0.42
13	-3.27	2.21	39	0.15	0.58
14	-3.82	2.12	40	0.54	0.63
15	-2.03	1.50	41	0.53	0.70
16	-1.70	1.29	42	0.40	0.83
17	-1.02	1.08	43	-0.21	0.84
18	-0.78	1.27	44	-0.37	1.48
19	-0.46	0.95	45	-0.11	0.60
20	-0.19	0.98	46	-0.13	0.82
21	-0.07	0.82	47	0.15	0.93
22	-0.03	1.09	48	-0.02	0.88
23	0.03	0.90	49	-0.34	1.04
24	0.00	0.75	50	-0.25	0.79
25	0.45	0.45	51	0.76	1.32
26	0.61	0.85	52	0.43	1.15

Source of basic data: Ambulong Weather Station, Tanauan, Batangas

Table 5.4. Estimates of μ and σ parameters of a lognormal rainfall distribution by week, Ambulong, Batangas, 1949-75

Week	$\hat{\mu}$	$\hat{\sigma}$	Week	$\hat{\mu}$	$\hat{\sigma}$
1	-1.98	1.53	27	0.43	0.46
2	-2.30	1.14	28	0.52	0.67
3	-3.18	2.00	29	0.76	0.93
4	-2.83	1.09	30	0.50	0.64
5	-3.25	1.86	31	0.68	0.52
6	-3.06	1.08	32	0.91	0.47
7	-3.20	2.01	33	0.71	0.51
8	-2.75	1.50	34	0.31	0.60
9	-2.17	1.18	35	0.65	0.61
10	-2.42	1.68	36	0.69	1.05
11	-2.41	1.74	37	0.39	0.31
12	-3.14	2.11	38	0.68	0.42
13	-3.27	2.21	39	0.15	0.58
14	-3.82	2.12	40	0.54	0.63
15	-2.03	1.50	41	0.53	0.70
16	-1.70	1.29	42	0.40	0.83
17	-1.02	1.08	43	-0.21	0.84
18	-0.78	1.27	44	-0.37	1.48
19	-0.46	0.95	45	-0.11	0.60
20	-0.19	0.98	46	-0.13	0.82
21	-0.07	0.82	47	0.15	0.93
22	-0.03	1.09	48	-0.02	0.88
23	0.03	0.90	49	-0.34	1.04
24	0.00	0.75	50	-0.25	0.79
25	0.45	0.45	51	0.76	1.32
26	0.61	0.85	52	0.43	1.15

Source of basic data: Ambulong Weather Station, Tanauan, Batangas

It must be noted that the lognormal density function is restricted to values of $X > 0$. Since rainfall data have a number of zero observations, the value of 0.001 was substituted for each zero observation before logarithms were taken.

Incomplete gamma distribution

The gamma distribution has been found to give good fits to precipitation series and is the most frequently used distribution in fitting probability functions for rainfall data.[9] The gamma distribution is defined by its frequency or probability density function,

$$g(x) = \frac{1}{\beta^{\gamma}\Gamma(\gamma)} x^{\gamma-1} e^{-x/\beta}$$

where β is a scale parameter, γ is a shape parameter, and $\Gamma(\gamma)$ is the ordinary gamma function of γ.

The method of moments of this density function give poor estimates of the parameters. Sufficient estimates are, however, available and these are closely approximated by[10]

$$\hat{\gamma} = \frac{1}{4A} (1 + \sqrt{1 + 4A/3})$$

---

[9]See for example G. L. Barger and H.C.S. Thom, "Evaluation of drought hazard," Agronomy Journal, 11:519-527; D.G. Friedman and B. E. James, "Estimation of rainfall probabilities," Univ. of Connecticut, Coll. of Agric. Bull. 332, 1957; and H.C.S. Thom, "A note on the gamma distribution, " Monthly Weather Review, 86: 117-122, April 1958.

[10]See H. C. S. Thom, "Some methods of climatological analysis," Technical Note No. 81, World Meteorological Organization, 1966.

and

$$\hat{\beta} = \bar{x} / \hat{\gamma}$$

where

$$A = \ln \bar{x} - \frac{\Sigma \ln x}{n} .$$

Table 5.5 shows the estimates of β and γ for each weed based on 27 years of weekly data in Ambulong, Tanauan, Batangas.

5.4 Generating Variables of a Particular Distribution

There are two important methods for generating random variables, namely, the inverse transformation method and the rejection method.[11]

Inverse transformation method

In the inverse transformation method, we seek to generate a series of random numbers $(x_1, x_2, \ldots, x_n)$ which have the density function $f(x)$.

The procedure is as follows:

a) Draw a series of random numbers $(r_1, r_2, \ldots, r_n)$ which are uniformly distributed between zero and one.

b) Determine the cumulative distribution function corresponding to $f(x)$: $F(x) = \int_{-\infty}^{x} f(x)dx$.

c) Compute x_i $(i=1,2,\ldots,n)$ as $x_i = F^{-1}(r_i)$ where $F^{-1}(\ )$ is the inverse of the cumulative distribution function.

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[11]This section draws heavily from G. Park and T. Manetsch, Systems Analysis and Simulation with Applications to Economic and Social Systems, Preliminary edition, Michigan State University, January 1973, Chapter 13.

Table 5.5 Gamma and beta parameters of the incomplete gamma distribution fitted on weekly rainfall data, Ambulong, 1949-1974.

Week	Gamma (γ)	Beta (β)	Week	Gamma (γ)	Beta (β)
1	0.328	0.907	27	1.504	1.283
2	0.378	0.468	28	0.822	2.860
3	0.292	0.386	29	0.640	5.335
4	0.420	0.242	30	1.040	2.179
5	0.328	0.300	31	1.066	2.398
6	0.411	0.196	32	1.822	1.728
7	0.294	0.376	33	1.588	1.764
8	0.283	0.476	34	1.341	1.375
9	0.331	0.626	35	1.110	2.345
10	0.264	0.778	36	0.831	4.056
11	0.313	0.683	37	1.372	1.254
12	0.247	0.505	38	2.067	1.173
13	0.269	0.424	39	1.352	1.444
14	0.302	0.210	40	1.472	1.602
15	0.318	0.870	41	0.769	3.154
16	0.269	1.292	42	1.103	2.039
17	0.503	1.229	43	0.689	1.799
18	0.441	1.956	44	0.354	4.092
19	0.368	2.766	45	0.582	2.088
20	0.558	2.416	46	0.627	2.107
21	0.481	2.912	47	0.472	3.916
22	0.506	2.308	48	0.580	2.634
23	0.661	2.457	49	0.433	2.749
24	1.074	1.354	50	0.486	2.387
25	0.886	2.209	51	0.354	2.544
26	1.199	2.346	52	0.372	3.113

Source: Output of computer programs.

Rejection method

This method can be used if the density function f(x) is finite and if x has a finite range: $A \leq x \leq B$. The procedure for implementing this method is as follows:

a) Normalize the range of the density function f by a scale factor c, such that $cf(x) \leq 1$, where $A \leq x \leq B$.

b) Define x as a linear function of the uniform (0,1) random number r, so that $x = A + (B - A)r$. Note that the range of x is (A,B) as required since $x = A$ when $r = 0$ and $x = B$ when $r = 1$.

c) Generate pairs of (0,1) random numbers (r_1, r_2).

d) Whenever a pair of random numbers that satisfies the relationship $r_2 \leq cf\{A + (B-A)\}r_1$ then the pair is "accepted" and the random number $x = A + (B-A)r_1$ has a density function of f(x).

This method is particularly useful when it is difficult, or impossible, to obtain the inverse of the cumulative distribution function, $F^{-1}(\ )$, required by the inverse transformation method.

Generating normally distributed rainfall

In order to generate random variables from a normal distribution, estimates of the mean μ_x and standard deviation σ_x must be given. In practice, we usually generate random variables from the so-called standardized normal distribution (with $\mu_x = 0$ and $\sigma_x = 1$). Then by means of a simple transformation, we convert them to normal variables with the desired mean and standard deviation. Let y represent a standardized normal random variable with zero mean and a standard deviation of one.

We then define the following transformation:

$$x = \sigma_x y + \mu_x.$$

The variable x is then a normally distributed random variable with mean μ_x and standard deviation σ_x.

The most efficient way to generate normal random variables is the inverse transformation method. Unfortunately, the inverse of the cumulative distribution function for the normal density function does not exist in a nice neat analytical form. It is therefore, necessary to approximate it.

In this study, the practical approach was to use a subprogram to construct a piecewise linear approximation for the inverse cumulative distribution function.

The method for computing normal random normal random variables with a specified mean and standard deviation by the above approach are as follows:

1. Generate a (0,1) uniformly distributed random number r_i.
2. Compute a standardized normal variable Y_i based on r_i.
3. Compute a normal random variable with the desired mean, μ_x, and standard deviation σ_x as $X_i = \sigma_x Y_i + \mu_x$.

Another approach to the generation of standardized normal distribution is by the use of the formula

$$Y = (-2 \ln r_1)^{1/2} \cos 2\Pi r_2$$

where Y is now a random variable from the standardized normal distribution and r_1, r_2 are (0,1) uniformly distributed random numbers. This approach is more convenient and has the advantage of being exact. However, it is much less efficient.

Generating gamma distributed rainfall

To generate rainfall which is distributed according to an incomplete gamma distribution, the weekly estimates of the gamma parameter G and of the beta parameter B are required. As indicated earlier, these are found by

$$G = \frac{1}{4A}\left(1 + \sqrt{1 + 4A/3}\right)$$

and

$$B = \bar{X}/G$$

where

$$A = \ln \bar{X} - \frac{\Sigma \ln x}{n}.$$

The general principle of the inverse transformation method is to find the value of x for a given random number uniformly distributed between zero and one. Since the inverse of the incomplete gamma distribution is difficult to obtain, the rainfall level R_i, corresponding to a given probability level r_i may be estimated as follows:[12]

$$x_i = x_j - \frac{x_j}{G}\left[1 + \frac{x_j}{G+1} + \frac{x_j^{\,2}}{G+2} + \ . \ . \ .\right] - \frac{r_i\Gamma(G)e^{x_j}}{x_j G-1}$$

where j = i - 1, G is the gamma parameter, and x_i is a preliminary estimate obtained by iteration. The initial estimate of x_i begins at G-1; that is, x_j = G-1. Iteration stops when x_i and x_j are approximately equal. Finally, the rainfall level is obtained by

$$R_i = x_i \cdot B$$

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[12]C.R. Weaver and M. Miller, "Aprecipitation probability computer program," Research Circular 155, Ohio Agric. Res. and Dev. Center, Wooster, Ohio, Nov. 1967.

where B is the beta or scale parameter. Normally, the above procedure requires only about 10 to 20 iterations.

Generating lognormally distributed rainfall

Generating lognormally distributed rainfall is more efficient than that of gamma distributed variables in terms of computer time. The procedure is as follows:

1. Provide estimates of the lognormal parameters μ and σ, of the following distribution:

$$g(x) = \frac{1}{x\sqrt{2\Pi\sigma^2}} e^{-(\log x - \mu)/2\sigma^2}$$

By maximum likelihood estimation,

$$\hat{\mu} = \frac{1}{n} \Sigma \log x_i$$

and

$$\hat{\sigma}^2 = \frac{1}{n} \Sigma (\log x_i - \mu)^2 .$$

2. Generate a random standardized normal deviate z_i (with mean 0 and standard deviation = 1).

3. Generate X_i using the equation

$$X_i = e^{\hat{\mu} + \hat{\sigma} z_i} .$$

5.5 Chi-Square Tests

The computation of the parameters of both the incomplete gamma distribution and the lognormal distribution were done by means of a computer program developed for this study.

In computing the parameters for a particular week, the estimation procedures as outlined earlier were used. In the case of the gamma function, the procedures are that of the modified method of moments, while for the lognormal function, the maximum likelihood estimates were used.

In order to test the goodness or fitness of a particular function to actual data, the latter were first tabulated according to classes based in magnitude of rainfall. A total of 20 classes were used in tabulating actual data, the class interval being one-half of an inch of rainfall. After obtaining the absolute frequency count for each class, the relative frequencies for the class were also computed.

To compute the chi-square, the expected frequency for a given class was obtained by first finding the probability density of the mid-point of that class and then multiplying it by the class interval to obtain an estimate of relative frequency of the class. Finally, the expected frequency was obtained by multiplying the relative frequency by the number of observations for that week, that is, 27 observations corresponding to the 27 years of available data.

The chi-square statistics were computed according to the usual formula

$$\chi^2 = \frac{(E-O)^2}{E}$$

where E is the expected frequency and O is the observed frequency.

Results of the goodness of fit tests

The choice as to which function to use depends on how well each one fits with the actual data. As in other goodness of fit tests the chi-square test was employed. Table 5.6 shows the comparison between the gamma distribution and the lognormal distribution in terms of the computed chi-square.

The interpretation of the figures are as follows: if the computed chi-squares are greater than 34.80, 28.87, or 25.99, then the distribution generates figures which are significantly different from the actual data at one percent, five percent or ten percent significance level, respectively.

Note that in the case of the incomplete gamma function, the computed chi-square values were consistently below the critical value at five percent level. There was no week in which the actual data was significantly different from those generated by the incomplete gamma function at five percent level. The results indicate that the incomplete gamma function is the more appropriate distribution function to use in generating simulated rainfall data for Cale, Batangas rather than the lognormal distribution.

5.6 Options Using Historical Data

As mentioned earlier, the rainfall generator component includes options using historical data. These options, though not intended to replace the rainfall generator using a distribution function, are able to provide alternative rainfall patterns for the simulated period. In addition, the added options provide facility in validating the other

Table 5.6 Comparison of chi-square statistics between incomplete gamma and lognormal distributions fitted on Ambulong rainfall data, 1949-75.

Week	Gamma	Lognormal	Week	Gamma	Lognormal
1	15.71	12.98	27	26.31	35.83
2	13.48	10.48	28	24.69	25.82
3	10.39	57.23	29	22.41	33.61
4	10.00	40.64	30	25.57	21.28
5	9.58	61.36	31	25.36	27.23
6	8.13	77.71	33	25.82	23.59
7	10.29	52.93	33	25.82	23.59
8	11.40	28.55	34	26.28	22.28
9	13.99	12.08	35	25.41	41.53
10	13.52	17.58	36	23.57	15.31
11	14.02	30.65	37	26.36	40.45
12	10.95	59.55	38	26.05	13.39
13	10.45	63.25	39	26.43	17.49
14	6.69	132.73	40	26.03	36.03
15	15.30	16.49	41	24.34	28.15
16	15.92	10.26	42	25.72	44.94
17	20.58	8.16	43	24.01	17.43
18	20.80	30.21	44	20.74	40.60
19	20.36	9.27	45	23.02	18.90
20	22.91	30.76	46	23.55	17.35
21	22.12	18.60	47	22.11	39.85
22	22.49	21.21	48	23.22	13.98
23	23.96	25.88	49	21.38	19.61
24	26.03	24.03	50	21.94	18.47
25	25.26	45.57	51	19.94	22.69
26	25.34	35.09	52	20.66	38.12

Source: Output of computer programs.

components of the model and the pre-setting of the kind of rainfall pattern desired for a particular simulation run.

(1) The first option using historical rainfall data is to randomly select a year from 1949 to 1975 and to use the rainfall data of the selected year as the rainfall pattern for the simulation run. This is achieved in the model by generating randomly a number between 0 and 1 and consequently multiplying the number by 27 which is the number of years for which data are available. The product is then used as an index for selecting the specific year in which year 1 corresponds to 1949 and year 27 corresponds to 1975.

(2) The second option is to use the historical rainfall data of a specific year as the rainfall pattern for a simulation run. The desired year is simply specified and the program automatically feeds the rainfall data for that year for use in the simulation.

(3) The third option using historical data is to randomly select a year of a given rainfall level based on annual total rainfall. Either a high, medium or low rainfall is specified and the program randomly selects from the array of years belonging to a particular level. High rainfall years are those years having total rainfall higher than 80.7 inches; medium rainfall years are those which have a total rainfall between 65.2 inches and 80.7 inches; and low rainfall years are those years having a total of less than 65.2 inches. The limitation of this option is that there is no _a priori_ reason to suppose that the rainfall pattern for a given period is dependent on total annual rainfall. Nevertheless, it allows for the use of this method of rainfall generation if desired.

(4) Finally, the fourth option using historical data is to use the mean weekly rainfall of the Ambulong Weather Station from 1949 to 1975 as rainfall pattern for the simulation run. The inclusion of this option is only for comparative purposes since no random elements are present in the means. It was specifically intended to show that average rainfall patterns can give different results from those individual year to year patterns.

5.7 Validation of the Rainfall Generating Model

The test of validity of a model can be done only by comparing the results of the model and with the actual data. In order to do this, some thirty years of weekly rainfall data was generated on a digital computer. The first comparison was annual totals and averages. Table 5.7 shows the annual totals and averages of the simulated rainfall data for the thirty years while Table 5.8 shows the annual totals and averages of the rainfall data from Ambulong Station, Tanauan, Batangas from 1949-1974.

Note that the mean annual total for the actual data is 69.35 inches while that of the simulated data is 68.53 inches. In terms of the average rainfall per week, the simulated data gave 1.32 while the actual data gave 1.33 inches.

The other test done was a comparison of the weekly averages and standard deviations. Table 5.9 shows the weekly means and standard deviations of the simulated and actual data. They are reasonably close, although the simulated data appear to be slightly drier

Table 5.7 Annual totals and average per week of 30 years of simulated rainfall based on gamma parameters computed from Ambulong, Tanauan, Batangas (inches).

Year	Sum	Average/Week
1	81.33	1.56
2	49.49	0.95
3	64.97	1.25
4	80.99	1.56
5	70.78	1.36
6	72.60	1.40
7	77.19	1.48
8	61.94	1.19
9	76.95	1.48
10	51.28	0.99
11	66.69	1.28
12	69.89	1.34
13	81.74	1.57
14	60.03	1.15
15	65.14	1.25
16	84.11	1.62
17	85.01	1.63
18	76.42	1.47
19	51.30	0.99
20	46.41	0.89
21	51.11	0.98
22	65.86	1.27
23	70.59	1.36
24	91.77	1.76
25	73.61	1.42
26	71.59	1.38
27	55.38	1.07
28	59.35	1.14
29	82.07	1.58
30	60.29	1.16
Average	68.53	1.32

Table 5.8. Annual totals and averages per week of actual rainfall data, Ambulong, Tanauan, Batangas, 1949-1974 (inches).

Year	Annual total	Average/week
1949	49.7	1.1
1950	67.3	1.3
1951	74.2	1.4
1952	84.3	1.6
1953	65.4	1.3
1954	54.1	1.0
1955	49.4	1.0
1956	80.4	1.5
1957	47.9	0.9
1958	53.0	1.0
1959	70.2	1.4
1960	89.8	1.7
1961	85.9	1.7
1962	96.2	1.9
1963	53.8	1.0
1964	66.8	1.3
1965	46.8	0.9
1966	81.7	1.6
1967	76.6	1.5
1968	53.8	1.0
1969	49.7	1.0
1970	71.0	1.4
1971	88.2	1.7
1972	91.4	1.8
1973	67.6	1.3
1974	87.9	1.7
All	69.35	1.33

Table 5.1. Comparison of weekly rainfall means and standard deviations, 30 years of simulated rainfall based on gamma parameters vs. actual data, Ambulong, Tanauan, Batangas (inches).

	Simulated		Actual			Simulated		Actual	
Week	Mean	Std.Dev.	Mean	Std.Dev.	Week	Mean	Std.Dev.	Mean	Std.Dev.
1	0.17	0.22	0.30	0.57	27	1.83	1.09	1.93	1.48
2	0.10	0.10	0.18	0.26	28	2.67	2.68	2.35	2.29
3	0.05	0.07	0.11	0.29	29	3.42	3.68	3.41	4.25
4	0.07	0.09	0.10	0.14	30	2.32	1.90	2.27	2.15
5	0.06	0.07	0.10	0.23	31	2.43	2.72	2.56	2.11
6	0.10	0.08	0.08	0.11	32	3.23	2.04	3.15	2.43
7	0.04	0.05	0.11	0.28	33	2.99	2.42	2.63	2.15
8	0.07	0.08	0.13	0.25	34	1.48	1.43	1.84	1.67
9	0.12	0.14	0.31	0.31	35	3.34	2.65	2.60	2.38
10	0.07	0.10	0.20	0.43	36	4.09	3.82	3.37	4.58
11	0.08	0.14	0.21	0.46	37	1.33	0.98	1.72	1.03
12	0.02	0.04	0.12	0.34	38	2.37	1.29	2.42	1.74
13	0.05	0.07	0.11	0.33	39	1.78	1.35	1.55	1.37
14	0.02	0.04	0.06	0.17	40	2.23	1.96	2.36	2.21
15	0.13	0.20	0.28	0.52	41	2.78	2.15	2.42	2.45
16	0.07	0.15	0.35	0.56	42	1.92	1.49	2.25	2.56
17	0.42	0.51	0.62	0.86	43	0.97	1.12	1.24	1.43
18	0.80	1.07	0.86	1.38	44	0.86	1.08	1.45	2.68
19	0.46	0.71	1.02	1.28	45	1.56	1.58	1.22	1.11
20	1.68	1.74	1.35	1.75	46	1.60	1.96	1.32	1.48
21	1.68	2.03	1.40	1.58	47	1.84	1.94	1.85	2.30
22	2.31	2.75	1.67	2.35	48	1.75	2.20	1.53	1.82
23	2.08	2.37	1.62	1.97	49	0.87	1.25	1.19	1.61
24	1.28	1.21	1.45	1.53	50	0.80	0.91	1.16	1.28
25	1.62	1.32	1.96	1.48	51	0.56	0.73	0.90	1.49
26	3.11	2.62	2.81	3.21	52	0.86	0.99	1.16	1.71

especially during the first 20 weeks. For the ensuing weeks, the means and standard deviations for both the actual and simulated data differed only very slightly.

5.8 Summary

This chapter discusses the purpose of the rainfall generator, the modeling considerations, and approaches to generating rainfall. The issue between the use of a synthetic generator and the use of historical data were also discussed. The testing of three different distribution functions and the eventual choice of the incomplete gamma distribution were also dealt with. Four other options using historical rainfall data were discussed. Finally, the validation of the rainfall generator was discussed.

CHAPTER 6

PRODUCTION COMPONENT

6.1 Introduction

The purpose of the production component is to determine the yield levels of the various crops given the environment under which they are grown, the management practices employed and the input levels. Perhaps, the production component is the most important component of the model as in other crop simulation models. It is also the most difficult to model quantitatively in view of complexity of the production process. There have been many attempts to predict yield though various types of quantitative models, but most of them are not adaptable for the purposes of the study because they are either too environment-specific or they include only a very limited number of factors affecting yield.

An ideal yield prediction model is one which can predict yield to a reasonable degree under various environmental conditions (temporal or locational) given the levels of inputs and management practices. While this may be difficult or impossible to achieve, it is the ideal goal of model builders.

6.2 Factors Affecting Yield

Crop yield is the end result of the interaction of many biological, physiological, and physical processes. The factors affecting these processes are numerous and it would be impossible, if not impractical to include all of them in a yield prediction model. However, the more important factors affecting yield may usefully be classified as follows:

A. Crop environment

1. Climate

a. Rainfall

b. Solar radiation

c. Day-length

d. Temperature

e. Relative humidity

2. Soil

a. Type

b. Texture

c. Topography

d. Fertility

3. Others

a. Weed population

b. Degree of insect and disease damage

B. Crop characteristics

1. Yield potential and stability

2. Response to N, P, K

3. Seedling characteristics

4. Leaf characteristics

5. Growth duration

6. Plant height and culm characteristics

7. Root system

8. Panicle and grain features

9. Tolerance to adverse environments

10. Other physiological characteristics

C. Management practices

1. Land preparation

2. Weeding

3. Fertilization

4. Pest and disease control

5. Irrigation

It is clear from the above list that there is a multitude of factors affecting yield. Although the inclusion of the above factors in a yield prediction model would result in more realism and accuracy, the task would be too enormous and impractical for the purposes of the study. Hence, some guidelines and considerations were first defined.

6.3 Modeling considerations

The kind of model to be developed must be tailored to the purpose at hand. If it is necessary to predict yields accurately, say to within one percent, then a very sophisticated model incorporating the detailed physiological processes down to the last stomate may have to be developed. However, if the degree of accuracy desired is modest, then a much simpler version of the model may suffice.

The model developed in this study has been kept simple for expediency. Very little detailed physiological processes were taken into account in the model because of the lack of time and resources, and expertise on the part of the author. Therefore, modeling was restricted mainly to the observed relationships between inputs and output. Moreover, only the more important variables, that is, those variables which have the most impact on the yield of crops were included.

Another consideration in deciding which factors to include in the model is the availability of data. Although the inclusion of a variable may aid in making a model more realistic, this may not be possible due to the unavailability of data on such variable. Thus, certain variables were ignored altogether if it was impossible to fill the data requirement.

In summary, the main considerations in the choice of variables included in the model were: (1) the degree of importance of the variable in explaining yield, (2) the feasibility of including the variable into the model given the time, resources and capabilities of the model builder, (3) the level of realism required by the study, and (4) the availability of data.

6.4 Factors Considered

Crop environment

Of the climatic variables, rainfall level and distribution were considered to be the most important variables. The subject of the study is an upland area which depends solely on rainfall for its moisture supply. Yoshida (1975) states that "...moisture stress is the primary limiting factor of growth and yield under upland condition.[1] Several authors have likewise made similar statements.[2]

Although solar radiation has been found to influence nitrogen response and yield,[3] it was not accounted for in this study mainly because of lack of data on the crops considered in the study and specifically in the area being studied. If and when data for relating solar radiation and yield are available, it should be included in the model, not only in relation to nitrogen response functions but also in relation to its role in water loss from the plant due to transpiration.

Temperature, relative humidity, and day length were not considered in the model because of their relatively negligible, and inconclusive quantitative effects on yield.[4] Moreover, there is not yet enough data available on their effects on yield.

Batangas soils are alfisols and the soil texture is clay loam. In the particular area of this study, it was assumed that the soil type is homogenous so that the innate fertility of the soil was not assumed to affect yield. Topography was also not regarded as an

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[1]S. Yoshida, "Factors that limit the growth and yields of upland rice." in IRRI, Major Researches in Upland Rice, Los Baños, Phils. 1975. pp. 46-71.

[2]See for example, Y. Murata, "Estimation and simulation of rice yield from climatic factors," Agricultural Meteorology, 15:117-131, 1975. See also, S. K. De Datta and B. S. Vergara, Climate of upland rice regions in IRRI, Major Research in Upland Rice, Los Baños, Phils., 1975, 14-26.

[3]R. Barker and C. Montaño, "The effect of solar energy in rice yield response to nitrogen," (mimeo.) 1971.

[4]A. K. Samsul Huda, et.al., "Contribution of climatic variables in predicting rice yield," Agricultural Meteorology, 15:71-86, 1975.

important factor affecting yield. However, future refinements of the model may require the inclusion of these factors. Soil type affects mainly the moisture retention capabilities and innate fertility of the soil as they affect the base yields of crops. Thus, its inclusion as a factor in affecting yield is important in making the model more general in its application to other areas.

Crop characteristics

Crop characteristis could be summed up into one factor namely, variety. Varieties differ in their yield potential, drought resistance, maturity periods, and other physiological characteristics. In this study, however, no fine distinctions were made among different varieties of each crop. In the case of rice, only the figures for the local traditional variety (Dagge) which is planted by all Cale farmers were included. For corn, only the figures for the local variety (Tinumbaga or Cale orange flint) were included in the model. For the other crops, namely sorghum, mungbean, cowpea, peanut, soybean and sweet potato, the figures used were averages of several varieties.

Management practices

From the farmer's point of view, the manipulation of yield consists of varying inputs such as labor, fertilizer, choice of variety, and levels of pest and disease control. Since it was not possible to allow for every combination of cultural practices, it was assumed that farmers follow the recommended or customary land preparation practices, seeding rates, timings of fertilizer and other labor input. For example, it is assumed that fertilizer application is done during seeding and panicle initiation. The model does not allow for yield adjustments resulting from applying fertilizer at other times.

In summary, the major factors considered to be important in determining yield in this study are as follows:

1. Rainfall amount and distribution
2. Soil type and texture
3. Fertilizer level
4. Weed control
5. Insect and disease control level
6. Variety of crop

For present purposes, the above factors must be incorporated into the model as a minimum requirement.

The choice of the above variables does not mean that data on them are immediately available. As a matter of fact, considerable problems were encountered in taking into account the effect of each factor on yield. Data availability and problems related to each factor will be discussed in detail later.

6.5 Method for Simulating the Production Component

Figure 6.1 shows a causal flow diagram for simulating the production component. Among the factors considered to affect yield, only rainfall (level and distribution) is non-controllable from the point of view of the farmer. The others, namely fertilizer input, weed control, pest and disease control, and variety of crops are controllable. Thus, the former has to be provided exogenously or model

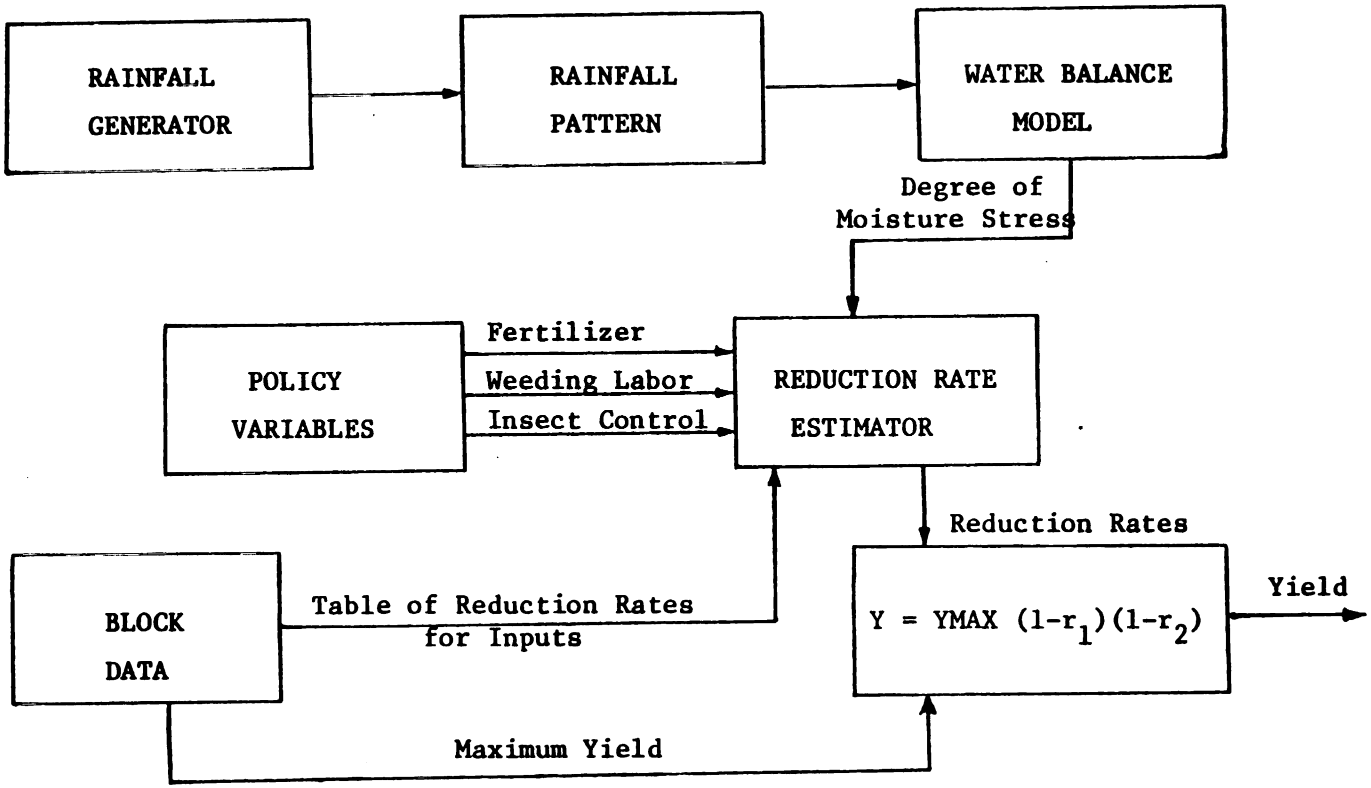

Fig. 6.1. Flow Chart of the Production Component.

generated while the latter have to be specified at the start of simulation as policy variables.

The rainfall generator as discussed in Chapter 5 generates the weekly rainfall pattern of the simulation year. Given the annual rainfall pattern, the planting date of each crop is determined based on certain "rules of thumb" which are discussed below. Given the planting date, the degree of moisture stress is determined for each stage of growth of the crop. Finally, the degree of moisture stress, and the information on the level of other inputs are brought together in a computing routine which, after referring to a given set of relevant parameters, computes the yield of each crop.

The computing routine is flexible in that there is no rigorous set of rules by which the yield is computed given the degree of moisture stress and level of production and management inputs. In this study, two main approaches were tested with the eventual choice of one final approach.

6.6 Approaches in Yield Estimation

Given the level of inputs, how is the relationship between the inputs and the resulting yield specified? There are two main approaches to the problem in the literature: (1) regression equation approach, and (2) reduction rates approach. There two approaches are differentiated below.

Regression equation approach

The regression approach estimates the yield of a crop by relating it with the factors in a single equation:

$$Y = f\cdot(X_1, X_2, \dots X_n)$$

where Y is the estimated yield and X_i, $i = 1,2,\dots,n$, are the levels of inputs. This equation is usually estimated by the statistical technique of multiple regression.

A number of yield prediction studies have employed this approach. However, these studies attempt to relate to yield only a limited number of factors, usually fertilizer and moisture stress.[5] Other important factors such as labor input and insect control are either held constant or left uncontrolled and are relegated to the constant term.

Multiple linear regression analysis was tried in this study using weekly survey data but it yielded very poor results. For example, Tables 6.1 and 6.2 show the results of regression analysis for rice and corn, respectively. Note that most of the coefficient of determination (R^2) are low, some coefficients have the wrong sign, and in most cases the regression coefficients were insignificant at 5 percent level. These unsatisfactory results may be attributed mostly to the poor or inappropriate data used but also to the non-inclusion of other important variables.

Aside from the poor results obtained from the regression analysis on rice and corn, the regression approach was not used in this study because very little or no comparable data were available for the other

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[5]See for example T. H. Wickham, "Predicting yield benefits in lowland rice through a water balance model," in IRRI, Water Management in Philippine Irrigation Systems: Research and Operations, Los Baños, Phils., 1973, pp. 155-181. See also W. L. Parks and J. L. Knetsch, Corn yields as influenced by nitrogen level and drought intensity." Agronomy Journal, 50:363-364, pp. 1958.

Table 6.1. Regression equations for rice, Cale farmers, Tanauan, Batangas, 1973-74 and 1974-75.[a]

Crop year	Equation[b]	R^2
1973-74[c]	YIELD = 122.41 + 0.743 FERT - 0.0002 $FERT^2$ + 0.098* LAB (0.477) (0.0016) (0.033)	0.11
1974-75[d]	YIELD = 76.81 + 0.452 FERT - 0.0020 $FERT^2$ + 0.240 LAB (0.526) (0.004) (0.344)	0.02

*Significant at 5 percent level. Coefficient with no asterik are not significant.

[a]The units used were as follows: yield in cans per hectare (1 can = 14.3 kilograms); fertilizer in kilograms of nitrogen per hectare; and labor in man-hours per hectare.

[b]The figures in parentheses are standard errors of coefficients.

[c]80 observations.

[d]70 observations.

Source of basic data: Cale weekly surveys I and II, IRRI.

Table 6.2. Regression equations for wet and dry seasons corn, Cale farms, Tanauan, Batangas, 1973-74 and 1974-75.[a]

Crop year	Equation[b]	R^2
	Dry season corn	
1973-74	YIELD = 1255.34 - 1.779 FERT + 0.0156 $FERT^2$ + 2.878 LAB (5.56) (0.0125) (1.254)	0.23
1974-75	YIELD = 1993.62 - 6.693 FERT + 0.1018 $FERT^2$ + 1.750 LAB (8.931) (0.027) (2.559)	0.53
	Wet season corn	
1973-74	YIELD = 1045.57 + 14.46 FERT + 0.238* $FERT^2$ - 5.23 LAB (13.25) (0.114) (3.30)	0.93
1974-75	YIELD = 458.16 - 13.96 FERT + 0.937 $FERT^2$ + 6.07 LAB (38.72) (0.591) (3.63)	0.52

*Significant at 5 percent level. Coefficients with no asterisks are not significant.

[a]The units used were: yield in kilogram per hectare; fertilizer is kilograms per hectare; and labor in man-hours per hectare.

Source of basic data: Cale weekly surveys I and II, IRRI.

crops. Regression analysis requires a minimum number of observations, given the number of indèpendent variables, for the coefficients to be estimated.

The advantage of the regression approach are that it combines in single equation the factors affecting yield and that it is easy to compute the coefficients especially with the availability of software packages to carry out the calculations.

Reduction Rates Approach

The "reduction rates" approach suggests the use of potential yield as a starting point. A series of reduction factors are then applied to the potential yield to account for input levels and environmental influences which depart from the optimum. Optimum levels of inputs and environmental influence are here defined as those levels which result in maximum yield. It should not be confused with the economically optimum level which is that level which maximizes net economic returns or profit.

Several studies have used this method of yield adjustment such as those of Longworth,[6] and Denmead and Shaw.[7] The latter two studies, however, differ in character in that the reduction rates were those of the effects of moisture stress on yield during the various physiological stages of crop growth. Gomez[8] also used a

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[6]J. W. Longworth, The Central Tablelands Farm Management Game, unpub. Ph.D. thesis, Univ. of Sydney, 1969.

[7]O. T. Denmead and R. H. Shaw, "The Effects of Soil Moisture Stress at Different Stages of Growth on the Development and Yield of Corn," Agron. J. 52:272-274, 1960.

[8]A. Gomez, "Optimizing Crop Production in Small Farms," (mimeo.), paper presented in a seminar, IRRI, October 2, 1975.

similar yield prediction model in his study for optimizing returns in small farms.

The yield equation may be expressed as

$Y = Y_o\ (1 - r_1)\ (1 - r_2)\ (1 - r_3)\ (1 - r_4)\ \ldots.$ where Y_o is the maximum potential yield and r_1 are yield reduction rates corresponding to various levels of input X_i. Here, the maximum yield is a function of the variety and soil type. That is,

$$Y_o = f\ (\text{variety, soil type})$$

On the other hand, the reduction rate r_1 is a function of the input level X_i. That is,

$$r_1 = g\ (X_i,\ X_o)$$

where X_i is the actual input level while X_o is the optimal input level. If $X_i \neq X_o$ then r_i 0. In other words, if the level of input X is not equal to the optimal level, then there is a reduction in yield hence the reduction rate r_i is positive.

Estimation of Y_o

The potential or maximum yield Y_o may best be obtained from yield trials in experiment stations. Yield trials are usually done under the best crop environment such as complete weed control, high fertilizer levels, irrigation, and maximum insect and pest control. These experiments are usually carried out with several varieties under varying soil conditions and planting dates.

Estimation of yield reduction rates (r_1)

The estimates on yield reduction rates can be obtained from various sources. The main source would be agronomic experiments either in experiment stations or in the field which used sub-optimal input levels. Other important sources of data are economic surveys as well as agronomic experiments done in various locations and seasons. However, when data on reduction in yields due to sub-optimal input levels are not available, a priori quantitative estimates or informed judgements and opinions can be used as substitutes.

Note that the functions f and g do not have to be smooth continuous functions. What may be necessary are several points of the curve. The other points can be approximated by interpolation techniques.[9] Thus, one is not restricted to a particular function, nor is it necessary to fit a specific functional relationship.

The advantage of using reduction rates over the regression approach is that it is easier to account for limiting factors. For example, if it happens that the whole reproductive stage of the crop suffered moisture stress, the resulting yield will be zero regardless of how optimal the other input levels are. This is quite difficult to obtain using multiple regression equations.

In terms of data requirements, both the reduction rates approach and the regression approach require considerable data although the former has an advantage in that rough estimates in yield reduction can be obtained even with scanty data. In contrast, the latter requires a minimum number of observations given the number of independent variables before the regression coefficients could be estimated.

While it is contended that the reduction rates approach is a superior method for the purpose of the study, it is not implied that

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[9]Various interpolation techniques are found in R. W. Llewellyn, "FORDYN -- an industrial dynamics simulation," Dept. of Industrial Engineering, North Carolina State Univ., Raleigh, 1965.

regressions equations are not useful. On the contrary, they play an important role in the determination and verification of reduction rates for the various factors. For example, a good source of reduction rates for various levels of nitrogen fertilizer application would be regression equations fitted on experimental or survey data.

6.7 Relationship Between Rainfall And Yield

In an upland setting, rainfall is the only source of moisture for field crops. Hence, it is considered the most important single factor affecting or limiting yields. When the intake of soil moisture is below that amount from the plant through evapotranspiration, the crop suffers moisture stress. Moisture stress has been recognized by many scientists tc reduce yields of upland crops. The purpose of this section is to examine the relationship between moisture stress and yield and to establish the quantitative relationships between the various degree of moisture stress and extent of yield reduction.

Many studies have been conducted to determine the effects of moisture stress on yield. Some studies consist of subjecting particular crops to moisture stress during various stages of crop growth including combination of stages.[10] Other studies have attempted to fit regression equations on either experimental data or actual farm data with degree of moisture stress (usually measured as drought days or some other drought index) as one of the independent

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[10] S. K. De Datta, T. T. Chang, and S. Yoshida, "Drought Tolerance in upland rice," in IRRI, Major Research in Upland Rice, Los Baños, Phils., pp. 101-116.

variables.[11] These studies all confirm the inverse relationship between degree of moisture stress and yield. An important finding is that moisture stress affects yield differently depending on the stage of crop growth and that the critical growth stage with respect to moisture stress is the reproductive stage. Finally, these studies have shown that there is an interaction between the nitrogen level and moisture stress. That is, under moisture stress conditions, yield decreases as the amount of nitrogen fertilizer applied is increased.

In this study, an attempt was made to derive the quantitative relationships between moisture stress in terms of reduction rates for each crop. Note that as mentioned earlier, there is no set procedure in deriving the reduction rates. Any available information was utilized. An effort was done, however, to express moisture stress in terms of drought weeks since the week is the shortest time period for which the simulation model has been designed. Hence, the main question directed in this section is: what are the reduction rates for various degrees of moistures stress (number of drought weeks) during each stage of crop growth?

The main approach in answering this question was to relate production data at different planting dates with the corresponding weekly series on available soil moisture.[12] Given the planting date

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[11] T. H. Wickham, op. cit.; W. L. Parks and J. L. Knetsh, op.cit.

[12] The method for deriving the available soil moisture and the sources of data are discussed in the following section.

Meaning and measurement of drought weeks

The concept of "drought week" needs clarification. A drought week is here defined as a week wherein potential evapotranspiration is greater than available soil moisture for that week. If this condition happens, it is assumed that the crop is suffering from moisture stress. The determination of available soil moisture (ASM) was done by a simple-soil-water budget approach. The available moisture supply for a given week is the sum of available moisture of the preceding week and the week's rainfall, less the water lost through evapotranspiration and through run-off.

That is,

$$ASM_w = ASM_{w-1} - ET_w + R_w - RO_w$$

where ASM_w is the available soil moisture in week m, ET_w is the evaporation in week w, R_w is the rainfall in week w, and RO_w is the run-off in week w.

The amount of evapotranspiration for each week is a proportion of the average evaporation from a free water surface for that week of the year, i.e.

$$ET_w = c_w E_w$$

where E_w is the average evaporation level.[13] The factor c_w varies with the stage of crop growth and the ASM level at the beginning of each week.[14]

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[13] H. P. Penman, "Natural evaporation from open water, bare soil, and grass," Proc. Royal Soc., 193A:120-145, 1948.

[14] J. C. Flinn, "The simulation of crop-irrigation systems," in J. B. Best and J. R. Anderson (eds.), Systems Analysis in Agricultural Management, John Wiley and Sons, Australasia Pty. Ltd., 1971, pp. 71-84.

The ASM level is next augmented by the amount of rainfall during the current week but with a limit of 102 millimeters.[15] Any additional rainfall is ass-med to be lost through run-off or deep percolation and is included in RO_w. The water balance model is thus of the "threshold" or "bucket" type; the soil bucket holds all the water until the brim is reached and all additional water spills out.

The use of the soil-bucket approach is superior to that of merely counting the number of weeks wherein rainfall is less than an arbitrary level because it takes into account the carry-over moisture from the previous week.

Sources of data

Data on pan evaporation are available at the Ambulong Weather Station. For some crops, the data on c_w were obtained from published sources.[16] For crops in which c_w were not available from published sources, data for similar crops[17] were substituted.

The rainfall data used in deriving the quantitative relationships between yield and moisture stress were taken from the daily rainfall measurements in Cale, Tanauan, Batangas from 1973 to 1975. In the simulation runs, weekly rainfall was generated within the model using the relationships synthesized from Ambulong, Tanauan, Batangas from 1948 to 1975.

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[15]This figure was adopted from S. Harrison, op.cit., Ch. 8.

[16]J. C. Flinn, op.cit. and T. H. Wickham, ibid.

[17]For example, data for corn were substituted for sorghum which data for mungbean were substituted for other legumes.

and the weekly data on available soil moisture, the number of drought weeks were noted for each crop growth stage, namely the vegetative, reproductive and maturation stages. Finally, conclusions were drawn on the effects of various degrees of drought during each crop growth stage on yield.

The major source of production data which were considered reliable came from field experiments since other input levels are usually held fixed and at optimum levels. With sufficient data, regression equations and simple averages provided the bases for estimating the reduction rates. However, experimental data were not sufficient for all crops so economic survey data were also used. The limitation of survey data is that the effect of moisture stress on yield could not be easily singled out since the crops have been subjected to different levels of inputs. Fortunately, the number of observations per planting week is large enough so that by the process of averaging it was assumed that variations in yield due to different levels of input cancel out. Regression equations and simple averages were also the bases for computing the reduction rates.

Finally, if no production data were available for a particular crop either informed opinions and guesses by agronomists were used or the figures of a crop were substituted to a similar crop.

Tables 6.3, 6.4 and 6.5 show the reduction rates in yield due to various degrees of moisture stress for the three general stages of crop growth of each crop. These figures were entered into the computer simulation program as data.

Table 6.3. Yield reduction rates for different levels of moisture stress in drought weeks during the vegetative stage of various crops (in percent).

Crop	Number of weeks	Number of drought weeks[a]									
		0	1	2	3	4	5	6	7	8	9
Rice	11	0	0	1	3	5	10	15	20	50	100
Corn	7	0	0	1	3	6	10	20	50	100	100
Sorghum	9	0	0	1	3	6	10	15	20	50	100
Mungbean	5	0	0	2	3	4	20	100	100	100	100
Cowpea	5	0	0	2	3	4	20	100	100	100	100
Peanut	7	0	0	2	3	5	10	50	100	100	100
Soybean	5	0	0	2	3	6	8	100	100	100	100
Sweet potato	11	0	0	1	2	3	5	10	15	50	70

[a] Drought week is defined as a week wherein available soil moisture is less than 0.5 inch.

Source of basic data: Experimental and survey data (see text).

Table 6.4. Yield reduction rates for different levels of moisture stress in drought weeks during the reproductive stage of various crops (in percent).

Crops	Number of weeks	Number of drought weeks[a] 0	1	2	3	4
Rice	2	0	3	7	20	100
Corn	3	0	3	7	20	100
Sorghum	3	0	3	7	20	100
Mungbean	3	0	3	7	10	100
Cowpea	3	0	3	7	10	100
Peanut	3	0	3	7	10	100
Soybean	3	0	3	7	10	100
Sweet potato	2	0	3	7	10	100

[a]Drought week is defined as a week wherein available soil moisture is less than .5 of an inch.

Sources of basic data: Experimental and survey data (see text).

Table 6.5. Yield reduction rates for different levels of moisture stress in drought weeks during the maturation stage of various crops (in percent).

Crop	Number of weeks	Number of drought weeks[a] 0	1	2	3	4
Rice	5	0	2	5	10	15
Corn	3	0	2	5	10	10
Sorghum	3	0	2	5	10	10
Mungbean	3	0	1	3	7	10
Cowpea	3	0	1	3	7	10
Peanut	4	0	1	3	7	10
Soybean	4	0	1	3	7	10
Sweet potato	5	0	1	2	4	8

[a]Drought week is defined as a week wherein available soil moisture is less than 0.5 inch.

Source of basic data: Experimental and survey data (see text).

6.8 Relationship Between Fertilizer Input And Yield

Fertilizer input, especially nitrogenous fertilizer, is one of the most important management inputs. When rainfall is not limiting, studies have shown that nitrogen tends to be the major limiting factor that limit yields in upland areas.[18]

The main approach in obtaining the yield reduction rates for various levels of fertilizer was first to fit a yield response function to nitrogen of the form

$$Y = a + bN + cN^2$$

where Y is the yield, N is the level of nitrogen application, and a, b and c are constants. It was deemed appropriate to use experimental data since other factors are usually held fixed and usually at optimal levels. However, when no experimental data were available for other crops, survey data were used. Table 6.6 shows the yield response function to nitrogen for each crop. Based on these response functions, the reduction rates were computed and these are shown in Table 6.7. In the simulation program, the reduction rates were supplied as parameters to the model.

6.9 Relationship Between Weeding Input And Yield

The weeding operation can taken on many forms. It can be accomplished by hand, by animal drawn implements, or by the use of weedicides. Some operations such as plowing and harrowing can remove a major proportion of weeds while the soil is tilled. Hence, the term "weeding" must be clarified.

Table 6.6. Summary of regressions on yield vs. nitrogen input, Cale, Tanauan, Batangas, 1974.[a]

Crop	Coefficients[b]			R^2
	a	b	c	
Rice[c]	1498.16	24.82	.0417	0.54*
Corn	548.09	21 25	-.0648	.68**
Sorghum	1187.96	24.34	.0638	.37**
Mungbean	466.61	5.03	-.0728	.01[ns]
Cowpea[d]	466.61	5.03	-.0728	-
Peanut	788.47	0.36	.0260	.19[ns]
Soybean	780.73	1.76	.0000	.58[ns]
Sweet potato	2980.20	93.13	-.4578	.21**

*Significant at 5 percent level.

**Significant at 1 percent level.

ns - not significant.

[a]Yield is expressed in kilogram per hectare and fertilizer in kilogram of nitrogen per hectare.

[b]The regression equations are of the form.

$$YIELD = a + bN + cN^2$$

where N is the nitrogen level.

[c]Based on 1973-74 Cale weekly survey data.

[d]The coefficients for mungbean were used for cowpea

Source of basic data: Dennis Garrity's experimental data in Batangas, 1974, Multiple Cropping Project, IRRI.

Table 6.7. Yield reduction rates for different levels of fertilizer, various crops (in percent).

Crop	Fertilizer input (kg. nitrogen/hectare)							
	0	20	40	60	80	100	120	140
Rice	50	35	22	12	5	2	0	2
Corn	50	35	22	12	5	2	0	2
Sorghum	50	35	22	12	5	0	0	2
Mungbean	30	20	10	2	0	0	2	10
Cowpea	30	20	10	2	0	0	2	10
Peanut	40	30	20	10	5	0	0	0
Soybean	30	20	10	2	0	0	2	10
Sweet potato	40	30	20	10	5	0	0	0

Source of data: Table 6.6.

In this study, the weeding operation is defined as that operation devoted solely to the elimination of weeds such as hand weeding or weeding which employs some hard tools. This implies that the labor used in land preparation operations such as plowing and harrowing as well as post-planting cultivation such as hilling-up and off-barring are not considered as weeding input. While these operations are also important forms of weed control, it was assumed in the model that their levels are equal among farmers, hence they do not affect yield. The model does not allow for yield changes resulting from different methods of land preparation and post-planting cultivation.

The main approach in determining the reduction rates for weeding input was to estimate them from experiments using the same input levels and environment except weeding labor and from regression equations in which weeding labor has been included as an independent variable. Table 6.8 shows the reduction rates for different levels of weeding labor.

6.10 Relationship Between Insect And Disease Control Level And Yield

Insect pests and diseases are other influences that may affect the yield of a crop. Therefore, its inclusion into the model can add to its realism and usefulness. There are, however, some problems that make it necessary to keep this aspect as simple as possible. First, there are a great number of insecticides in the market. Unlike fertilizers, which may be converted into a common unit such as kilograms nitrogen, insecticides are of extremely varied formulations and chemical composition. The problem is to find a common denominator for

Table 6.8. Yield reduction rates for different levels of weeding labor, various crops (in percent).

Crop	Weeding labor (man-hours/hectare)					
	0	20	40	60	80	100
Rice	20	15	10	5	2	0
Corn	20	15	10	5	2	0
Sorghum	20	15	10	5	2	0
Mungbean	20	15	10	5	2	0
Cowpea	20	15	10	5	2	0
Peanut	20	15	10	5	2	0
Soybean	20	15	10	5	2	0
Sweet potato	30	20	15	10	5	0

Source of basic data: Experimental and survey data (see text).

various insecticides. One way of overcoming this problem is to express insecticide levels in monetary units. However, the limitation is that a peso of one chemical may not have the same effect on insect pest control as a peso of another chemical.

Secondly, farmers typically apply insecticides only when insect damage is evident. There is also a great number of possible insects and diseases that may attack a crop. For the purpose of yield prediction, it would be ideal to predict first the degree of infestation of each insect or disease as affected by external and internal influences. The farmers may then react to the predicted infestation with the necessary control measures. This entails a detailed plant-insect-environment modeling which in itself is a very complicated matter.

Because of the above problems, some simplifying assumptions had to be made in estimating the yield reduction rates for different levels of insect and pest control. It was assumed that only certain types of insect or disease attack a crop and only certain types of insecticide controls them. The types of pests selected were the most common pests attacking the crop. The insecticides used as basis for the reduction rates were the most effective insecticides controlling the pests. Table 6.9 shows the most common pests and the most effective insecticides used for each crop.

Given the common pests and diseases and insecticides, the reduction rates were based from experiments, from observations and from qualitative opinions of agronomists and entomologists. There are shown in Table 6.10. It must be borne in mind that the reduction rates

Table 6.9. Most common pests and recommended chemical control by crop.

Crop	Pest	Chemical control
Palay	Rice borer, leafhopper	Furadan, Basudin
Corn	Earworm, corn borer	Furadan Azodrin
Sorghum	Earworm, borers	Furadan, Azodrin
Mungbean	Cutworm, pod borer	Furadan, Azodrin
Cowpea	Cutworm, pod borer	Furadan, Azodrin
Soybean	Cutworm, pod borer	Furadan, Azodrin
Peanut	Cutworm, pod borer	Furadan, Azodrin
Sweet potato	Cutworm	Furadan, Azodrin

Table 6.10. Yield reduction rates for different levels of insect control, various crops, in percent.

Crop	Insect control level (in ₱/ha)							
	0	100	200	300	400	500	600	700
Rice	10	5	4	3	2	1	0	0
Corn	15	7	6	5	4	3	2	0
Sorghum	15	5	4	3	2	1	0	0
Mungbean	20	8	6	5	4	3	2	1
Cowpea	20	8	6	5	4	3	2	1
Peanut	20	8	6	5	4	3	2	1
Soybean	20	8	6	5	4	3	2	1
Sweet potato	10	3	2	1	0	0	0	0

are artificial and may be unrealistic owing to the strong simplifying assumptions. However, it was felt that the use of the reduction rates is an improvement over the alternative of ignoring the effect of insect control on yield completely.

6.11 Computer Implementation of the Production Component

In the computerized version of the production component, the potential yields of each crop as well as the reduction rates are provided exogenously to the model. Table 6.11 shows some of the crop data entered into the BLOCK DATA subprogram.

The fertilizer levels, weeding labor levels, and the levels of pest and disease control for each crop planted are specified at the start of the simulation run. The rainfall pattern is determined within the model through the rainfall generator. Planting dates are specified before the simulation run but are subject to change depending on the generated rainfall pattern. The rule is that land preparation could not start unless a strong rain (at least 0.5 inch) has fallen and that planting could not be done unless there has been sufficient rainfall characteristics (number of drought weeks) are counted for each stage of crop growth throughout the growing season. Once these have been determined, the applicable reduction rates for each factor are determined by means of lack-up functions. Finally, the reduction rates and potential yield are fed into the yield formula. The computed yields of each crop are then passed to other sub-routines.

Table 6.11 Various crop data used in the cropping sytems simulation model.

Crop	Crop Maturity Periods (weeks)	Number of Weeks in Stage: Vege-tative	Repro-ductive	Maturation	Potential Yield (ton/ha)
Rice	18	11	2	5	4.0
Corn	13	7	3	3	4.0
Sorghum	15	9	3	3	4.5
Mungbean	11	5	3	3	1.5
Cowpea	12	5	3	3	2.0
Peanut	14	7	3	4	3.0
Soybean	13	5	3	5	2.5
S. Potato	18	11	2	5	18.0

Source: IRRI, Multiple Cropping Project, Economics Section

6.12 Validation of the Model

The purpose of validating a model is to compare the results of the model with the real world performance. If the simulation results are significantly different from actual figures then some adjustment should be done with the simulation model to make it more realistic and hence acceptable.

The validation of the model was done mainly by plugging actual data on rainfall, fertilizer levels, weeding and pest control inputs and other data into the simulation model and comparing the simulated yield with actual yield. The final reduction rates used in the model already reflect the adjustments that have been made after several validation runs. Table 6.12 shows the comparison between simulation results and actual data. Although the results are different, the simulated results appear reasonable and therefore the production component was considered an adequate representation of the real-world production relationships.

6.13 Summary

This chapter discussed the production component of the simulation model with emphasis on the various factors affecting crop yield. Because of the complexity of the production processes, only key variables were included. The main considerations is the choice of variables included in the model were: (1) the degree of importance of the variable in explaining yield, (2) the feasibility of including the variable into the model gives the time, resources and capabilities of the model builder, (3) the level of realism required in the study, and (4) the availability of data. On the basis of the above conside-

Table 6.12 Comparison between actual and simulated yields based on actual rainfall and input levels, 1973-1974[a]

CROP	Plant Week[b]	Number of Dry Weeks[c]			Fertilizer (kg.N/ha)	Weeding (M-H/ha)	Insecticide (₱/ha)	Yield (t/ha)	
		Veg.	Rep.	Mat.				Actual	Simulated[d]
Rice	23	3	1	0	51	188	0	2.85	2.81
Corn	45	0	2	3	30	28	0	1.87	1.78
Sorghum	47	2	3	3	30	120	100	2.74	2.29
Mungbean	47	1	2	3	40	42	0	0.52	0.84
Cowpea	45	1	1	3	40	45	0	1.00	1.33
Peanut	45	1	2	3	30	115	100	0.96	1.79
Soybean	47	2	3	3	10	53	50	1.06	1.23
S. Potato	45	4	2	4	40	45	50	7.82	9.89

[a] For rice and corn, the data are from the Cale Weekly I Surveys (1973). The figures for the other crops are based on the data obtained by D. Garrity from his controlled experiments on actual farms in Cale in 1974.

[b] Although other planting dates were observed, these dates are the modal values.

[c] A dry week is one with less than 0.5 inch of soil moisture.

[d] Obtained by plugging actual values into the simulation model.

rations, the major factors considered were rainfall level and distribution, soil type and texture, fertilizer level, weed conbrol, insect disease control level, and crop variety.

Two approaches of yield estimation were contrasted: the regression approach and the reduction rates approach. It was concluded that the reduction rates approach was more appropriate for the study.

The relationship between yield and rainfall, fertilizer, weed control, and insect and disease control were also discussed and the estimation of their corresponding yield reduction rates described. Finally, the computer implementation and the validation aspects of the production component were also described.

CHAPTER 7

PRICE GENERATOR

7.1 Introduction

The purpose of the price generator is to provide an appropriate price of each crop at any given week of the year. The basic assumption is that the production of an individual farm is such a small part of the total market that it cannot influence market prices. This assumption of a perfectly elastic supply is reasonable in the Cale environment since farm sizes are relatively small. Moreover, the main market in Tanauan is supplied by a large number of small farmers from several barrios. The implication of this assumption is that Cale farmers are price takers; therefore, it is sufficient to deal only with the total market in the determination of prices at any given time. The prevailing prices at a particular time in Tanauan are also assumed to apply in Cale, the area of study.

One approach to price determination would be the estimation of supply and demand functions of the market for each time period. This approach, however, was considered impractical for the purposes of the study. The dynamic nature of supply and demand functions necessarily makes the task very complicated requiring vast amounts of information. Hence, a relatively simple method of providing reasonable estimates of prices for each period was devised.

The main approach in determining prices in this study was to use base prices and seasonal price indexes. The base price is the expected annual average price while the seasonal price indexes show the fluctuations in price over the year. In this approach, it is the average price fluctuations in the past are assumed to persist to the present and future periods.

7.2 Seasonal Price Indexes

The procedure is computing the seasonal price indexes used are well explained in many economics statistics textbooks.[1] It is based on the premise that seasonal fluctuations can be measured from an original series (O) and separated from trend (T), cyclical (C) and irregular (I) fluctuations. The seasonal component (S) is defined as the intra-year pattern of variation which is repeated constantly from year to year. The assumption adopted in this study that the seasonal, trend, cyclical, and irregular components are related in a multiplicative fashion. That is,

$$O = T \times S \times C \times I.$$

The method of obtaining the seasonal indexes used is the ratio-to-moving average method. It is assumed that the seasonal variation (S) has a 12-month period and that the shape of the variation is the same each year. It is also assumed that the irregular variations (I) are independent for different periods (years). Briefly, the computational process are as follows:

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[1]See for example Taro Yamane, Statistics: An Introductory Analysis, Harper and Row; New York, 1964, Ch. 13.

The basic approach is estimating the price at any given week is to adjust the base price, which the expected annual average price, by the seasonal index applicable to that week. Since monthly price indexes are provided to the model, the price index during the given week was estimated by linear interpolation, assuming that the change in seasonal indexes from month to month is linear. In the model, this is achieved by means of a look up function (TABLI).

As options, the prices can either be randomly or non-randomly generated. The normal distribution was assumed for random price determination. The mean is represented by the base prices (BP) multiplied by the estimated seasonal price index of the week. Standard deviation of prices for each month were computed from the series on irregular variations. These could be obtained from the output of the X-11 variant of the Census Method II seasonal adjustment program. It was further assumed that the standard deviation of prices in a particular week is equal to the standard deviation of prices during the month the week falls on.

The random component is obtained by generating a random number between 0 and 1. This is achieved by a built-in computer function in digital computers (RANF in CDC series and RANDU in IBM series). Then the normal standard deviate Z corresponding to the random number is determined by a function FNL.

The estimated price is thus obtained by the following formula:

$$P = BP \times SI + Z\sigma$$

1. Compute a 12-month moving average of the original series.[2] This process smooths out the S x I from the original series so the moving average is T x C.

2. Divide the original series by the 12-month moving average S x I. That is

$$\frac{\text{Original date}}{\text{Moving average}} = \frac{T \times S \times C \times I}{T \times S} = S \times I$$

3. Compute the monthly averages of the ratios-to-moving average (S x I) to remove the irregular fluctuations (I). The results are the seasonal indexes (S).

Computing seasonal indexes on a desk calculator is a tedious and time consuming process. Fortunately, the procedures are easily programmed in a digital computer which allows the accurate computation of seasonal indexes for a large number of crops in a very short period of time. Moreover, some software packages have been developed recently to compute seasonal indexes and other time series analyses on prices. The particular software package used in this study is the X-11 variant of the Census Method II seasonal adjustment program.[3] Aside from doing the three steps above, it does many other types of analyses. One of the useful features used in this study is the test for stable seasonality which is an F-statistics indicating whether it is reasonable to assume a regular seasonal pattern.

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[2]The process involves the following steps: (1) take the 12-month moving totals of the original series; (2) divide by 12 to obtain the uncentered 12-month moving average; (3) "center" by taking the 2-month moving averages of the results of step 2.

[3]U. S. Bureau of Census. The X-11 variant of the Census Method II Seasonal Adjustment Program, Technical Paper No. 15 (1967 revision) U.S. Government Printing Office, Washington, D.C. 1967.

Source of data

The primary source of data on crop prices was the Central Bank of the Philippines. Prices of various crops are available on a weekly basis from as early as 1948 to date for selected trading centers in the Philippines of which Tanauan, Batangas is one. For certain crops in which data were not available from the Central Bank, the prices were obtained from the Bureau of Agricultural Economics, the Bureau of Commerce, and other agencies. In cases where data were not available for the Tanauan market, price data for Manila markets were substituted. Finally, when no time series data were available for a crop (such as soybeans and sorghum), the seasonal price indexes of related crops were used as proxy.

Table 7.1 shows the base prices and the monthly price indexes for each crop used in the study.

7.3 Generating Prices

As stated earlier, the main function of the price generator is to provide the prevailing price of a crop in any given week. Thus, two items are specified in the sub-compcnent: the week is question and the crop involved. The output of the sub-component is the price of the crop estimated to prevail at the particular week. In this study, the price of the crop is determined during the harvest week since no storage facilities are assumed. The week during which the crop is harvested is determined in the model on the basis of the planting date and the number of weeks the crop matures.

Table 7.1. Base prices and monthly price indexes of various crops, Batangas, Philippines.

Crop	Base price (₱/kg)	Price Index[a]											
		J	F	M	A	M	J	J	A	S	O	N	D
Rice	1.20	101	96	96	96	97	97	99	102	109	104	102	101
Corn	1.10	103	100	97	100	103	107	104	95	95	96	99	101
Sorghum	1.10	103	100	97	100	103	107	104	95	95	96	99	101
Mungbean	4.90	108	105	97	96	95	95	97	99	100	102	102	104
Cowpea	4.90	108	105	97	96	95	95	97	99	100	102	102	104
Peanut	3.20	103	102	100	98	96	96	98	99	100	102	102	103
Soybean	2.90	97	98	99	101	101	102	103	102	100	101	98	98
S. potato	1.02	99	91	95	95	96	99	102	106	104	109	100	104

[a]In percent.

Source: IRRI, Multiple Cropping Project, Economics Section.

where P is the estimated price during the given week, BP is the base price, SI is the seasonal index, Z is the standard normal variable, and σ is the standard deviation.

Under the non-random option, the expected price is simply equated to the base price multiplied by the seasonal index.

In the model, base prices are also allowed to vary as an option to allow for changes from year to year. If allowed to vary, two choices are available: linear or logarithmic trend. These two methods of price adjustments were supplied because it was found out that annual prices of crops included in the study showed either linear or exponential trends. Thus, associated to a crop is a code which either corresponds to a linear or exponential change.

Linear adjustments in base prices are given by:

$$BP_t = BP_o + rx$$

where BP_t = new based price at year t, BP_o is the original base price, r is the average annual increase or decrease in price obtained by least-square regression methods, x is the number of years between year t and year 0.

Exponential change is computed by:

$$BP_t = BP_\sigma (1 + r)^x$$

where BP_t is the new base price at year t, BP_σ is the original base price, r is the average rate of change in price, and x is the number of years between year t and year o.

Table 7.2 shows the annual rates of change of prices for each crop and the corresponding shape of the trend line. The appropriate functional forms were determined by comparing the coefficients of

Table 7.2. Annual rates of change in price and the form of trend lines by crop, Cale, Tanauan, Batangas, 1956-1975.

Crop	Rate of change	Shape of trend line[a]
Rice	1.10	2
Corn	1.10	2
Sorghum	1.10	2
Mungbean	1.11	2
Cowpea	1.11	2
Peanut	1.12	2
Soybean	1.06	2
Sweet potato	1.10	2

[a]1 = linear, 2 = exponential

Source of basic data: Central Bank of the Philippines, Bureau of Agricultural Economics, Bureau of Commerce.

determination obtained by least-square regression method between linear and exponential trend lines.

7.4 Summary

This chapter described the method of generating prices for use in the model. The main approach is to adjust the base price by means of seasonal indexes. Two options are available in the price determination algorithm: random and non-random. Base prices are also allowed to vary either in a linear or in an exponential fashion.

CHAPTER 8

LABOR UTILIZATION COMPONENT

8.1 Introduction

The purpose of the labor component is to determine labor utilization by operation and time distribution of labor use of each planted crop. It also determines the total weekly labor use for the whole cropping pattern, compares it with weekly available family labor, and computes the amount of labor hired each week.

The labor component interacts primarily with the policy variables and the production component. The area planted determines the amount of labor required for land preparation, seeding, and other post-planting operations based on per-hectare labor requirements. The amount of fertilizer, weeding input, and insect and disease control applied to a crop also affect labor use. Finally, harvest and post-harvest labor are determined by the level of production. This implies that no labor is done when output is zero and that more labor is required with higher levels of output.

8.2 The Labor Utilization Component Sub-Model

As stated earlier, the labor component computes the following: (1) labor utilization by operation of each planted crop; (2) time distribution by week of total labor used of each crop; (3) total labor utilization by week of all crops; and (4) total labor hired by week. The computation of these items relies to a large extent on exogenous information which are provided as data to the model. These include (1) labor requirements per hectare distributed by work and by operation for each crop,[1] (2) harvest and post-harvest labor requirements per unit of output; (3) labor requirements per unit of fertilizer applied; and (4) family labor availability for each week of the year.

Labor use by operation and labor use by time are determined through the use of the time by operation labor (TXOL) matrices (see Appendix I). Before the totals by operations and by time are taken, however, the matrices are modified to allow for actual input usage and yield levels. Given fertilizer input, weeding labor input, and insect and disease control levels, labor use on fertilizing, weeding, and spraying are determined through fixed coefficients which are supplied as data.[2] Harvest and post-harvest labor are determined through their respective labor requirement per unit of outputs which are also supplied as data. Harvesting is not usually accomplished in one week so total harvest labor must be allocated to each week of the harvest period. In this study, the harvest period was assumed to last for two weeks so that harvest labor was allocated into two equal parts in the TXOL matrix.

Let l_{ijt} be an element of the time by operation labor (TXOL) matrix where l is the labor requirement for the jth operation (j=1,

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[1]Twelve operations were distinguished in the model. The operations are plowing, harrowing, other land preparation, furrowing, planting, off-barring, fertilizing, weeding, spraying, other care, harvesting, and post-harvest operations.

[2]In the case of weeding, however, the weeding labor input is simply carried to the relevant matrix element.

2,....,12), at time t (t=1, 2,....,24)[3] of crop i (i=1, 2,....,8). Then, the labor use on operation j of crop i is given by

$$RLOP_{ij} = \sum_{t=1}^{24} l_{ijt} \times A_i$$

where A_i is the area of crop i. Total labor use at time t of crop i is obtained by adding the labor requirements of each operation at time t. That is,

$$TLB_{it} = \sum_{j=1}^{12} l_{ijt} \times A_i$$

The above calculations refer only to the relative timing of operations from the week of land preparation to the week of harvesting where t=5 is the planting period. The index t does not refer to any specific week of the year. To obtain a picture of the farm labor utilization for the whole year, the total labor use of crop i at time t or TLB_{it} is assigned to the corresponding week n based on the planting date specified.[4] Let

$$TLBY_{in} = TLB_{it}$$

where $TLBY_{in}$ is the total labor use of crop i at week n, n=1, 2,..., 52. Then the total labor utilization of the farm during a given week is computed as the labor used by each crop during that week. That is,

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[3]Since the planting operation is done at t=6, n is related to the planting date PD and t as follows: n = PD + t - 5.

[4]In simulation runs where planting date is allowed to vary according to the rainfall pattern, the specified planting may not be the actual planting date.

$$TLABn = \sum_{i=1}^{8} TLBY_{in}$$

where $TLAB_n$ is the total labor utilization at week n.

The amount of labor hired during each week was determined on the basis of total labor requirements and available family labor. Labor is hired if total labor requirements for a given week is greater than available family labor. There are some instances, however, wherein labor is hired even if the above condition is not met. This is so in the case of planting and harvesting, provided that the area planted is greater than three-tenths of a hectare and that total production is greater than 500 kilograms. This provision is in conformity with the observation that Batangas farmers usually hire labor for planting and harvesting, presumably so that the farmer can attend to supervisory activities.

8.3 Sources of Data

Available family labor

Available family labor is based on the assumption that a farm family is composed of the farmer available for work full time, his wife available one-third man-equivalent and two children available one-half man-equivalent each or a total of 2.3 man-equivalents. It was assumed that on the average, a man-equivalent is available for work eight hours a day and six days a week. Therefore, the available family labor of 2.3 man-equivalents is about 110 man-hours per week.[5]

[5] Some downward adjustments may be necessary for certain weeks of the year such as those period when children are in school and during special events such as village feast and the Christmas season.

Labor requirements

Table 8.1 shows the labor requirements by operation for each crop. These figures were obtained from the Cale weekly surveys and from economic data gathered from agronomic experiments. The general procedure was to add up the amount of time spent on each operation by each farm and the area of the farm. The average labor requirement for an operation is then obtained by dividing total time spent on each operation by the total area.

There were several problems encountered in the process of tabulation. One was that in some farms, the data for an operation were either missing or no such operation was done. In this case, the procedure was simply to ignore those farms in which no data were available. Another problem was that for some crops, very few observations were available because very few farmers planted those crops. Here, instead of using the Cale survey data, other sources were used. The most important source of these was the economic data which were collected for agronomic experiments. In some cases, labor requirement from other similar crops (e.g. legumes) were used as substitute data as long as the same type of operation was concerned. Finally, there were some figures which did not seem reasonable, that is, either very large large or small were compared to the average. In this case, they were not included in the calculations.

Labor use by time

The time distribution of total labor utilization by crop and by operation were also tabulated. These data were the bases for the construction of the time by operation labor matrix which was mentioned

Table 8.1. Labor requirements by operation by crops, Cale, Tanauan, Batangas (in man-hours/hectare).

Operation	Rice	Corn	Mung	Cowpea	Sorghum	Peanut	Bean	Sweet potato
Plowing	69.4	35.1	52.0	52.0	61.0	34.7	39.1	52.0
Harrowing	37.7	13.0	26.8	32.0	18.0	9.4	22.2	32.0
Other land preparation	35.8	27.0	1.6	8.0	12.0	5.0	10.0	10.8
Furrowing	14.9	18.1	14.4	13.0	29.0	12.8	13.0	26.5
Seeding/planting	14.5	44.4	43.2	54.0	45.0	50.0	47.0	90.3
Off-barring	35.7	14.9	23.2	20.0	35.0	25.6	35.2	80.0
Fertilizing	5.7	28.4	28.8	24.0	34.0	80.8	67.2	24.5
Weeding	188.2	12.9	19.2	25.0	85.0	90.0	17.9	20.0
Spraying	16.0	-	10.8	-	-	-	-	-
Other care	-	-	-	21.0	27.0	21.0	-	21.5
Harvesting	256.0	34.9	384.0	204.0	188.0	200.0	168.0	204.0
Threshing/husking	29.2	78.0	108.0	102.0	68.0	100.0	55.2	-
Total	703.1	306.7	712.0	555.0	594.0	730.3	488.0	561.6

Source: Calculated from Cale Weekly Surveys I and II.

earlier. Table 8.2 shows the average labor requirements per hectare is in Cale, tabulated by week from planting day of each crop. It should be noted that these figures are average figures. In simulation runs, the resulting labor utilization may be different depending on the level of inputs specified and the level of simulated physical output.

Fortunately, Cale data are done on the daily basis so the construction of the labor by time matrix was relatively easy. It was noted, however, that farmers differ greatly in their timing of operations. Here, it was impractical to take average labor use by time period since it would result in figures which are inconsistent with total labor requirements.

The alternative was to take a sample of farmers (all farmers if number of observations was less than 15) and record the (1) frequency and (2) timing of each operation relative to planting date. From the sample data, the averages or model values of frequency and timing of operations were determined. A labor by time matrix was then constructed for each crop by distributing the labor requirements for an operation to each time an operation is performed. Some operations require more labor the first time it is done such as plowing and harrowing. On the other hand, some operations require less labor the first time it is done compared to the second or third time such as spraying. In these cases, labor requirement was distributed accordingly. In other cases, labor was simply divided equally among the number of times the operation was done.

Table 8.2. Labor requirements for each week from planting week by crop (man-hours/hectare).[a, b]

Week	Rice	Corn	Mung	Cowpea	Sorghum	Peanut	Soybean	Sweet potato
1	32.0							
2	25.0	29.9	-	-	-	-	-	26.0
3	25.0	18.2	26.0	26.0	30.5	20.4	25.0	42.0
4	24.2	27.0	39.4	42.0	39.5	19.0	34.1	16.0
5	32.8	18.1	15.0	24.0	21.0	9.7	27.2	10.8
6[c]	19.2	44.4	57.6	67.0	91.0	71.8	60.0	125.0
7	-	-	11.6	19.0	17.0	45.4	102.4	7.5
8	4.7	14.2	11.6	22.5	9.0	45.0	-	40.0
9	27.5	-	28.8	19.0	29.0	16.6	8.9	7.0
10	16.4	14.2	15.0		17.0	48.4		7.0
11	23.6	6.5	9.6	10.0	17.0	45.0	9.0	56.3
12	20.5	14.9	5.4	7.0	29.0	9.0		10.0
13	32.1	6.4	0.0	12.5	9.0			10.0
14	25.9		128.0					
15	24.2		164.0		29.0			
16	20.2		164.0	68.0			84.0	
17	20.2		36.0	102.0			111.6	
18	24.2			102.0		150.0	27.6	
19	20.2	17.5		34.0		150.0		
20	56.4				94.0	100.0		
21	39.0				128.0			
22	128.0				34.0			102.0
23	142.6							102.0
24	14.6							
	703.1	306.7	712.0	555.0	594.0	730.3	489.8	561.6

[a] Missing values denote zero labor utilization.

[b] The figures in the table reflect the average labor utilization of Batangas farmers. In the simulation, the labor utilization may differ depending on the input levels specified and the resulting level of physical output. Missing values denote zero labor utilization.

[c] Planting week.

Source: Calculated from Cale Weekly Surveys I and II.

There were some crops for which no farm data were available as to timing of operations. The only recourse was to base the distribution of labor use on recommended cultural practices. For example, if the recommended practice is to apply fertilizer one-third at planting and two-thirds at 45 days after seeding, then one-third of the fertilization labor is allocated at planting and two-thirds is allocated at 45 days after seeding.

Wage rates

The assumed wage rate for hired labor was ₱6.00 per day or about 75 centavos an hour. It was noted that harvesting and threshing labor were usually paid in kind at an average rate of one-seventh of total production. That fact has been built-in into the simulation model to automatically compute for the harvest and threshing labor cost.

There are several issues with respect to wage rate that remain unanswered. One is the fact that wage rates for various type of operations have different wage rates. For example, plowing commands a higher wage rate than weeding. Another particularly important point which has as yet been ignored in the simulation model is the role of livestock (draft animals). A farmer's own draft animal is of course limited in capacity thus affecting the area that can hire men with animal power, a limit or the amount of operating capital restricts the amount of hired animal power that can be hired.

8.4 Summary

This chapter discussed the assumptions, the computational aspects and the sources of data of the labor component. This component was designed to compute (1) labor utilization by operation of each planted crop; (2) time distribution by week of total labor used of each crop; (3) total labor utilization by week of all crops; and (4) total labor hired by week.

CHAPTER 9

THE COMPUTER SIMULATION MODEL

9.1 Introduction

The purpose of this chapter is to provide a detailed description of the cropping systems simulation model. It describes the structure, the features, and the available options of the model. In addition, it describes the deck set-up required for running the model. It is felt that an understanding of how the model works is a prerequisite for the revision and the improvement of the model. Moreover, the potential user of the model will find the description of the various options and the program deck set-up in running a given job useful.

9.2 Structure of Computer Simulation Model

The computer simulation model was written in FORTRAN computer language. The complete source listing of the program is found in Appendix II. The choice of FORTRAN as opposed to other languages[1] was mainly influenced by the programming skills of the author. Although software packages were avilable for DYNAMO, GPSS, and GASP in the computer installation used, their use was not considered

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[1]For a discussion of various computer languages suitable for simulation purposes, see Charlton, P.J., "Computer Languages for system simulation" in Dent & Anderson (eds.), System Analysis in Agricultural Management, John Wiley and Sons, Australasia Pty. Ltd: Sydney, 1971, pp. 53-70. General purpose languages such as FORTRAN, ALGOL, AND PL/1) and special purpose languages such as CMPS, DYNAMO, GPSS, and SIMSCRIPT are described and compared.

practical for the purpose at hand. It was felt that FORTRAN was adequate because of its universality in its usage and its flexibility in dealing with a number of discrete phenomena which are characteristic in this study.

The computer model is composed of an executive routine (MAIN program) and eight major sub-programs. In addition, there are six minor sub-programs which are used by the major programs as needed. Figure 9.1 shows the flow chart of the main program. Note that it carries three functions, namely, job initialization, run initialization, and simulation. Most of the job initialization is actually carried out is the compilation phase of the program through the BLOCK DATA sub-program which contains most of the exogenous data. However, when the subroutine CONTRL is called, it reads in the number of simulation runs desired, the title of the job, and other data which are not possible to include in the BLOCK DATA.

Before the first simulation run is executed, the job is first initialized through CONTR1 which reads the mode and options desired in a particular run. CONTR2 initializes the policy variables, namely, area, planting date, fertilizer application level, weeding labor input and input control expenditure level for each crop planted. These are either read from cards or set within the model depending on the mode of run.

Given the values of the policy variables, and the options chosen, simulation is carried out by calling the sub-programs RNGEN, PRODN, PRGEN, LABOR, CROPAC, and PRINT in sequence. These sub-programs correspond to the rainfall generator, production component, price

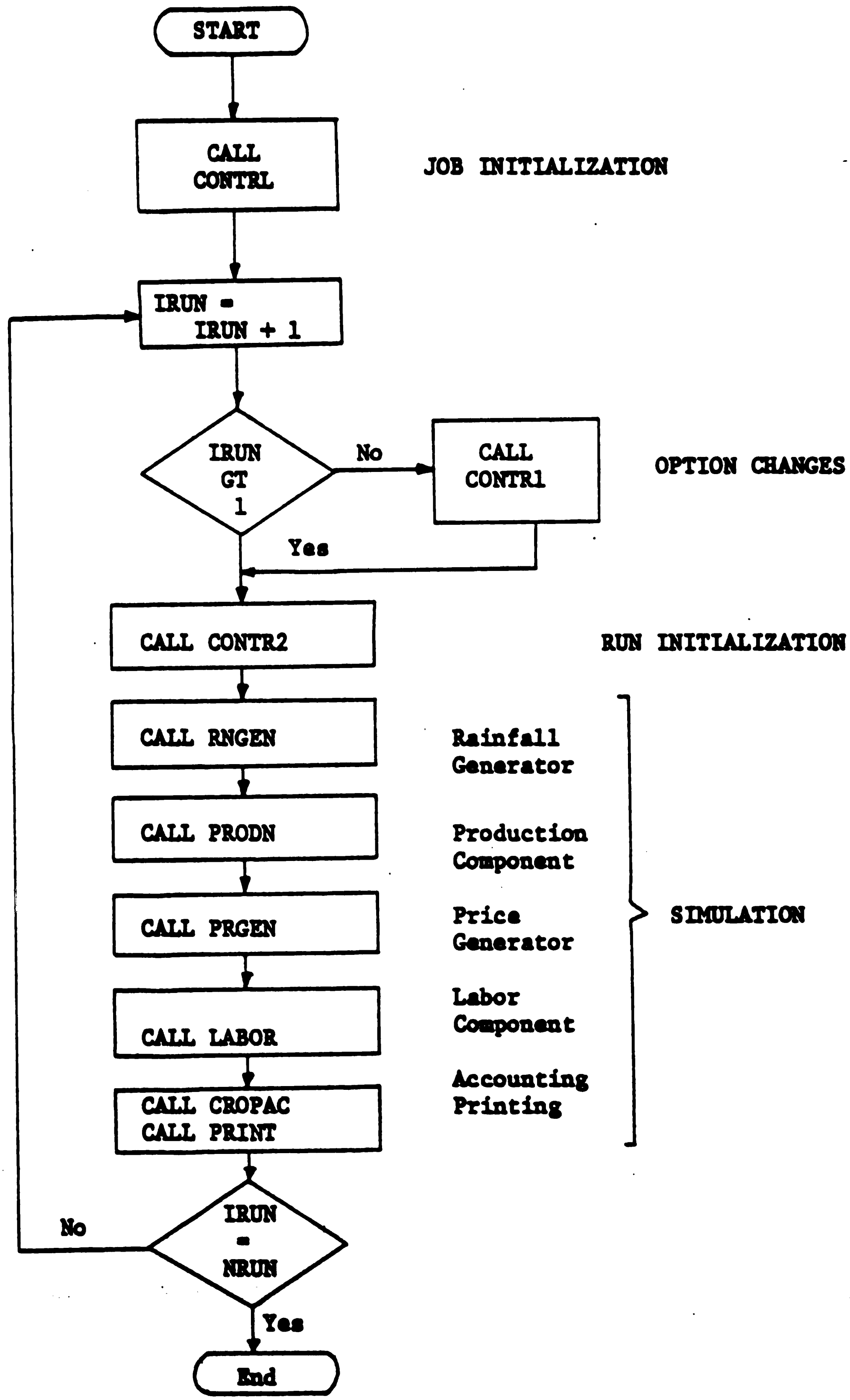

Fig. 9.1. Flowchart of Main Program, Cropping Systems Simulation Model.

generator, labor component, crop account component and the report generator, respectively. Recall that, as discussed in Chapter 4, land allocation is set by the user and is provided as an input to the program, hence no land allocator sub-program is called.

The simulation phase is achieved simply by calling the above-mentioned sub-programs in sequence and not in an apparent interactive fashion. This is justified by the fact that the model structure is such that the interrelationships among components are mostly "one-way". That is, if in the sequence subroutine A is called earlier than subroutine B, then B depends on the values generated by A and not vice-versa. The operation and the resultant computed values of components called later depend on the values generated in the preceding sub-routines called.

Communication among subroutines and with the main program are achieved through labelled COMMON statements. Table 9.1 shows the structure of labelled COMMON statements in relation to the subroutines. The asterisks indicate that the subroutine uses some values of the variables which are included in the corresponding labelled COMMON variable. The values which are stored in the common memories are used by other subprograms and are eventually used by the printing subroutine or report generator (PRINT). Some of the values are passed on the next simulation run within the same job.

Table 9.1 Structure of labelled COMMON statements and the subroutines using them.

LABELLED COMMON	SUBROUTINE									
	CONTRL	BLOCK DATA	RNGEN	PRODN	PRGEN	LABOR	CROPAC	PRINT	SUMMA	GAMFCN
ACC								*	*	
COND	*		*	*	*	*	*	*	*	
CONTR	*		*	*	*	*	*	*	*	
FCNVAL		*			*					
LAB	*	*				*	*	*		
LABEL	*	*	*					*		
LEVELS		*		*						
PRDAT		*			*		*	*		
RNHIST	*	*	*							
RNPAR		*	*							*
RRATES		*		*						
STAGE		*	*	*	*	*		*		
SUMRY							*		*	
TMPDAT	*	*								
YIELD				*		*	*	*		

9.3 Features and Options

The next section discusses in detail the preparation of the input deck in accordance with the following features and options.

Modes of Run. There are four modes of running the simulation program:

Mode 1: Areas, planting dates, and input levels are specified by the user. The rainfall option is also set by the user.

Mode 2: An input (fertilizer, weeding or insect control) chosen by the user is varied internally in the model with increments specified by the user. Other inputs are held fixed at levels (zero, low, medium, and high) desired by the user. The rainfall pattern can either be fixed or allowed to vary between runs.

Mode 3: Planting dates are varied between runs while input levels are held fixed. The different planting dates are set by the user and are provided to the model by means of input cards. As in Mode 2, the rainfall pattern can either be fixed or allowed to vary between runs.

Mode 4: Rainfall patterns are varied from one simulation run to another while input levels and planting dates are held fixed.

The four modes of running the program were designed to make the use of the simulation model as flexible as possible. The different aspect of farm performance due to various influences such as input levels, rainfall pattern, and planting dates, could be studied separately.

Rainfall generation options. There are five rainfall generation options available for use in the model. These options are designed to give some flexibility on the kind of rainfall pattern that is desired for simulation. The options are as follows:

1. Generate rainfall based on the parameters of an incomplete gamma distribution for each week synthesized from actual data;

2. Randomly select a year between 1949 and 1975 and to use the historical rainfall data of the Ambulong Weather Station for that year as the rainfall pattern for the simulation run;

3. Use the historical data of a pre-determined year;

4. Randomly select a high, medium, or low rainfall year on the basis of annual total rainfall and to use the historical data of the selected year in the simulation run.

5. Use the average weekly rainfall of the Ambulong Weather Station from 1949 to 1975 as rainfall pattern for the simulation run.

The use of any option simply requires the specification of the option number. A seed for generation of a random number between 0 and 1 are required for option 1, 2, and 4 and must be provided by the user. In the case of option 3, the year desired is to be provided and in option 4, the level of rainfall year desired is also required.

Price adjustment options. Prices are allowed to vary inter-seasonally through seasonal price indices which are provided in the model as data for each crop. However, base price could also be made to vary by trend if more than one run is made and the additional runs are intended to be a simulation of succeeding years. If a trend adjustment is allowed, the choices are exponential and linear adjustments.

The type of trend relationship which is appropriate for type of suitable for each crop can be established. These are then provided to the model as data. Thus, it is possible for one crop to have a linear price trend adjustment while another crop has an exponential trend adjustment.

Another adjustment that can be made on prices is random or irregular variations. Here, the normal distribution is assumed. The base price multiplied by the seasonal price index appropriate for a given week is taken as the mean. Standard deviations or irregular price movements for each crop by month are also provided as data into the program. Through a routine which determines the normal deviate given a random number between 0 and 1, the adjustment required for irregular or random price variations is also determined.

Planting date options. The planting date of each crop is an input to the program. It is entered as a week number according to the code of weeks and corresponding dates as shown in Table 9.2. The default option in the model is for planting dates to be adjusted according to rainfall pattern. That is, if rainfall level is below a threshold level during the specified planting date, the latter is postponed by a week and the rainfall level during the new planting week is again re-tested if planting is possible. However, it may be desired that no adjustment in planting date is allowed, for example, to determine the effect on yield of a crop if planted at a particular time of the year regardless of moisture conditions. Hence, an option of no change in planting date has also been provided.

Table 9.2 Dates and corresponding week codes used in the simulation model

Date	Week code	Date	Week code
Jan 1-7	01	Jul 2-8	27
Jan 8-14	02	Jul 9-15	28
Jan 15-21	03	Jul 16-22	29
Jan 22-28	04	Jul 23-29	30
Jan 29-Feb 4	05	Jul 30-Aug 5	31
Feb 5-11	06	Aug 6-12	32
Feb 12-18	07	Aug 13-19	33
Feb 19-25	08	Aug 20-26	34
Feb 26-Mar 4	09	Aug 27-Sep 2	35
Mar 5-11	10	Sep 3-9	36
Mar 12-18	11	Sep 10-16	37
Mar 19-25	12	Sep 17-23	38
Mar 26-Apr 1	13	Sep 24-30	39
Apr 2-8	14	Oct 1-7	40
Apr 9-15	15	Oct 8-14	41
Apr 16-22	16	Oct 15-21	42
Apr 23-29	17	Oct 22-28	43
Apr 30-May 6	18	Oct 29-Nov 4	44
May 7-13	19	Nov 5-11	45
May 14-20	20	Nov 12-18	46
May 21-27	21	Nov 19-25	47
May 28-June 3	22	Nov 26-Dec 2	48
Jun 4 - 10	23	Dec 3-9	49
Jun 11-17	24	Dec 10-16	50
Jun 17-24	25	Dec 17-23	51
Jun 25-Jul 1	26	Dec 24-31	52

Other options. Two other features which are useful to the user are options on the type of computer output and on statistical summary of results.

The user can opt for a short print-out or a long print-out of the simulation output. The short print-out option yields (1) a rainfall generator output of the particular generation option in use; (2) a summary of planting dates, area, and input levels, number of dry weeks in each crop stage, and yield, harvest dates, and prices as determined by the simulation model; and (3) a summary of performance variables namely, yield, total production, gross returns, farm expenses, net returns and labor use.

With the long print-out, in addition to the above computer outputs, the following are also printed: (1) available soil moisture by week, (2) labor utilization of cropping pattern by week showing available for family labor, required labor, and hired labor, (3) detailed cost and returns analysis for each crop planted, and (4) labor utilization by operation of each crop.

Another option provides a statistical analysis of variables generated by several simulation runs of the same set of policy variables and cropping patterns. When this option is used, the means and standard deviations of yield, total production, prices, gross returns, farm expenses, net returns and labor utilization for each crop are computed and printed. Appendix III contains samples of types of output generated by the computer simulation model.

9.4 Deck Set-up for Running the Model

The deck required for running the computer program of the model is composed of 3 main parts: (1) the Job Control Language (JCL) cards, (2) the program cards, and (3) the input cards.

Job Control Language Cards. The job control cards required in any FORTRAN program is dependent on the computer installation where the program is run. In any case, they instruct the computer to do basically three things: (1) compilation, (2) linkage, and (3) execution. The speed with which these functions are done depend on the computer.

Source Program. Normally, the source program deck can be run with the use of cards together with the input deck. However, the experience of the author is that it is very cumbersome and expensive since the length of the program makes the deck very bulky and the compilation time very long, usually a minute and a half in IBM 370 Model 65. Considerable computer time could be saved by first compiling the program and saving the object deck on a magnetic tape or disk. On subsequent runs, only linkage and execution are the operations to be performed.

Input Cards. The input cards instruct the program what job is to be performed. A job may consist of one or more simulation runs, but each job must utilize only one of the four modes of run discussed earlier. Basic to all jobs of any mode are the following three cards and the corresponding punching locations on a standard 80-column Hollerith card:

Table 9.3 Instructions for preparation of the option card.

Columns	Variable/ Option Name	Format	Explanation
1-9	IX	I9	Seed for random number generator (subroutine RANDU)
10	MODE	I1	Mode of simulation run 1 - Policy variables are set by the user 2 - A desired input is varied internally 3 - Planting dates are varied in each run 4 - Rainfall pattern is varied in each run
11	IROPT	I1	Rainfall generation option 1 - Gamma distribution 2 - Random year selection 3 - Specified year 4 - Predetermined rainfall level 5 - Average rainfall
12	LVR	I1	Level of annual rainfall 1 - High 2 - Medium 3 - Low
13	INPUT	I1	Input incremented while holding the rest fixed (Increments are specified by DELT) 1 - Fertilizer 2 - Weeding labor 3 - Insecticide
14	LVINP	I1	Level of management inputs fixed by the user 1 - Zero 2 - Low 3 - Medium 4 - High
15	PSW	I1	Planting date adjustment option 1 - No adjustment 2 - Adjust planting date according to rainfall situation

Table 9.3 (continued)

Columns	Variable/ Option Name	Format	Explanation
16	RSW	I1	Price adjustment option 0 - None-random price adjustment 1 - Random price movements
17	LSW	I1	Type of tenure of farm 0 - Owner operated 1 - Tenant operated
18	KPI	I1	Print Option 0 - Short printout 1 - Long printout
19	KP2	I1	Statistical summary option 0 - No statistical summary 1 - With statistical summary
20	IPOPT	I1	Trend Adjustment option for prices 0 - No trend adjustment 1 - With trend adjustment
21-24	IYR	I4	Year specified if IROPT=3 Punched e.g. as "1971"
25-30	DL	F5.2	The level of moisture or rainfall, in inches, below which drought occurs
31-35	DELT	F5.2	Amount by which the variable input is incremented

Card 1 : Number of runs - Cols. 1-5

Card 2 : Title of job - Cols. 1-80

Card 3 : Option card - See Table 9.3

The option card contains all the user-specified options which includes the mode of simulation run, rainfall generation option, planting date option, price adjustment options, printing option and threshold drought level. The other items in the option card are dependent on the mode of run and the other options. For example, if mode 2 is chosen, the input that is varied and the level of other fixed input must be specified. In addition, the level by which the input is varied per run must be specified in the option card Table 9.3 shows how the option card is prepared.

The other input cards to be included depend on the mode of run desired of the simulation model. It will be recalled that with Mode 1, the user specifies the policy variables, namely, area, planting date, input levels, and the rainfall generator option for each run. On the other hand, with the other modes, some of the variables are specified only for the first run and they either remain fixed in subsequent runs or are varied internally within the model. How these variables are varied also depend on the instructions given by the user as indicated in the option card.

The remaining cards for each of the modes are as follows:

<u>Mode 1</u>. Under mode 1, there are 16 policy cards that must be prepared for each run. Cards 4 through 11 are the policy cards for <u>first croppings</u> of rice, corn, sorghum, mungbean, cowpea, peanut, soy-

bean, and sweet potato in that order. Cards 12 through 19 are the policy cards for second croppings of the same crops, respectively. Each additional run using mode 1 requires 16 additional policy cards.

Each policy card is prepared by entering the area, planting date, and input levels of an individual crop included in the cropping pattern. Thus, if a crop is to be planted, Table 9.4 shows the respective columns and input format of each information. If a crop is not planted, its policy card is simply left blank. However, it has still be provided.

Table 9.4 Preparation of the Policy Card, Mode 1

Item	Columns	Format
Area	1-5	F5.1
Planting date	6-10	I5
Fertilizer input (kg.N/ha)	11-15	F5.0
Weeding labor (man-hours/ha)	16-20	F5.0
Insecticide (₱/ha)	21-25	F5.0

Mode 2. It will be recalled that under Mode 2, an input is varied internally while the other input are held fixed at levels specified by the user. The level of incrementation is equal to DELT as indicated in the option card. The levels of other inputs are held fixed are determined by the option variable LVINP. When LVINP is equal to 1, it means that the input levels are to be specified by

the user. In this case, 16 policy cards have to be provided and are prepared the same way as indicated in Table 9.4.

When LVINP has a value of either 2, 3, 4 or 5, the input levels are set withint the model corresponding to zero, low, medium or high, respectively. In this case, only a planting date card (card 4) has to be provided. The preparation of the planting date card is shown in Table 9.5.

Mode 3. In mode 3, planting dates are varied in each run. Here, the additional cards to include are similar to those of mode 2 (16 policy cards when LVINP equals 1 and a planting date card when LVINP is not equal to 1). With the exception that there will be as many sets of policy cards or planting date cards as there are runs.

Mode 4. Under Mode 4, only the rainfall pattern is varied in between runs. The cropping pattern, input levels, and planting dates are fixed during the first run. Rainfall variation is achieved by specifying rainfall optionsl, 2 and 4. The additional cards required are the same as in mode 2, that is, 16 policy cards if LVINP equals 1 or a planting date card if LVINP is not equal to 1.

9.5 Summary

The purpose of this chapter was to describe the structure of the simulation model; to describe its various features and options available; and to provide instructions on how to prepare the program deck and run the model. This chapter would be particularly useful to those who wish to run the model themselves.

Table 9.5 Preparation of the planting date card

Columns	Crop
1-5	First crop rice
6-10	First crop corn
11-15	First crop sorghum
16-20	First crop mungbean
21-25	First crop cowpea
26-30	First crop peanut
31-35	First crop soybean
36-40	First crop sweet potato
41-45	Second crop rice
46-50	Second crop corn
51-55	Second crop sorghum
56-60	Second crop mungbean
61-65	Second crop cowpea
66-70	Second crop peanut
71-75	Second crop soybean
76-80	Second crop sweet potato

CHAPTER 10

EXPERIMENTATIONS, RESULTS, AND DISCUSSION

10.1 Introduction

In this chapter, the cropping systems simulation model as described in the preceding chapter is put to use. A number of experiments were performed and the results are discussed below. As stated earlier the model was developed primarily for evaluating cropping patterns and as an aid in the design and testing of cropping sytems. Thus a number of simulation runs concern the evaluation of cropping patterns which are of interest in the Philippines. However, the model was also used to simulate other experiments which are usually conducted in the field.

Specifically, the various experiments conducted are as follows: (1) yield response of various crops to different levels of nitrogen; (2) yield response of various crops to different levels of weeding labor; (3) evaluation of specific cropping patterns in terms of selected performance variables with respect to variations in rainfall and product prices; (4) comparison of economic performance of cropping patterns under favorable and unfavorable conditions; (5) comparison between intensive and non-intensive cropping patterns, and (6) comparison of planting dates and yields using two strategies of choice of planting dates.

It should be emphasized at the very outset that the results from these various experimentations simply reflect the assumptions regarding the model structure and the coefficients and parameters used. Whatever limitations there are of the model structure as well as of the estimates of the parameters are carried over in the results. It is recognized that a number of components need further refinements and many of the estimates of parameters and coefficients are still unsatisfactory. Hence, the results of the experiments conducted here should best be treated as illustrations of the usefulness and potentials of the simulation model. It is felt, however, that as long as the limitations are recognized, the present model could be of practical use not only to researchers in multiple cropping but also to farmers.

10.2 Results of Experiments

10.2.1 Yield response to nitrogen fertilizer at zero, medium, and high levels of other inputs

The purpose of this experiment was to test the simulation model for realism of estimated yield and income levels corresponding to various levels of fertilizer input. This was done using Mode 2 of the model where fertilizer is incremented in steps of 20 kilograms of nitrogen per hectare, holding the other inputs and the rainfall pattern constant. Weeding labor and insect control were held fixed at three levels: zero, medium, and high levels. The medium level of other inputs consisted of 60 man-hours of weeding labor and ₱300 of insect control (insecticides) per hectare. The high level of other inputs consisted of 100 man-hours of weeding labor and ₱600 of insect control per hectare. Using the third option of the rainfall generator, the rainfall pattern was held fixed using the 1973 historical rainfall data, a year which had a relatively good weather.

Tables 10.1 to 10.3 show the simulated yield response of various crops to nitrogen fertilizer at zero, medium, and high levels of other inputs, respectively. Palay (rice) and Corn 1 are wet season crops with their planting dates set at week 18 (April 30 to May 6). The other crops are dry season crops with their planting dates set initially at week 38 (September 17-23). The actual planting dates will of course depend on soil moisture conditions and in the case of dry season crops, on whether the first crop has been harvested.

As expected, higher levels of fertilizer resulted in higher yields for all crops although diminishing yields are apparent for very high levels of fertilizer application. The tables also show the fact that some legumes such as mungbean, cowpea, and soybean are relatively unresponsive to high levels of nitrogen. These observations of course reflect the base yields and the reduction rates which were used.

It should be noted that yield levels of each crop increase as the level of weeding labor and insect control are increased. Yield levels are considerably higher in the case of high weeding and insect control levels than those at zero levels. As an illustration, figure 10.1 shows that the fertilizer response curve of upland palay is higher for high weeding and insect control levels than at zero levels.

Table 10.4 shows the net returns of the various crops at different levels of fertilizer. These figures also reflect the prices

Table 10.1. Simulated yield response to fertilizer, zero weeding and insect control (tons/hectare).[a]

Crop	Fertilizer level (kg N/ha)						
	20	40	60	80	100	120	140
Palay	2.1	2.5	2.8	3.0	3.1	3.2	3.1
Corn 1	2.2	2.6	3.0	3.2	3.3	3.4	3.3
Corn 2	1.6	1.9	2.1	2.3	2.4	2.4	2.4
Sorghum	0.9	1.1	1.2	1.3	1.4	1.4	1.4
Mungbean	0.6	0.7	0.8	0.8	0.8	0.8	0.8
Cowpea	0.9	1.0	1.1	1.1	1.1	1.1	1.1
Peanut	1.3	1.5	1.7	1.8	1.9	1.9	1.9
Soybean	1.1	1.2	1.3	1.4	1.4	1.4	1.4
Sweet potato	8.0	9.0	10.1	10.7	11.3	11.3	11.3

[a]Mode=2, 1973 rainfall. Initial planting dates for palay and corn 1 were set at week 18; the rest were set at week 38.

Table 10.2. Simulated yield response to fertilizer, medium weeding and insect control (tons per hectare).[a]

Crop	Fertilizer level (kg N/ha) 20	40	60	80	100	120	140
Palay	2.4	2.8	3.2	3.5	3.6	3.6	3.5
Corn 1	2.3	2.7	3.1	3.3	3.4	3.5	3.4
Corn 2	2.3	2.7	3.1	3.4	3.5	3.5	3.4
Sorghum	2.4	2.9	3.3	3.5	3.6	3.7	3.6
Mungbean	1.1	1.2	1.3	1.4	1.4	1.3	1.2
Cowpea	1.4	1.6	1.8	1.8	1.8	1.8	1.6
Peanut	2.1	2.4	2.7	2.9	3.1	3.1	3.1
Soybean	1.8	2.0	2.2	2.2	2.2	2.2	2.0
Sweet potato	11.8	13.5	15.2	16.1	16.9	16.9	16.9

[a]Mode=2, 1973 rainfall, weeding input = 60 man-hours/ha., insect control = ₱300/ha. Initial planting dates for palay and corn 1 were set at week 18. All others were set at week 38.

Table 10.3. Simulated yield response to fertilizer, high weeding and insect control levels (tons/ha).[a]

Crop	Fertilizer level (kg N/ha) 20	40	60	80	100	120	140
Palay	2.8	3.3	3.8	4.1	4.2	4.3	4.2
Corn 1	3.1	3.7	4.2	4.5	4.7	4.8	4.7
Corn 2	2.2	2.6	3.0	3.2	3.3	3.4	3.3
Sorghum	1.3	1.6	1.8	1.9	2.0	2.0	2.0
Mungbean	0.9	1.1	1.1	1.2	1.2	1.2	1.2
Cowpea	1.3	1.5	1.6	1.6	1.7	1.6	1.5
Peanut	1.9	2.2	2.5	2.6	2.8	2.8	2.7
Soybean	1.7	1.9	2.0	2.1	2.1	2.0	1.9
Sweet potato	12.1	13.5	15.3	16.1	16.9	17.0	16.9

[a]Mode = 2, 1973 rainfall, weeding input = 100 man-hours/ha., insect control = ₱600/ha. Initial planting dates for rice and corn 1 were set at week 18; the rest were set at week 38.

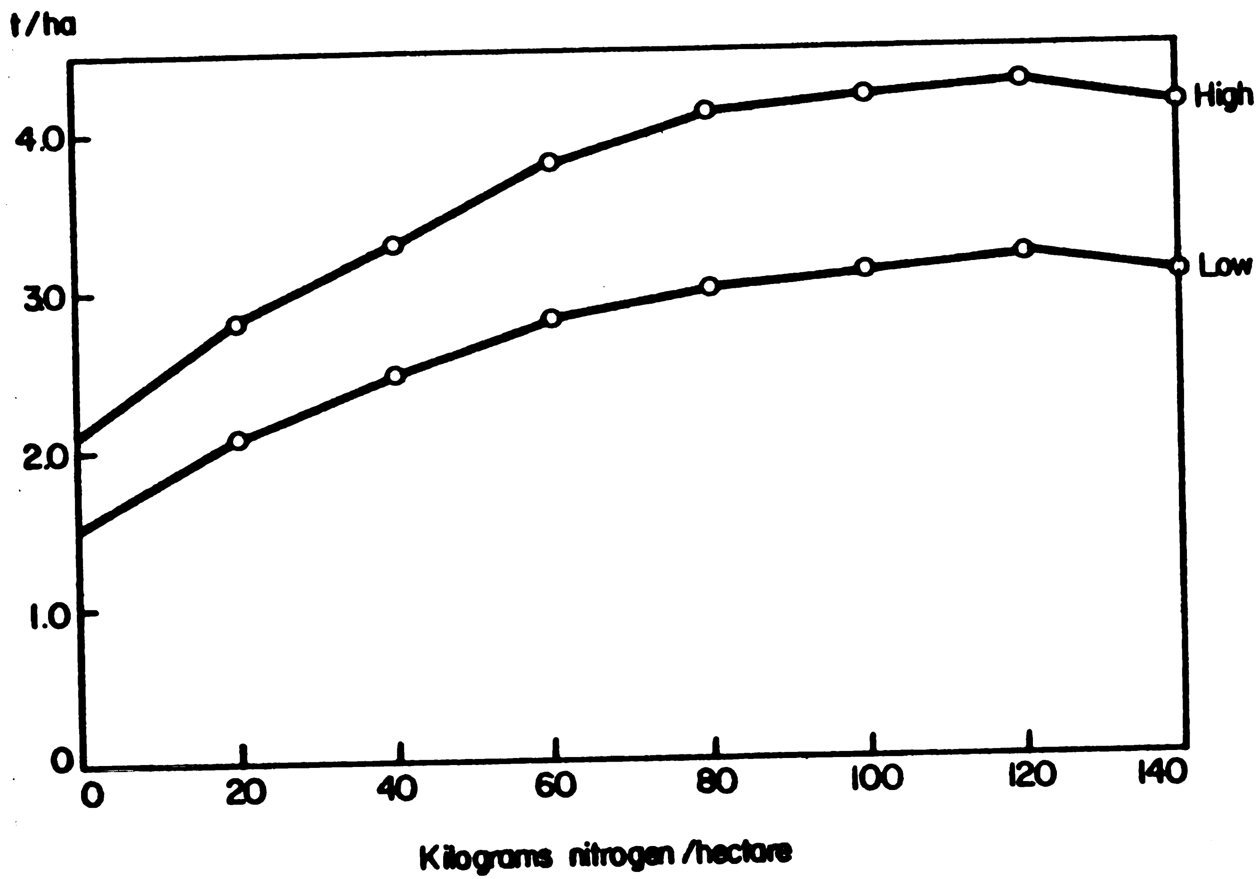

Figure 10.1 Simulated Yield Response of Upland Rice to Fertilizer, High vs. Low Weed and Insect control

Table 10.4. Net returns of various crops to different levels of nitrogen fertilizer, medium level of other inputs (pesos/ha)[a]

Crop	Fertilizer level (kg N/ha)							
	0	20	40	60	80	100	120	140
Palay	666	941	1163	1302	1362	1313	1237	1053
Corn 1	439	622	765	843	860	792	705	533
Corn 2	528	738	903	1000	1028	966	882	707
Sorghum	459	674	845	945	977	915	832	656
Mungbean	1919	2175	2437	2611	2558	2428	2221	1782
Cowpea	2886	3271	3657	3939	3913	3782	3550	3007
Peanut	2764	3210	3658	4105	4264	4422	4292	4162
Soybean	1827	2061	2296	2498	2400	2270	2068	1646
Sweet potato	4809	5598	6835	7174	7503	7831	7702	7571

[a]Mode = 2, Rainfall year = 1973, weeding input = 60 man-hours/ha., insect control = ₱300/ha. Planting dates for palay and corn 1 were set at week 18; the rest were set at week 38.

of the crops and the cost of inputs as incorporated in the price generator. A significant point that should be noted is that as fertilizer level is increased net returns also increase but only up to a certain point. Further increases in fertilizer resulted in decreasing net returns. In the case of rice, for example, net returns increased as fertilizer level is increased from zero to 80 kilograms of nitrogen. At higher levels, net returns started to decrease. Thus, this model is useful in determining the optimal level of a particular input, given the level of other inputs.

The results stated above, as mentioned earlier, simply reflect the assumptions that were incorporated in the production component and hence the outcome is not entirely unexpected. However, the value of such a feature in the model is that given the rainfall pattern and the level of other inputs, the yield of a crop can be predicted easily for a particular level of fertilizer application. To the extent that the reduction rates approach is valied, the joint effects of rainfall pattern, fertilizer, weed control, and insect control are all accounted for.

10.2.2 Yield response to weeding labor at high vs. low fertilizer and insect control levels

This experiment was done to test the simulation model for realism of crop yield response to various levels of weeding labor at different levels of fertilizer and insect control inputs.

The results of this experiment were also obtained using Mode 2 where weeding labor is incremented in steps of 20 man-hours per hectare while holding fertilizer and insect control levels fixed. The rainfall pattern in 1973 was also used all throughout. The low levels of other inputs consisted of 20 kilograms of nitrogen fertilizer and ₱100 of insecticides while high levels of other inputs consisted of 100 kilograms of nitrogen fertilizer and ₱600 of insecticides.

Tables 10.5 and 10.6 show the simulated yield of various crops corresponding to different levels of weeding labor at low and high levels of other inputs, respectively. As expected, yield levels were higher at high fertilizer and insect control levels than at low levels for all crops. Moreover, yield increases as weeding labor is increased but only up to a certain point. Additional weeding labor has no effect on yield.

Figure 10.2 shows the graphs of the simulated yield response of upland rice to weeding labor at low and high levels of other inputs. Note that the response curve at high levels of fertilizer and insecticide is considerably higher than that of low levels of fertilizer and insecticide.

As in the preceding experiment, the results in this experiment simply reflect the assumptions concerning the reduction rates, the base yields, and the yield equation. However, the prediction of yield is facilitated by the model.

10.2.3 Evaluation of specific cropping patterns

Five specific rice-based cropping patterns were evaluated for biological and economic stability with respect to rainfall and price variability. The cropping patterns are: (1) rice-mungbean, (2) rice-soybean, (3) rice-sweet potato, (4) rice-peanut, and (5) rice-corn-corn.

Table 10.5. Simulated yield response to weeding labor, low fertilizer and insect control levels (tons/ha).[a]

Crop	Weeding labor (manhours/ha) 20	40	60	80	100
Palay	2.3	2.4	2.6	2.6	2.7
Corn 1	2.6	2.7	2.9	3.0	3.0
Corn 2	1.8	1.9	2.0	2.1	2.1
Sorghum	1.1	1.1	1.2	1.3	1.3
Mungbean	0.7	0.8	0.8	0.9	0.9
Cowpea	1.0	1.1	1.2	1.2	1.2
Peanut	1.6	1.7	1.8	1.8	1.8
Soybean	1.4	1.5	1.5	1.6	1.6
Sweet potato	9.9	10.3	10.9	11.5	11.5

[a]Mode = 2, 1973 rainfall, fertilizer = 20 kg N/ha, insect control = ₱100/ha. Planting dates for palay and corn 1 were set at week 18; the rest were set at week 38.

Table 10.6. Simulated yield response to weeding labor, high fertilizer and insect control levels (tons/ha).[a]

Crop	Weeding labor (manhours/ha) 20	40	60	80	100
Palay	3.6	3.8	4.1	4.2	4.2
Corn 1	4.1	4.3	4.5	4.7	4.7
Corn 2	2.9	3.1	3.2	3.3	3.3
Sorghum	1.7	1.8	1.9	2.0	2.0
Mungbean	1.0	1.1	1.2	1.2	1.2
Cowpea	1.4	1.5	1.6	1.6	1.7
Peanut	2.4	2.5	2.7	2.8	2.8
Soybean	1.8	1.9	2.0	2.1	2.1
Sweet potato	14.6	15.2	16.0	17.0	17.0

[a]Mode = 2, 1973 rainfall, fertilizer = 100 kg N/ha., insect control = ₱600/ha. Planting dates for rice and corn 1 were set at week 18, other crops at week 38.

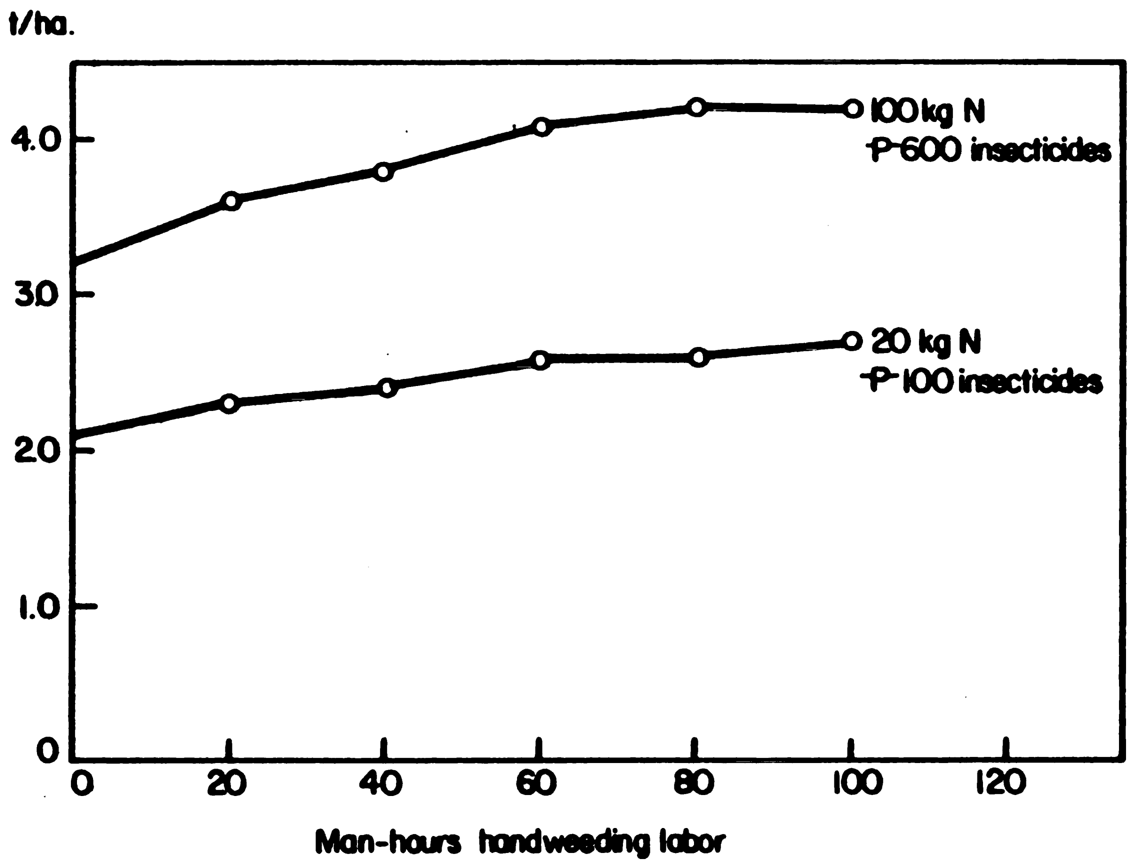

Figure 10.2 Simulated Yield Response of Upland Palay to Weeding Labor, High vs. Low Fertilizer and Insect Control

The general procedure was to let the rainfall pattern and prices vary randomly over several runs and to compute the means and standard deviations of selected performance variables. The means are to be interpreted as the expected values of the performance variables while the standard deviations are measures of the variability of the performance variables. The latter may give us an idea of the risk associated with the growing of a particular cropping pattern.

Ten runs of each pattern were done using Mode 4 of the model in which rainfall pattern was varied for each run while the input levels were held fixed at 100 kg of nitrogen fertilizer, 100 man-hours of weeding labor, and ₱300 worth of insect control (medium levels). The rainfall pattern was randomly generated using option 1 which makes use of the parameters of an incomplete gamma distribution. The prices were also allowed to vary randomly based on the base prices, seasonal indexes, and standard deviations assuming normal distribution.

In each pattern, the area of farm was set at one hectare. The first crop was rice followed by another crop. The planting date of rice was initially set at week 18 while those of the other crops at week 38. In the case of the third crop corn, the planting date was set at week 50. Actual planting dates were, however, allowed to vary according to the rainfall pattern generated.

Tables 10.7 to 10.11 present the means and standard deviations of yield per hectare, crop prices, gross returns, farm expenses, net returns, and labor utili-ation of each crop for the five cropping patterns. It was noted that the variations in yield over the ten simulation runs were very small for all patterns. This can be

Table 10.7. Means and standard deviations of selected variables of the rice-mungbean cropping pattern with random rainfall and prices, medium level of inputs.[a]

Variable	Mean		Standard deviation	
	Rice	Mungbean	Rice	Mungbean
Yield (kg/ha)	3201.5	1326.7	57.3	0.0
Price (₱/kg)	1.19	4.91	0.21	0.34
Gross returns (₱/ha)	3817.98	6516.32	666.22	453.09
Farm expense (₱/ha)	2711.47	3970.51	285.52	194.18
Net returns (₱ha)	1106.52	2545.81	380.70	258.91
Labor use (man-hours/ha)	721.0	655.1	5.5	0.0

[a]10 runs, mode 4, rainfall option 2, fertilizer = 60 kg N/ha., weeding labor = 60 man-hours/ha., insect control = ₱300/ha.

Table 10.8. Means and standard deviations of selected variables of the rice-soybean cropping pattern with random rainfall and prices, medium level of inputs.[a]

Variable	Mean		Standard deviation	
	Rice	Soybean	Rice	Soybean
Yield (kg/ha)	3232.9	2224.5	16.2	22.6
Price (₱/kg)	1.20	4.91	0.20	0.25
Gross returns (₱)	3877.97	6448.55	649.85	533.03
Farm expense (₱)	2738.28	3879.79	279.34	228.44
Net returns (₱)	1330.50	2707.96	526.93	583.21
Labor use (man-hours)	723.9	514.7	1.55	2.53

[a]10 runs, mode 4, rainfall option 2, fertilizer = 60 kg N/ha., insect control = ₱300/ha., weeding labor = 60 man-hours/ha.

Table 10.9. Means and standard deviations of selected variables of the rice-sweet potato cropping pattern with random rainfall and prices, medium level of inputs.[a]

Variable	Mean		Standard deviation	
	Rice	S. potato	Rice	S. potato
Yield (kg/ha)	3208.0	15273.9	44.4	201.6
Price (₱/kg)	1.18	0.93	0.32	0.17
Gross returns (₱)	3779.12	14210.51	1026.85	2667.21
Farm expenses (₱)	2694.81	7178.97	440.08	1143.09
Net returns (₱)	1084.31	7031.54	586.77	1524.12
Labor use (man-hours)	721.6	564.7	4.2	2.7

[a]10 runs, mode 4, rainfall option 2, fertilizer = 60 kg N/ha., weeding labor = 60 man-hours/ha., insect control = ₱300/ha.

Table 10.10. Means and standard deviations of selected variables of the rice-peanut cropping pattern with random rainfall and prices, medium level of inputs.[a]

Variable	Means		Standard deviation	
	Rice	Peanut	Rice	Peanut
Yield (kg/ha)	3117.2	2771.8	165.0	95.0
Price (₱/kg)	1.27	3.23	0.30	0.13
Gross returns (₱)	3942.01	8964.02	949.28	432.91
Farm expense (₱)	2764.62	4930.47	406.83	185.53
Net returns (₱)	1177.39	4033.54	542.44	247.38
Labor use (man-hours)	713.0	618.8	15.7	12.7

[a]10 runs, mode 4, rainfall option 2, fertilizer = 60 kg N/ha., weeding labor = 60 man-hours/ha., insect control = ₱300/ha.

Table 10.11. Means and standard deviations of selected variables of the rice-corn-corn cropping pattern with random rainfall and prices, medium level of inputs.[a]

Variable	Mean			Standard deviation		
	Rice	Corn 1	Corn 2	Rice	Corn 1	Corn 2
Yield (kg/ha)	4214.5	3142.3	1813.5	38.6	89.0	367.9
Price (₱/kg)	1.24	1.11	1.00	0.25	0.32	0.36
Gross returns (₱)	3987.22	3496.01	1789.65	784.54	987.95	761.68
Farm expenses (₱)	2784.00	2494.64	1763.34	336.23	423.41	326.44
Net returns (₱)	1203.22	1001.37	26.31	448.31	564.55	435.25
Labor use (man-hours)	722.2	330.5	272.7	3.7	3.9	15.9

[a]10 runs, mode 4, rainfall option 2, fertilizer = 60 kg N/ha., weeding labor = 60 man-hours, insect control = ₱300/ha.

explained by the fact that variations in yield were due solely to the variations in rainfall since input levels were held fixed during these runs. Yield varies from one run to another only in the event that the number of drought weeks in each stage of crop growth also varies. There were not enough variations, however, in the number of drought weeks resulting from the specified drought level (0.49 inch). Thus, the results reflect the rather crude and weak link between the rainfall variability and yield changes. This points to the need for a more refined production component which relates week to week variations in rainfall to changes in yield.

The variations in gross returns are explained by the variations in yield and prices. The simulated prices appear to be reasonable. The variations in farm expenses are also explained by yield and price variations even if the input levels are held fixed since they both affect the cost of seeds, harvesting and threshing, and landlord's share.

In this particular experiment, and in general using Mode 4 of the simulation model, variations in labor utilization are explained solely by variations in yield since input levels are held fixed. Labor utilization increases when yield increases since more harvest and post-harvest (threshing, husking, etc.) labor are required when total production is greater. Thus, the low standard deviations of labor utilization for almost all crops in the cropping patterns also reflect the low variations in yield over the ten simulation runs.

Table 10.12 summarizes the net returns and labor utilization of each of the five cropping patterns tested. In terms of net returns,

Table 10.12. Comparison of net returns and labor utilization of selected cropping patterns due to joint rainfall and product price variability.[a]

Cropping pattern	Net returns (₱/ha)	Labor use (man-hours/ha)
Rice-mungbean	3652.33	1376.1
Rice-soybean	4038.46	1238.7
Rice-Sweet potato	8115.85	1286.3
Rice-peanut	5210.93	1331.8
Rice-corn-corn	2230.90	1325.4

[a]Average of 10 runs, mode 4, rainfall option 2, random prices, fertilizer = 60 kg N/ha., weeding labor = 60 man-hours/ha., insect control = ₱300/ha.

the rice-sweet potato cropping pattern showed the highest net returns per hectare of ₱8116, followed by rice-peanut, rice-soybean, rice-mungbean, and rice-corn-corn in that order. In terms of labor utilization, the cropping pattern which was the most labor intensive was rice mungbean with 1376 man-hours per hectare followed by rice-corn-corn, rice-peanut, rice-sweet potato, and rice-soybean in that order.

10.2.4 Comparison of yields between favorable and unfavorable conditions

The objective of this run was to determine the yield differences as well as differences in other performance variables when each crop is subjected to extremely unfavorable and extremely favorable growing conditions. Unfavorable conditions were simulated by using zero fertilizer, weed control, and insect control levels and low rainfall years. On the other hand, favorable conditions were simulated by high management levels along with high rainfall years. High and low rainfall years were randomly obtained using option 4 of the rainfall generator.

Table 10.13 shows the means of five runs of the resulting yields of each crop under both conditions. It can be seen that the yield differences are considerable. Yield differences are particularly large for grains compared to legumes owing to the fact that in the model, the former are more fertilizer responsive than the latter. While the differences in yield could be attributed to the large gap in management levels, the use of high rainfall versus low rainfall also contributed to the difference in yields since high rainfall years would show less drought weeks than low rainfall years. Table 10.14

Table 10.13. Comparison of simulated yield, favorable vs. unfavorable conditions (tons/ha).[a]

Crop	Yield (t/ha) Unfavorable[b]	Favorable[c]	% diff.
Palay	1.53	4.23	176
Corn 1	1.61	4.56	183
Corn 2	1.56	4.71	202
Sorghum	0.82	2.73	233
Mungbean	0.66	1.44	118
Cowpea	0.88	1.92	118
Peanut	0.99	3.33	236
Soybean	1.07	2.42	126
Sweet potato	7.11	18.24	157

[a]Mean of 5 runs; planting dates for palay and corn 1 were set at week 18 and the rest at week 38.

[b]Low rainfall years, zero input of fertilizer, weeding labor, and insect control.

[c]High rainfall years, fertilizer = 100 kg N/ha., weeding labor = 100 man-hours/ha., insect control = ₱600/ha.

Table 10.14. Comparison of economic performance by crop under favorable vs. unfavorable weather and input conditions.[a] (₱/ha)

Crop	Gross returns		Crop costs		Net returns	
	U	F	U	F	U	F
Palay	1954	5489	560	1810	1394	3679
Corn 1	1684	4860	388	1638	1296	3222
Corn 2	1734	5124	388	1638	1346	3486
Sorghum	872	2945	588	1808	288	1137
Mungbean	3374	7200	750	2000	2624	5200
Cowpea	4551	9600	600	1850	3951	7750
Peanut	4122	10968	573	1823	3549	9145
Soybean	3029	6893	573	1823	2456	5070
Sweet potato	7861	18604	2834	8732	5027	9872

[a]Mean of five runs. Unfavorable was simulated by low rainfall years and zero input of fertilizer, weeding and insect control. Favorable conditions were simulated by high rainfall years and 100 kg N of fertilizer/ha., 100 man-hours of weeding labor, and ₱600 of insect control/ha.

further shows the considerable differences in gross and net returns of each crop subjected to extremes in management levels and rainfall conditions.

10.2.5 Comparison between intensive and non-intensive cropping patterns

The objective of this run was to compare the gross returns, crop costs, net returns, and labor utilization between an intensive and a non-intensive cropping pattern. The non-intensive cropping pattern consisted of one hectare of palay in the wet season followed by one hectare of corn in the dry season. The intensive cropping pattern consisted of 0.6 hectare of palay and 0.4 hectare of corn in the wet season and 0.5, 0.3, 0.1 and 0.1 hectare of corn, sorghum, mungbean, and cowpea, respectively in the dry season. Both cropping patterns were subjected to both low and high management levels. Nine runs were done on each cropping pattern for both input levels. Rainfall was varied randomly using the first option of the rainfall generator.

Table 10.15 shows the results of the simulation runs. It is apparent that in both cropping patterns, high management or input levels consistently resulted in higher gross returns, crop costs, net returns and labor utilization than low management levels. However, it is interesting to note that in the intensive cropping pattern with low input levels, the economic measures were higher than the non-intensive cropping pattern. Under high input levels, gross and net returns were higher with the non-intensive cropping pattern. This can be attributed to the fact that the yield reduction rates for palay (rice) and corn in the model are such that they are more responsive

Table 10.15. Comparison between intensive and non-intensive cropping patterns at low and high input levels.[a]

Variable	Non-intensive[b] Low	Non-intensive[b] High	Intensive[c] Low	Intensive[c] High
Gross returns	3710	8570	4819	8492
Crop costs	948	2667	1128	2760
Net returns	762	5903	3691	5735
Labor utilization (man-hours)	1160	1460	1254	1940
Effective crop area (hectares)	2.0	2.0	2.0	2.0

[a]Means of nine runs, mode 4, rainfall option 1. Low input levels: fertilizer = 20 kg N/ha., weeding labor = 20 man-hours/ha., and insect control = ₱100/ha. High input levels: fertilizer = 100 kg N/ha., weeding labor = 100 man-hours/ha., and insect control = ₱600/ha.

[b]1 ha palay - 1 ha corn.

[c]Wet season: 0.6 ha palay, 0.4 ha corn. Dry season: 0.5 ha corn, 0.3 ha sorghum, 0.1 ha mungbean, and 0.1 ha cowpea.

to high input levels especially to fertilizer. As expected, the labor utilization levels are higher in the intensive cropping patterns at both levels of input.

10.2.6 <u>Comparison of planting dates and yields using two strategies for choice of planting date</u>

Two strategies for choosing planting dates were examined to determine their effect on the feasibility of a three-crop sequence, and the yields of the crops in the sequence. The simulated pattern was rice, followed by corn, followed by cowpea. One strategy was to prepare the land during the earliest week after March 1 or week 10 when 0.5 inch of rainfalls, and then to plant during the subsequent week when rainfall is 0.5 inch. The second strategy was similar, but with May 1 to 7 or week 18 selected as the earliest planting week. The rainfall option used was to randomly select an actual year of rainfall from 1949 to 1975 (option 2). No fertilizer, insecticide, or weeding labor applications were assumed.

Nine runs were performed under each planting strategy, one rice crop was planted during the week March 5-11, all other planting dates were much later and closely comparable to the rice planting dates under the second strategy. Table 10.16 shows that an average difference of 1.4 weeks or roughly ten days resulted from following the different strategies. The average planting date in the first strategy is 18.4 as compared to the intended planting date of week 10 or an average delay of 8.4 weeks. This can be attributed to the fact that the rainfall pattern in Cale, Batangas is such that it is not feasible to plant any crop before week 17 (April 23-29). The average

Table 10.16. Comparison of planting dates and yields using two strategies for choice of planting date, low input levels.[a]

Plant ASAP after March 1			Plant ASAP after May 1		
Rainfall years	Palay date	Corn date	Rainfall years	Palay date	Corn date
1965	21	40	1950	26	45
1960	20	39	1966	19	38
1958	22	41	1953	19	38
1956	20	39	1957	20	39
1955	21	40	1951	18	37
1971	17	36	1975	19	38
1974	18	37	1962	19	38
1952	10	30	1963	20	39
1973	17	36	1951	18	37
Av. date	18.4	37.6	Av. date	19.8	38.8
Av. yield, t/ha					
Av. yield	1.3	1.7		1.6	1.7

[a]Mode 4, rainfall option 2, fertilizer = 20 kg N/ha., weeding labor = 20 man-hours/ha, insect control = ₱100/ha.

planting date in the second strategy is about week 19.8 as compared to the intended planting date of week 18. The average simulated yield of rice over the nine runs in the first strategy is 1.27 tons per hectare while that in the second strategy is 1.59 tons per hectare. The difference of about 0.3 ton is attributed to the more favorable rainfall distribution during the growing period of rice after week 18.

The tendency of Cale farmers to plant at about the same time each year has been noted previously by researchers working in the area and this has been casually attributed to custom. However, it is apparent that the physical environment, combined with the motivation to plant early, almost fully explains the tendency.

Corn yields were fairly uniform under both strategies, around 1.7 tons per hectare. This, and the fact that corn crops were usually planted in the earliest available week after rice harvest (i.e., no delays waiting for rain) indicate that soil moisture is usually ample during August.

The yield reductions resulting from early planting would be more than offset in an average year by better cowpea yields. In 8 out of the 9 years when an early rice planting strategy was followed, a copwea crop was feasible and the average yield was 0.64 ton per hectare. In comparison, cowpea crop was possible in only 4 out of the 9 years when a late planting strategy was followed, with an average yield of 0.32 ton per hectare.

Although an average 10-day delay in planting the rice crop is small, it may nevertheless be critical to feasibility of planting a third crop towards the end of the wet season.

10.3 Summary

In this chapter, several experiments were conducted to test the usefulness and potentials of the cropping systems simulation model developed. The experiments were (1) yield response of various crops to different levels of nitrogen; (2) yield response of various crops to different levels of weeding labor; (3) evaluation of specific cropping patterns in terms of selected performance variables with respect to variations in rainfall and product prices; (4) comparison of economic performance of cropping patterns under favorable and unfavorable conditions, and (5) comparison of planting dates and yields using two choices of planting dates.

The yield response experiments simply showed that yield increases as the level of an input is increased, holding the other inputs fixed. Moreover, the yield response curve is higher, the greater the levels of the other inputs. Among the cropping patterns evaluated, rice-sweet potato and rice-peanut sequence seem to be promising in terms of level of net returns. As to be expected, crop yields were higher under favorable weather conditions and high input levels. Intensive cropping patterns result in higher labor utilization than non-intensive ones although the net returns depend on whether input levels, particularly nitrogen fertilizer, are kept high or low. Finally, it was found that the planting date for the first crop rice tended to be around week 18 or 19 no matter how early the intended planting date is set.

Chapter 11

SUMMARY, CONCLUSIONS, AND SUGGESTIONS FOR FURTHER RESEARCH

11.1 Summary

This study was conducted with the following objectives: (1) to develop a systems model for simulating upland rice-based multiple cropping systems, and (2) to evaluate by means of the computer simulation model the effects of environmental and economic influences, as well as alternative cropping patterns on the performance of the system. It was felt that a systems analysis and simulation approach of studying cropping systems was possible, useful and considered a worthwhile alternative to traditional methods of analysis such as linear programming.

The simulation model developed in this study has been designed for an upland area. Eight upland crops were included, namely rice (palay) corn, sorghum, mungbean, cowpea, peanut, soybean and sweet potato. The data used were obtained mostly from the weekly economic surveys in Cale, Tanauan, Batangas from 1973 to 1975 conducted by the Multiple Cropping Project at the International Rice Research Institute in the Philippines.

The major components of the simulation model are (1) land allocation component, (2) rainfall generator, (3) production component, (4) price generator, (5) labor utilization component, and (6)income component. The land allocation component has the function of allocating limited land over time to various crop enterprises. The method for land allocation in this study was one wherein an experimenter allocates land by specifying a cropping pattern as well as the area and planting dates of each crop.

The function of the rainfall generator is to provide to the model the rainfall pattern for the simulated year. There were five options developed in generating rainfall. The choice largely depends on the mode with which the simulation model is run. The generated rainfall data have some bearing on actual planting dates and on the yield of crops.

The production component has the function of determining the yield of each crop based on (1) fertilizer level, (2) weed control level, (3) insect control level, and (4) number of drought stress weeks during the vegetative, reproductive and maturation stages of crop growth. The main approach used in the prediction of yield is the reduction rates approach. The approach suggests the use of potential yield as the initial point and then a series of reduction factors are applied to the potential yield to account for input levels and environmental influences which depart from optimal levels.

The price generator estimates the price of a crop at any given week of the year. A relatively simple method was employed wherein the price at a given week is estimated by means of seasonal price indexes and base prices. The prices could be made to vary randomly under a normal distribution and also to change in trend as options.

The labor component merely accounts for the use of labor in the production process. For some farm operations labor requirements by time distribution were provided exogenously to the model. The labor requirements such as fertilization, weeding, harvesting and threshing were, however, determined endogenously depending on the level of the relevant input or the level of output. Thus, given the areas, input levels, and planting dates of each crop planted, the weekly labor utilization pattern is obtained for the entire simulated year. This component also determines the amount of labor hired by the farm.

Finally, the crop accounting component has the function of keeping track of all farm income and expenses. It also determines most of the performance variables, namely, total production, value of production, cost of production, and net returns of each crop planted and for the whole cropping pattern.

The simulation model could be run in four modes. In Mode 1, areas, planting dates and input levels are specified by the user. The rainfall option is also set by the user. In Mode 2, a chosen input is varied internally in the model with increments specified by the user. The other inputs are held fixed internally either at zero, low, medium or high levels. Alternatively, the user could opt for other levels of inputs desired. The rainfall pattern can either be fixed or allowed to vary between runs. Under Mode 3, planting dates are varied from one run to another while input levels are held fixed either at zero, low, medium, or high levels or some other desired levels. Again, the rainfall pattern can either be held fixed or allowed to vary between runs.

Finally, under mode 4, the rainfall pattern is varied during each run while holding input levels and planting dates fixed.

With these different modes of usage, various experiments are possible with the model. For example, Mode 2 may be used in yield response experiments while the evaluation of economic and biological stability of a cropping pattern with respect to rainfall variability can be done using mode 4.

Several experiments were conducted using the computer simulation model primarily to show its various uses, capabilities, and flexibility. These were of the following types: (1) yield response to various levels of inputs, (2) performance of specific cropping patterns with respect to variations in rainfall and prices, (3) comparison of performance of crops between favorable and unfavorable conditions, (4) comparison between intensive and non-intensive cropping patterns, and (5) comparison of planting dates and yields using two strategies for choice of planting dates. The results of these experiments were discussed in Chapter 10.

11.2 Conclusions

The cropping systems simulation model developed in this study can be a very useful tool in the design and testing of cropping systems. Its primary usefulness is in the evaluation of a particular cropping pattern in terms of economic profitability, stability of economic returns, and efficiency of labor utilization. As demonstrated in Chapter 10, the model can be used in several other ways such as for the comparison of economic performance of a cropping pattern under unfavorable and favorable weather and price conditions; comparison between intensive and non-intensive cropping patterns; etc.

Specifically, the uses and capabilities of the model are: (1) it can evaluate the profitability of a cropping pattern and show the most profitable levels of inputs; (2) it can evaluate the stability of economic returns of a cropping pattern to rainfall variations; (3) it can be used to evaluate the economic stability of a cropping pattern to price fluctuations; (4) it can determine whether a particular cropping pattern is biologically viable on the basis of predicted yields; (5) it can determine the detailed labor utilization by operation for each crop and the labor utilization of the whole cropping pattern broken down by family labor and hired labor.

While the present model is specifically applicable to upland areas in Batangas province, Philippines, it can be adapted to other upland areas with the appropriate modifications in the relevant parameters. Furthermore, it can easily be revised for application to lowland areas with irrigation as a controllable input.

Despite its potential uses, the model developed thus far must be considered tentative in view of certain limitations which are due to lack of reliable data; to the lack of expertise on the part of the researcher on agronomic and biological aspects of cropping systems; and to the specific computer program developed for the model.

In view of the preliminary nature of the model, no particular recommendations are suggested for Cale, Batangas. It may simply be noted that on the basis of the assumptions adopted in this study the experiments have shown that rice in combination with legumes show a lot of potential in Batangas.

The model in this study was designed primarily to answer the questions of "what if" rather than to answer the question of "why". That is, it attempts to determine what will be the performance of a particular cropping pattern if it were subjected to certain levels of inputs and the normal variability of rainfall and crop prices in the study area. It does not attempt to answer why the farmer adopts a particular cropping pattern and how he determines the level of inputs he uses.

A model which deals with the latter type of questions requires a much more elaborate model because it would have to include behavioral aspects of the farm and the household. These behavioral aspects are mostly concerned with decision making processes.

A model which incorporates behavioral aspects with respect to land allocation, input use, output allocation, investment funds allocation, income allocation, etc. would be a powerful policy tool since more control or policy variables would be at the policy maker's disposal to affect the performance of the farm. Among them are crop prices, input prices, markets, extension, and credit.

In building a more comprehensive model, the present model could serve as an integral component. Its role would be as a link between the behavioral aspects, that is, the decision criteria for the determination of cropping pattern, input levels, land allocation and that of technical aspects, namely, the determination of the farm performance given the cropping pattern, land allocation and input levels.

It is apparent that the principal bottleneck in the model building process has been the lack of data. Indeed one contribution of the present research has been to identify data needs when a farming unit is viewed in a systems context. The rate at which the model can be improved depends on how fast the required data could be made available. This in turn depends on whether or not a concious effort is made to obtain the data. Data generation would be very slow indeed if we only hope passively that agronomists and economists would produce the necessary data in the course of pursuing their own research interests. It is therefore necessary to have a unified research program that would incorporate priority areas of study. Some suggestions for further research are discussed in the next and final section.

It should be understood, however, that the suggestions for further research are not necessarily for the sake of model building. The outcome of the various research efforts would be interesting in themselves and would be useful for other purposes.

Another point which needs underscoring is that a more realistic and useful model would result from a multidisciplinary effort where the expertise from various disciplines are pooled together in one research endeavor. Perhaps a major stumbling block that must be overcome towards this effort is to give crop simulation models more credibility. It has been observed that the non-quantitatively inclined practictioners are skeptical about the value of simulating agricultural processes using the computer. It is therefore important to emphasize the fact that a model may not currently be as useful as desired primarily because the state of data availability has still a lot to be desired. It is not implied that the model could never be made useful regardless of the amount of improvements done.

Perhaps a significant by-product of the whole modeling exercise is that it attempted to bring together a host of known information about agronomic, biological and economic aspects of cropping systems. It also helped point out gaps in information and therefore helps identify additional area for further research.

Finally, it is concluded that the use of crop simulation models in the near future is not likely to be widespread. Although it has been shown to be a useful tool, considerable effort has still to be done in terms of improving the model structure; improving the estimates of parameters and coefficients; and generating the data needed for model specification and estimation of the parameters.

11.3 Suggestions for Further Research

The model developed in this study was shown to have some potential as an aid in the design and testing of cropping systems which can help improve the economic returns of farmers from their small farms; give them a more stable farm income; and improve their family labor utilization. However, there are a number of characteristics of the model which presently limit its usefulness. Some of the limitations are concerned with the structure of the model itself which could be improved by better model specification. The other limitations are concerned with the accuracy of the parameters used in the model. In either case, further research can be of great help towards the improvement of the model.

In this section some suggestions for improving the structure of the cropping systems simulation model and suggestions for further research needed for the generation of data for the model are discussed. These suggestions may be divided into the following categories: (1) those related to crop-soil-environment relationships; (2) those concerning economic relationships; and (3) those concerning the structure of the model itself.

11.3.1 Crop-Soil-Environment Relationships

In crop simulation models the interrelationships between the crop and the various factors affecting its performance occupies a prominent role. It is therefore important that the model be able predict yield and other performance variables to a reasonable degree of accuracy given a specific set of soil and environmental influences which the crop is subjected to. The ability of a model to accurately predict depends to a large extent on how the model is specified and on the availability and reliability of the data used.

In many cases, important components maybe omitted from the models primarily because it is not possible to estimate the required parameters due to lack of reliable data. In this regard the crop scientists such as the agronomists, entomologists, plant physiologists and others would play a vital role not only in the modelling aspect but also in the generation of data needed for estimation of parameters and coefficients of various relationships.

The crop-soil-environment interrelationships are embodied in the production component of this study. The purpose of the component is to predict the yield of various crops depending on the particular set of factors affecting it. Thus the model must take into account not only the direct effects of the various factors affecting yield but also the interrelationships among factors. Some of the factors were identified in Chapter 6. These included: variety of the crop; soil type; fertilizer level; degree of land preparation; weed population and weed control; degree of insect and pest attack and the level of control; degree of post-planting cultivation; soil moisture level as affected by rainfall, irrigation, evapotranspiration, and water losses through seepage, runoff and direct evaporation; solar radiation; temperature; and atmospheric humidity.

As pointed out in Chapter 6, each of the above factors may have direct and/or indirect effects on yield. Hence, it is important to know quantitatively not only the differential effects of each factor on yield but also the interrelationships among the factors.

It is recognized that some scattered research has been done on the effects of certain factors on the yield of some crops by a number of research institutions in the Philippines and elsewhere. While these provide us with valuable information, further studies are needed on the factors which have been left out and also on other crops. An ideal approach to achieve this is to undertake a unified research program whereby the effects of each relevant factor as well as of the interrelationships among factors on the yield of various crops are systematically studied. This would of course entail large amounts of financial and human resources and would involve a considerable amount of time.

Specifically, the suggested priority areas for further research are as follows:

1. The effects of weed population on yield. Research on this aspect should focus on three related studies. First, the effects of different densities and types of weeds on yield must be determined. Secondly, the quantitative effects of different soil types and levels of fertilizer, land preparation, post-planting cultivation, and soil moisture on the weed population needs to be investigated. Finally, the effects of various forms of weed control (manual, mechanical, and chemical) on weed population needs to be quantified.

2. The effects of various degrees of insect and pest attack on the yield of various crops. Research on this area requires the determination of the degree of insect and pest attack corresponding to the population and types of insects and pests attacking the crop. It is also essential to determine the population level and types of insects and pests attacking the crop which could be dependent on a number of factors including weed population, soil moisture, temperature, humidity and time of the year. Finally, the effects of various forms of insect and pest control on the population level, degree of damage, and hence yield must be investigated. Research on these related areas would improve the capability of the model is accounting for the effects of insect and pest control of crop yield.

3. The effects of fertilizer on yield. Although this area has been reasonably well-investigated for most of the crops considered in this study, further research should be done on the interrelationships of fertilizer with other factors. One is the effect of solar radiation

on the yield response of crops to nitrogen fertilizer. Another is the interrelationship between soil moisture and fertilizer levels of crop yield, particularly the efficiency of fertilizer utilization under extremes of soil moisture conditions. Finally, more attention should be given on the effects of various levels of other elements particularly phosphorus and potassium on the yield of various crops. These studies will help greatly in improving the accuracy of the model parameters pertaining to fertilizer application.

4. Effects of various moisture conditions on crop yield. The effects of various soil moisture conditions on yield has been relatively well studied for rice. Research efforts should now emphasize other crops. This research should enable the determination of the optimal moisture requirements of each crop for the entire growing period. More importantly, it should make possible the determination of the quantitative effects of too much or too little soil moisture on yield particularly since upland areas are affected by both extremes at different times of the year. This would help identify the tolerance characteristics of crops for drought and excessive moisture as well as to quantify the differential effects of various degrees of drought stress and excessive moisture on yield. Further research on this area will make possible a more realistic accounting of the effects of various moisture regimes on yield instead of the simplistic assumption in this study of one drought stress level for all crops.

A related area which needs further study concerns the determination of soil moisture level, given the soil type, topography, rainfall pattern, and the particular crop grown. Specifically, the study should make possible the construction of realistic water-balance models for each soil type. Among the information that would be useful are: parameters on seepage, run-off, and water retention capacity characteristics of each soil type; parameters on direct evaporation of soil moisture; and evapotranspiration characteristics of various crops during different stages of crop growth. The results of this research would enable us to obtain more accurate measures of available soil moisture as it affects the growth and yield of a crop. It would also enable the introduction of irrigation water into the model as a policy variable in controlling soil moisture.

5. Specific crop combinations. There are also some possible interrelationships resulting from the sequential growing of crops as opposed to monoculture which should be investigated. For example, land preparation and weeding times may be reduced if one crop is immediately followed by another crop. Weed and insect populations may also be affected by specific sequences of crops. Another possibility is that fertilizer requirements of a crop may be reduced due to residual fertilizer from a previous crop.

6. Inter-cropping. Although inter-cropping was not formally included in this study, it is an important farming practice which warrants possible inclusion into the model. If included, however, a host of additional data would be necessary. Hence, more research effort must be devoted on intercropping.

7. Further work on the rainfall generator. In the rainfall generator developed in this study the incomplete gamma distribution function was used. Although it generally fared better in goodness-of-fit

comparisons with the lognormal and normal distributions and also showed a close correspondence with the actual rainfall data in the area of study, further improvements are possible. The possibility of using one distribution function for certain weeks of the year and other distribution function for certain weeks of the year and other distribution functions for other weeks may result in better rainfall simulation. This follows from the fact that the Chi-square tests have shown that for certain weeks of the year, the lognormal distribution fits the data better than the incomplete gamma distribution.

Another area which needs further study is on the possibility of generating rainfall for periods longer than one week in view of the fact that the tests of independence showed that auto-correlation among weekly data exists. Another possibility is the generation of rainfall on a weekly basis but taking account for the fact that adjacent weekly observations may not be independent from one another.

8. <u>The decision to plant behavior of farmers</u>. In this model, the decision as to when to plant was assumed to depend on the weekly rainfall and on the condition that plowing and harrowing (land preparation) have been used. The latter is also dependent on the rainfall during the week. While these observations are supported by facts other hypotheses could be forwarded concerning the decision to plant behavior of farmers. One is that farmers would plant depending on their expectations regarding rainfall based on past year's rainfall and the rainfall during the preceding weeks.

11.3.2 Economic Relationships

In this study, economic relationships are involved only in the computation of costs and returns and the determination of labor utilization and hiring. The allocation of land to various crops and the level of input use are pre-determined and the model proceeds to compute various performance variables under varying rainfall and price conditions. On the basis of the means and variances of selected performance variables, a cropping pattern is judged to be superior to other patterns. It is felt that this procedure is very similar to research on cropping system design as they are actually practiced in experimental and field plots.

In the present model, the components involving economic relationships are the price generator, the labor component, and the crop accounting component. Some directions for improving these components and further research are as follows:

1. Price generator. Although the use of seasonal price indexes is perhaps sufficient for the purposes of the study, alternative methods of price generation which give more emphasis on current trends rather than historical prices should be looked into. Since the non-deterministic generation of prices depend on measures of means and variances of prices, a study of price indexes would also be very useful.

Another area which needs attention is on the price movements of farm inputs and wage rates. If a seasonal pattern can be discerned from past data then some form of seasonal indexes could be computed and incorporated into the price generator. This would lend it more realism rather than the constant prices assumed for farm inputs and wages throughout the year in this study.

2. Labor component. The improvements that can be made on the labor component would mostly be in the form of better measures of labor requirements of various operations by crop. This could perhaps be achieved by more precise methods of observing actual labor use instead of estimates based on recall. Since the distribution of total labor requirements during the growing season by time is crucial in the decision to hire additional labor, more attention should be given along this aspect. Finally, there are operations which depend on the level of output (harvesting, threshing, husking, shelling) and on the level of inputs (spraying and fertilizing). Here, more accurate measures of labor requirement per unit of input or output would be valuable.

11.3.3 Suggested Revisions in the Model Structure

When the farm is looked at as a system where biological, technical, and economic interrelationships are well defined, then a systems model can provide us with the useful tool in the improvement of the farm as a business entity. Given a set of control variables and performance variables, the systems model maps out the effects of changes in control variables on the performance of the system.

The set of control variables may be divided into two types: those controllable by the farmer and those controllable from the point of view of policy makers. When the model is used at the farm level, the latter could be assumed as given. Conversely, from the policy point of view, the former is assumed as given or affected by the latter.

A suggested modification is therefore the inclusion of those components mentioned in Chapter 2 but were omitted. These are mostly those describing economic behavior of farmers, particularly decision making. This would then change the capabilities of the model from that of testing and design of cropping patterns to a complete analysis of the farm business.

If it were possible to construct a model which incorporates decision making, what would be the value of such a model? The model would be very useful in finding ways to improve the farm. If we know the controllable factors or the policy variables then we can investigate how the alteration of these factors can influence the performance of the farm business. For example, if land allocation is controllable, then we can theoretically determine the optimal land allocation that will maximize net returns of the farm. Note that the way the problem is specified is similar to linear programming models.

Another value of the model would be to help us understand why a farmer adopts one particular cropping pattern rather than another. We could trace this to several factors, perhpas relating to land allocation, labor availability, cash requirements, investment opportunities, and exogenous factors such as markets, availability of farm inputs, etc.

A model which incorporates decision-making processes must as a minimum include a submodel for land allocation (how land is allocated among various crops at a given time); a sub-model for input use (how the levels of fertilizer, weeding, insect and pest control per unit of land area are decided upon); a sub-model for output disposal (how total output is allocated among home consumption, sales and other uses); a sub-model for income allocation (how income is allocated among household expenditures, savings, and re-investment to the farm business); a sub-model for investment (how available investment funds are allocated to various uses: acquisition of additional land, farm machinery, equipment, current inputs, etc.) There are additional decisions to be made aside from the above-mentioned ones. These include decisions as to when planting should start, alternative strategies when the first crop fails; and marketing decisions especially if the product price periodically fluctuates.

With the above components it would be possible to determine endogenously those variables which are predetermined in the current model, namely, land allocation, level of fertilization, weeding, and insect and disease control. If one were to build a satisfactory model incorporating the various components, it is obvious that considerable effort will be required. For each decision that has to be made there are a multitude of factors that have to be considered. How each factor influences the decision; how much weight the factor carries; and how the form of the decision function is specified must be carefully investigated, tested and validated.

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APPENDIX I

TIME BY OPERATION MATRICES OF LABOR UTILIZATION BY CROPS

APPENDIX I

TIME BY OPERATION MATRICES OF LABOR UTILIZATION BY CROPS

The following tables show the labor requirement of each crop by time and by operation. All planting operations are assigned to time period 6. The following are the codes used for each operation:

Code	Operation
1	Plowing
2	Harrowing
3	Other land preparation
4	Furrowing
5	Seeding/planting
6	Fertilizing
7	Off-barring
8	Weeding
9	Spraying
10	Other care
11	Harvesting
12	Threshing/husking

Appendix Table I.1. Rice: Time by operation matrix of labor utilization.[a]

Time period	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	32.0												32.0
2	18.7	6.3											25.0
3	18.7	6.3											25.0
4		6.3	17.9										24.2
5			17.9	14.7									32.8
6		4.7			14.5								19.2
7													
8		4.7											4.7
9						11.9		11.6	4.0				27.5
10		4.7						11.7					16.4
11						11.9		11.7					23.6
12		4.7						11.8	4.0				20.5
13						11.9		20.2					32.1
14							5.7	20.2					25.9
15								20.2	4.0				24.2
16								20.2					20.2
17								20.2					20.2
18								20.2	4.0				24.2
19								20.2					20.2
20													
21													
22											128.0		128.0
23											128.0	14.6	142.6
24												14.6	14.6
Total	69.4	37.7	35.8	14.9	14.5	35.7	5.7	188.2	16.0	-	256.0	29.2	703.1

[a]Missing figures denote zero labor utilization.

Source: Calculated from Cale Weekly surveys I and II, 1973-74 and 1974-75.

Appendix Table I.2. Corn: Time by operation matrix of labor utilization.[a]

Time	Operation												
period	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	11.7												11.7
2	11.7	6.5											18.2
3	11.7	6.5											18.2
4			27.0										27.0
5				18.1									18.1
6					44.4								44.4
7													
8							14.2						14.2
9													
10							14.2						14.2
11								6.5					6.5
12						14.9							14.9
13								6.4					6.4
14													
15													
16													
17													
18											17.5		17.5
19											17.4	39	56.4
20												39	39.0
21													
22													
23													
24													
Total	35.1	13.0	27.0	18.1	44.4	14.9	28.4	12.9		0	34.9	78	306.7

[a]Missing figures denote zero labor utilization.

Source: Calculated from Cale weekly surveys I and II, 1973-74 and 1974-75.

Appendix Table I.3. Sorghum: Time by operation matrix of labor utilization.[a]

Time period	Operation 1	2	3	4	5	6	7	8	9	10	11	12	Total
1													
2													
3	30.5												30.5
4	30.5	9.0											39.5
5		9.0	12.0										21.0
6				29.0	45.0		17.0						91.0
7						17.0							17.0
8										9.0			9.0
9								29.0					29.0
10							17.0						17.0
11						17.0							17.0
12								29.0					29.0
13										9.0			9.0
14													
15								29.0					
16													
17													
18													
19													
20											94.0		94.0
21											94.0	34.0	128.0
22												34.0	34.0
23													
24													
Total	61.0	18.0	12.0	29.0	45.0	34.0	34.0	87.0		18.0	188.0	68.0	594.0

[a] Missing figures denote zero labor utilization.

Source: Calculated from Cale Weekly Surveys I and II, 1973-74 and 1974-75.

Appendix Table I.4. Mung Bean: Time by operation matrix of labor utilization.[a]

Time period	Operation 1	2	3	4	5	6	7	8	9	10	11	12	Total
1													
2													
3	26.0												26.0
4	26.0	13.4											39.4
5		13.4	1.6										15.0
6				14.4	43.2								57.6
7							11.6						11.6
8							11.6						11.6
9						28.8							28.8
10								9.6		5.4			15.0
11								9.6					9.6
12										5.4			5.4
13													0.0
14											128.0		128.0
15											128.0	36.0	164.0
16											128.0	36.0	164.0
17												36.0	36.0
18													
19													
20													
21													
22													
23													
24													
Total	52.0	26.8	1.6	14.4	43.2	28.8	23.2	19.2		10.8	384.0	108.0	711.6

[a]Missing figure denote zero labor utilization.

Source: Calculated from Cale Weekly Surveys I and II, 1973-74 and 1974-75.

Appendix Table I.5. Cowpea: Time by operation by labor utilization.[a]

Time	Total Operation												Total
period	1	2	3	4	5	6	7	8	9	10	11	12	
1													
2													
3	26.0												26.0
4	26.0	16.0											42.0
5		16.0	8.0										24.0
6				13.0	54.0								67.0
7										7.0			19.0
8						10.0		12.5					22.5
9							12.0			7.0			19.0
10													
11						10.0	12.0			7.0			10.0
12								12.5					7.0
13													12.5
14													
15													
16											68.0		68.0
17											68.0	34.0	102.0
18											68.0	34.0	102.0
19												34.0	34.0
20													
21													
22													
23													
24													
Total	52.0	32.0	8.0	13.0	54.0	20.0	24.0	25.0		21.0	204.0	102.0	555.0

[a]Missing figures denote zero labor utilization.

Source: Calculated from Cale Weekly Surveys I and II, 1973-74 and 1974-75.

Appendix Table I.6. Peanut: Time by operation matrix of labor utilization.[a]

Time period	Operation 1	2	3	4	5	6	7	8	9	10	11	12	Total
1													
2													
3	20.4												20.4
4	14.3	4.7											19.0
5		4.7	5										9.7
6			-	12.8	50.0		9.0						71.8
7						40.4			5.0				45.4
8								45.0					16.6
9							16.6						48.4
10						40.4			8.0				45.0
11								45.0					9.0
12									9.0				
13													
14													
15													
16													
17													
18													
19										150.0			150.00
20										150.0			150.00
21											100.0		100.00
22													
23													
24													
Total	34.7	9.4	5.0	12.8	50.0	80.8	25.6	90.0	22.0	300.00	100.00		729.00

[a]Missing figures denote zero labor utilization.

Source: Calculated from Cale Weekly Surveys I and II, 1973-74 and 1974-75.

Appendix Table I.7. Soybean: Time by operation matrix of labor utilization.[a]

Time	Operation												
period	1	2	3	4	5	6	7	8	9	10	11	12	Total
1													
2													
3	25.0												25.0
4	14.1	20.0											34.1
5		17.2	10.0										27.2
6				13.0	47.0								60.0
7						35.2	67.2						102.4
8													
9								8.9					8.9
10													
11								9.0					9.0
12													
13													
14													
15													
16													
17											84.0		84.0
18											84.0	27.6	111.6
19												27.6	27.6
20													
21													
22													
23													
24													
Total	39.1	37.2	10.0	13.0	47.0	35.2	67.2	17.9			168.0	55.2	489.8

[a]Missing figures denote zero labor utilization.

Source: Calculated from Cale Weekly Surveys I and II, 1973-74 and 1974-75.

Appendix Table I.8. Sweet Potato: Time by operation matrix of labor utilization.[a]

Time period	1	2	3	4	5	6	7	8	9	10	11	12	Total
1													
2	26.0												26.0
3	26.0	16.0											42.0
4		16.0											16.0
5			10.8										10.0
6				26.5	90.3		8.2						125.0
7										7.0			7.0
8						40.0							40.0
9										7.0			7.0
10										7.5			7.5
11						40.0	16.3						56.3
12								10.0					10.0
13								10.0					10.0
14													
15													
16													
17													
18													
19													
20													
21													
22											102.0		102.0
23											102.0		102.0
24													
Total	52.0	32.0	10.8	26.5	90.3	80.0	24.5	20.0		21.5	204.0		561.6

[a]Missing figures denote zero labor utilization.

Source: Calculated from Cale Weekly Surveys I and II, 1973-74 and 1974-75.

APPENDIX II

FORTRAN SOURCE PROGRAM OF THE COMPUTER SIMULATION MODEL

FORTRAN SOURCE PROGRAM OF THE COMPUTER SIMULATION MODEL

```
      PROGRAM CSSMS(INPUT,OUTPUT,TAPE60=INPUT,TAPE61=OUTPUT)
C     MAIN PROGRAM CSSMS.
C     ******************
C        THIS IS THE EXECUTIVE ROUTINE OF THE CROPPING SYSTEMS
C     SIMULATION MODEL.  EIGHT CROPS WITH TWO PLANTING PERIODS
C     PER CROP ARE MODELED .
C        THIS COMPUTER PROGRAM IS PRELIMINARY AND WILL BE SUBJECT
C     TO A NUMBER OF REVISIONS.  THIS VERSION WAS USED IN THE
C     STUDY ENTITLED SYSTEMS ANALYSIS ANS SIMULATION OF RICE-
C     BASED MULTIPLE CROPPING SYSTEMS IN THE PHILIPPINES.
C        *************DEVELOPED BY  TIRSO B. PARIS, JR.
C
C   * * * * * * *  COMMON STATEMENTS  * * * * * * * * * * * *
C
      COMMON/ACC    / EXFERT(8,2),EXSEED(8,2),EXOTH(8,2),EXHT(8,2),
     1                EXRNT(8,2),TEXP(8,2),VPROD(8,2),GPROF(8,2),
     2                EXHLAB(8,2),TPROD(8,2),EXCHEM(8,2),
     3                TPROF,ECA,THLEX,TFEX,TSDEX,TOTHEX,TRNTEX,
     4                THTEX,TOTEXP,TVP,TCHMEX
      COMMON/COND   / A(8,2),PD(8,2),FAR(8,2),HL(8,2),DCL(8,2),ND(8,2)
      COMMON/CONTR  / NRUN,NPER,NCROP,IRUN,IYR,IROPT,IPOPT,DELT,
     1                LVR,IX,DL,PSW,RSW,LSW,KP1,KP2,MODE,LVINP,INPUT
      COMMON/FCNVAL/  NMLVAL(41)
      COMMON/LAB    / TLAB(52),AVLAB(52),HLAB(52),XLAB(8,2),YLAB(8,2),
     1                TXOM(24,12,8),RLOP(8,2,12),HLPUD(8),PHL(8),
     2                TTLAB,THLAB
      COMMON/LABEL  / NAME(8),CSSM(10),TITLE(10),OPER(2,12),NPAGE
      COMMON/LEVELS/  ARG1(8),ARG2(6),ARG3(8),ARG4(10),ARG5(5),
     1                ARG6(5),YMAX(8)
      COMMON/PRDAT  / BP(8),PNOX(12,8),PSDEV(12,8),PFERT(12),WR(12),
     1                PDELT(8),IFORM(8),PCROP(8,2),CPFERT(8,2),WAGE(8,2),
     2                AVOTH(8),SF(8),PSEED(8),IHW(8,2),SHT,SL
      COMMON/RNHIST/  HRAIN(28,52),NTRNH(15),NTRNM(15),NTRNL(15),EV(52),
     1                NLWKS(3)
      COMMON/RNPAR  / RNMEAN(52),FSDEV(52),GP(52),BETA(52)
      COMMON/RRATES/  RDR1(8,8),RDR2(6,8),RDR3(8,8),RDR4(10,8),
     1                RDR5(5,8),RDR6(5,8)
      COMMON/ STAGE/  NW(3,8),OW(8,2,3),CMP(8)
      COMMON/SUMRY  / PVAR1(8,2,40),PVAR2(8,2,40),PVAR3(8,2,40),
     1                PVAR4(8,2,40),PVAR5(8,2,40),PVAR6(8,2,40),
     2                PVAR7(8,2,40)
      COMMON/TMPDAT/  HRN1(208),HRN2(208),HRN3(208),HRN4(208),HRN5(208),
     1                HRN6(208),HRN7(208)
      COMMON/YIELD  / YLD(8,2)
      INTEGER CMP,PD,PSW,RSW,LSW,OW
      REAL NMLVAL,NAME
C
C   * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C   SUBSCRIPTS FOR CROPS
C        1. RICE
C        2. CORN
C        3. SORGHUM
C        4. MUNGBEAN
C        5. COWPEA
C        6. PEANUT
C        7. SOYBEAN
C        8. SHEET POTATO
C   OPTIONS MEANINGS
C          NRUN  = NO. OF RUNS
C          NPER  = NO. OF TIME PERIODS
C          NCROP = NO. OF CROPS
C          IRUN  = CURRENT RUN NUMBER
C          IROPT = RAINFALL GENERATOR OPTION (SEE SUBROUTINE RNGEN)
C          IROPT = RAINFALL GENERATOR OPTION (SEE SUBROUTINE RNGEN)
C          IPOPT = PRICE TREND ADJUSTMENT OPTION
C          LVR   =RAINFALL LEVEL DESIRED IF IROPT =4
C          IX    = INITIAL INTEGER FOR THE RANDOM NUMBER GENERATOR
C          RSW   = RANDOM SWITCH FOR PRICE GENERATOR
C          PSW   = PLANTING DATE ADJUSTMENT OPTION
C          LSW   = TYPE OF FARM OWNERSHIP
C          KP1   = PRINTING OPTION (SHORT OR LONG PRINTOUT)
C          KP2   = SWITCH FOR STATISTICAL SUMMARY
C          IYR   = YEAR SELECTED IF RAINFALL OPTION IS IROPT=3
C          MODE  = MODE OF SIMULATION RUN (SEE SUBROUTINE CONTRL)
C          INPUT = INPUT VARIED WHILE HOLDING OTHERS FIXED
C          LVINP = LEVEL OF OTHER INPUTS (G,L,M,H,OTHER)
C          DL    = DROUGHT LEVEL IN INCHES
```

```
C        DELT   = LEVEL OF INCREMENTATION OF INPUT FOR MODE=2
      CALL CONTRL
      DO 100 IRUN=1,NRUN
      IF(IRUN.GT.1) GO TO 10
      CALL CONTR1
      GO TO 20
   10 CALL CONTR2
   20 CALL RNGEN
      CALL PRODN
      CALL PRGEN
      CALL LABOR
      CALL CROPAG
      CALL PRINT
  100 CONTINUE
      IF(KP2.NE.1) GO TO 1000
      CALL SUMMA
C    DEFINITION OF VARIABLES
C
C        A      = AREA (HA.)
C        PD     = PLANTING DATE
C        FAR    = FERTILIZER APPLICATION RATE (KG.N/HA)
C        WL     = WEED CONTROL LEVEL (MAN-HOURS/HA.)
C        DCL    = INSECT AND DISEASE CONTROL LEVEL ($/HA)
C        EXFERT= FERTILIZER EXPENSES
C        EXSEED= SEED EXPENSE
C        EXOTH  = OTHER INPUTS EXPENSE
C        EXHT   = HARV & THRESH EXPENSE
C        EXRNT  = LAND RENT
C        TEXP   = TOTAL EXPENSE
C        VPROD  = VALUE OF PRODUCTION
C        GPROF  = GROSS PROFIT
C        TPROF  = TOTAL PROFIT
C        TLAB   = TOTAL LABOR UTILIZED (MAN-HOURS/WK)
C        AVLAB  = AVAILABLE FAMILY LABOR (MAN-HOURS/WK)
C        HLAB   = HIRED LABOR (MAN-HOURS/WK)
C        RLPHA  = LABOR REQUIRED PER HECTARE BY WEEK
C        XLAB   = TOTAL LABOR USED BY CROP
C        TTLAB  = TOTAL LABOR USED BY PATTERN
C        THLAB  = TOTAL HIRED LABOR BY PATTERN
C        NMLVAL= ORDINATES OF THE INVERSE NORMAL CUMULATIVE DIST.
C        NAME   = CROP LABELS
C        ARGP   = LEVELS OF INPUTS FOR WHICH REDUCTION RATES ARE GIVEN
C        YMAX   = MAXIMUM YIELDS
C        BP     = BASE PRICE OF EACH CROP
C        PNDX   = MONTHLY PRICE INDEX
C        RDR1   = REDUCTION RATES FOR FERTILIZER
      CONTINUE
C        RDR2   = REDUCTION RATES FOR WEED CONTROL
C        RDR3   = REDUCTION RATES FOR INSECT CONTROL
C        RDR4   = REDUCTION RATES FOR DROUGHT - VEGETATIVE STAGE
C        RDR5   = REDUCTION RATES FOR DROUGHT - REPRODUCTIVE STAGE
C        RDR6   = REDUCTION RATES FOR DROUGHT - MATURATION STAGE
C        PSDEV  = STANDARD DEVIATION OF CROP PRICES
C        WR     = MONTHLY WAGE RATES
C        PFERT  = MONTHLY FERTILIZER PRICES
C        PDELT  = CHANGE IN TREND OF PRICES PER YEAR
C        IFORM  = FORM OF TREND LINE : 1=LINEAR, 2=EXPONENTIAL
C        PCROP  = PRICE OF CROP AT HARVEST
C        CPFERT= PRICE OF FERTILIZER AT PLANTING
C        AVOTH  = AVERAGE OTHER EXPENSES
C        SR     = SEEDING RATES
C        SHT    = HARVESTERS AND THRESHER'S SHARE
C        SL     = LANDLORD SHARE
C        HRAIN  = HISTORICAL WEEKLY RAINFALL
C        NTRNH  = ARRAY OF YEARS WITH HIGH TOTAL RAINFALL
C        NTRNH  = ARRAY OF YEARS WITH MEDIUM TOTAL RAINFALL
C        NTRNL  = ARRAY OF YEARS WITH LOW TOTAL RAINFALL
C        EV     = AVERAGE EVAPORATION PER WEEK
C        RNMEAN= AVERAGE RAINFALL PER WEEK
C        RSDEV  = STANDARD DEVIATION OF WEEKLY RAINFALL
C        GP     = GAMMA PARAMETER OF THE INCOMPLETE GAMMA FUNCTION
C        BETA   = BETA PARAMETER OF THE INCOMPLETE GAMMA FUNCTION
C        NW     = NUMBER OF WEEKS OF EACH CROP STAGE
C        DW     = NUMBER OF DROUGHT WEEKS IN EACH CROP STAGE
C        CMP    = CROP MATURITY PERIOD
C
 1000 STOP
      END
```

```
      SUBROUTINE CONTRL
C     ----------------
C   THIS SUBROUTINE SETS THE DEFAULT VALUES OF OPTIONS, READS THE
C   DESIRED CHANGES IN OPTIONS, SETS THE MODE OF OPERATION OF THE
C   MODEL, AND INITIALIZES THE LEVEL OF INPUTS.
C
C   SIMULATION RUN MODES --
C       MODE 1 - AREA, PLANTING DATE, AND INPUT LEVELS FOR EACH
C                CROP ARE SPECIFIED BY THE USER. THESE ARE INDICATED
C                IN POLICY CARDS, ONE CARD PER CROP. RAINFALL OPTION
C                IS ALSO SPECIFIED BY THE USER IN THE OPTION CARD.
C       MODE 2 - A SPECIFIED INPUT IS VARIED INTERNALLY WITH INCREMENTS
C                CHOSEN BY THE USER.  OTHER INPUTS ARE HELD FIXED
C                EITHER AT ZERO, LOW, MEDIUM OR HIGH LEVELS OR SOME
C                OTHER LEVELS DESIRED BY THE USER.  PLANTING DATES
C                AND RAINFALL PATTERN ARE HELD CONSTANT.
C       MODE 3 - PLANTING DATES ARE VARIED BETWEEN RUNS WHILE HOLDING
C                INPUT LEVELS AND RAINFALL PATTERN FIXED.
C       MODE 4 - RAINFALL PATTERNS ARE VARIED BETWEEN RUNS WHILE
C                HOLDING INPUT LEVELS AND PLANTING DATES FIXED.
C
      COMMON/CONTR / NRUN,NPER,NCROP,IRUN,IYR,IROPT,IPOPT,DELT,
     1               LVR,IX,DL,PSW,RSW,LSW,KP1,KP2,MODE,LVINP,INPUT
      COMMON/COND  / A(8,2),PD(8,2),FAP(8,2),WL(8,2),DCL(8,2),NJ(8,2)
      COMMON/RNHIST/ HRAIN(28,52),NTRNH(15),NTRNM(15),NTRNL(15),EV(52),
     1               NLWKS(3)
      COMMON/LAB   / TLAB(52),AVLAB(52),HLAB(52),XLAB(8,2),YLAB(8,2),
     1               TXOM(24,12,3),RLOP(8,2,12),HLPUO(8),PHL(8),
     2               TTLAB,THLAB
      COMMON/LABEL / NAME(8),CSSM(10),TITLE(10),OPER(2,12),NPAGE
      COMMON/TMPDAT/ HRN1(208),HRN2(208),HRN3(208),HRN4(208),HRN5(208),
     1               HRN6(208),HRN7(208)
      INTEGER CMP,PO,PSW,RSW,OW
C
C   SET DEFAULT VALUES OF OPTIONS
C
      NCROP=8
      NPER =2
      MODE =1
      IROPT=1
      LVR  =2
      IPOPT=1
      LVINP=5
      INPUT=1
      PSW  =0
      RSW=0
      DELT=20
      KP1  =0
      KP2  =0
      DL   =.49
      IX=1523749
C   READ OTHER DATA NOT INCLUDED IN BLOCKDATA
C
      DO 1010 I=1,4
      DO 1010 J=1,52
      K =(I-1)*52+J
 1010 HRAIN(I,J)=HRN1(K)
      DO 1020 I=5,8
      DO 1020 J=1,52
      K=(I-5)*52+J
 1020 HRAIN(I,J)=HRN2(K)
      DO 1030 I=9,12
      DO 1030 J=1,52
      K=(I-9)*52+J
 1030 HRAIN(I,J)=HRN3(K)
      DO 1040 I=13,16
      DO 1040 J=1,52
      K=(I-13)*52+J
 1040 HRAIN(I,J)=HRN4(K)
      DO 1050 I=17,20
      DO 1050 J=1,52
      K=(I-17)*52+J
 1050 HRAIN(I,J)=HRN5(K)
      DO 1060 I=21,24
      DO 1060 J=1,52
      K=(I-21)*52+J
 1060 HRAIN(I,J)=HRN6(K)
```

```
      DO 107 I=25,27
      DO 107  J=1,52
      K=(I-25)*52+J
  107. HRAIN(I,J)=HRN7(K)
C
C   READ RUN NAME
C
      READ 6,(TITLE(I),I=1,10)
    6 FORMAT(10A8)
C
C
C   READ NUMBER OF RUNS
C
      READ 5, NRUN
    5 FORMAT(I5)
      RETURN
C
C      RUN INITIALIZATION
C
      ENTRY CONTR1
C     ------------
C   READ CHANGES IN OPTIONS FROM NAMELIST CARD
C
      READ 7, IX,MODE,IROPT,LVR,INPUT,LVINP,PSW,RSW,
     1        LSW,KP1,KP2,IPOPT,IYR,DL,DELT
    7 FORMAT(I9,11I1,I4,F6.2,F5.1)
C
C   INITIALIZE INPUTS ACCORDING TO MODE OF RUN
C
      ENTRY CONTR2
C     ------------
      GO TO(20,40,40,40),MODE
C
C   --- MODE 1
C
   20 DO 25 I=1,8
      DO 25 J=1,2
   25 READ 30,A(I,J),PD(I,J),FAR(I,J),WL(I,J),DCL(I,J)
   30 FORMAT(F5.1,I5,3F5.0)
      GO TO 250
C
C   SET INPUT LEVELS TO HIGH, MEDIUM, LOW, ZERO OR SOME OTHER LEVELS
C      LVINP- 1= OTHER FIXED LEVELS
C             2= ZERO LEVELS
C             3= LOW LEVELS
C             4= MEDIUM LEVELS
C             5= HIGH LEVELS
   40 IF(IRUN.NE.1)GO TO 140
      GO TO(50,60,80,100,120),LVINP
C
C   --- READ INPUT LEVELS TO BE FIXED
   50 DO 55 I=1,NCROP
      DO 55 J=1,NPER
   55 READ 30,A(I,J),PD(I,J),FAR(I,J),WL(I,J),DCL(I,J)
      GO TO 140
C
C   --- ZERO LEVELS
   60 DO 65 I=1,NCROP
      DO 65 J=1,NPER
      A(I,J)=1.
      FAR(I,J)=0.
      WL(I,J)=0.
   65 DCL(I,J)=0.
      GO TO 140
C
C   --- LOW LEVELS
   80 DO 85 I=1,NCROP
      DO 85 J=1,NPER
      A(I,J)=1.
      FAR(I,J)=20.
      WL(I,J)=30.
   85 DCL(I,J)=100.
      GO TO 140
C
C   --- MEDIUM LEVELS
  100 DO 105 I=1,NCROP
      DO 105 J=1,NPER
```

```
      A(I,J)=1.0
      FAR(I,J)=60.0
      WL(I,J)=60.0
  105 DCL(I,J)=300.0
      GO TO 140
C
C  --- HIGH LEVELS
  120 DO 125 I=1,NCROP
      DO 125 J=1,NPER
      A(I,J)=1.0
      FAR(I,J)=100.
      WL(I,J)=100.
  125 DCL(I,J)=600.
C
C  SET DESIRED OPTIONS FOR EACH MODE
C
  140 GO TO(250,160,200,240),MODE
C
C  --- MODE 2- VARY LEVELS OF INPUTS
C
  160 IF(IRUN.NE.1)GO TO 170
      READ 165,((PO(I,J),I=1,8),J=1,2)
      DO 161 I=1,NCROP
      DO 161 J=1,NPER
  161 NO(I,J)=PO(I,J)
  165 FORMAT(16I5)
  170 IF(INPUT-2)175,180,185
C
C     --- FERTILIZER
  175 CURNT= DELT*FLOAT(IRUN-1)
      DO 176 I=1,NCROP
      DO 176 J=1,NPER
  176 FAR(I,J)=CURNT
      GO TO 250
C
C     --- WEEDING LABOR LEVEL
  180 CURNT= DELT*FLOAT(IRUN-1)
      DO 181 I=1,NCROP
      DO181 J=1,NPER
  181 WL(I,J)=CURNT
      GO TO 250
C
C     --- INSECT CONTROL LEVEL
  185 CURNT= DELT*FLOAT(IRUN-1)
      DO 186 I=1,NCROP
      DO 186 J=1,NPER
  186 DCL(I,J)=CURNT
      GO TO 250
C
C  --- MODE 3- VARY PLANTING DATES
C
  200 READ 211, ((PO(I,J),I=1,8),J=1,2)
  211 FORMAT(16I5)
      DO 212 I=1,NCROP
      DO 212 J=1,NPER
  212 NO(I,J)=PO(I,J)
      GO TO 250
C
C  --- MODE 4- VARY RAINFALL PATTERN
C
  240 IF(IRUN.NE.1) GO TO 250
      READ 211,((PO(I,J),I=1,NCROP),J=1,NPER)
      DO 241 I=1,NCROP
      DO 241 J=1,NPER
  241 NO(I,J)=PO(I,J)
C
C  PRINT OPTIONS IN EFFECT
C
  250 IF(IRUN.NE.1) GO TO 280
      NPAGE=NPAGE+1
      PRINT 260,(DSSM(I),I=1,6),NPAGE,IRUN,(TITLE(J),J=1,10)
  260 FORMAT(1H1,6A8,10X,*PAGE *,I3/1X,*RUN NO.*,I3,* - *,10A8/)
      PRINT 270,MODE,IPOPT,LVR,IYR,INPUT,LVINP,RSW,PSW,LSW,
     *      KP1,KP2,IPOPT,DELT,DL
  270 FORMAT(1X,*OPTIONS IN EFFECT*//10X,*MODE     =*,I5//10X,
     1   *IPOPT    =*,I5//10X,*LVR      =*,I5//10X,*IYR      =*,I5//10X,
     2   *INPUT    =*,I5//10X,*LVINP    =*,I5//10X,*RSW      =*,I5//10X,
     3   *PSW      =*,I5//10X,*LSW      =*,I5//10X,*KP1      =*,I5//10X,
     4   *KP2      =*,I5//10X,*IPOPT    =*,I5//10X,*DELT     =*,F8.2//10X,
     5   *DL       =*,F8.2)
  280 RETURN
      END
```

```
      BLOCK DATA
      COMMON/FCNVAL/ NMLVAL(41)
      COMMON/LAB   / TLAB(52),AVLAB(52),HLAB(52),XLAB(8,2),YLAB(8,2),
     1               TXOM(24,12,6),RLOP(8,2,12),HLPUO(8),PHL(8),
     2               TTLAB,THLAB
      COMMON/LEVELS/ ARG1(8),ARG2(6),ARG3(8),ARG4(10),ARG5(5),
     1               ARG6(5),YMAX(8)
      COMMON/LABEL / NAME(8),CSSM(10),TITLE(10),OPER(2,12),NPAGE
      COMMON/PRDAT / BP(8),PNOX(12,8),PSDEV(12,8),PFERT(12),WR(12),
     1               PDELT(8),IFORM(8),PCROP(3,2),CPFERT(3,2),WAGE(8,2),
     2                AVDTH(8),SR(8),PSEED(8),IHW(8,2),SHT,SL
      COMMON/RNHIST/ HRAIN(28,52),NTRNH(15),NTRNM(15),NTRNL(15),EV(52),
     1               NLWKS(3)
      COMMON/RNPAR / RNMEAN(52),FSDEV(52),GP(52),BETA(52)
      COMMON/RFATES/ ROR1(8,8),ROR2(6,8),ROR3(8,8),ROR4(10,8),
     1               ROR5(5,8),ROR6(5,8)
      COMMON/ STAGE/ NW(3,3),DW(3,2,3),CMP(8)
      COMMON/TMPDAT/ HRN1(2 8),HRN2(2,8),HRN3(208),HRN4(208),HRN5(208),
     1               HRN6(2,8),HRN7(208)
      INTEGER CMP,PD,PSW,RSW,LSW,DW
      REAL NMLVAL,NAME
      DATA NMLVAL/
     1       -3.500,   -1.960,   -1.645,   -1.439,   -1.281,   -1.150,
     2       -1.037,    -.925,    -.841,    -.755,    -.674,    -.599,
     3        -.524,    -.454,    -.386,    -.312,    -.253,    -.189,
     4        -.126,    -.056,     .000,     .056,     .126,     .189,
     5         .253,     .312,     .386,     .454,     .524,     .598,
     6         .674,     .755,     .841,     .925,    1.037,    1.150,
     7        1.281,    1.439,    1.645,    1.960,    3.500/
      DATA AVLAB/
     1           52*112.8/
      DATA NAME/ 8HPALAY   ,8HCORN    ,8HSORGHUM ,8HMUNGBEAN,
     1           8HCOWPEA  ,8HPEANUT  ,8HSOYBEAN ,8HS.POTATO/
      DATA CSSM/
     1    8HCSSM 3- ,8H     CRO,8HPPING SY,8HSTEMS SI,
     2    8HMULATION,8H MODEL   /
      DATA OPER/
     1    8HPLOWING ,8H        ,8HHARROWIN,8HG       ,
     2    8HOTHER LA,8HND PREP.,8HFURROWIN,8HG       ,
     3    8HPLANTING,8H        ,8HOFF-BARR,8HING     ,
     4    8HFERTILIZ,8HING     ,8HWEEDING ,8H        ,
     5    8HSPRAYING,8H        ,8HOTHER CA,8HRE      ,
     6    8HHARVESTI,8HNG      ,8HPOST-HAR,8HVEST    /
      DATA ARG1/  0., 20., 40., 60., 80.,100.,120.,140./,              FERT
     1     ARG2/  0., 20., 40., 60., 80.,100./,                        WEEDING
     2     ARG3/  0.,100.,200.,300.,400.,500.,600.,700./,              CHEMEX
     3     ARG4/  0.,  1.,  2.,  3.,  4.,  5.,  6.,  7.,  8.,  9./,    VEGETAT
     4     ARG5/  0.,  1.,  2.,  3.,  4./,                             REPRODUC
     5     ARG6/  0.,  1.,  2.,  3.,  4./                              MATURITY
      DATA YMAX/      4.0, 4.0, 4.5, 1.5, 2.0, 3.5, 2.5, 20.0    /
      DATA BP    / 1.20, 1.10, 1.05, 4.90, 4.90, 3.20, 2.90, 1.02 /
      DATA PNOX/
     1     101., 96., 96., 96., 97., 97., 99.,102.,103.,104.,102.,101.,   RICE
     2     103.,100., 97.,100.,103.,107.,104., 95., 95., 96., 99.,101.,   CORN
     3     103.,100., 97.,100.,103.,107.,104., 95., 95., 96., 99.,101.,   SORG
     4     108.,105., 97., 96., 95., 95., 97., 99.,100.,102.,102.,104.,   MUNG
     5     108.,105., 97., 96., 95., 95., 97., 99.,100.,102.,102.,104.,   COWP
     6     103.,102.,100., 98., 96., 96., 98., 99.,100.,102.,102.,103.,   PEAN
     7      97., 98., 99.,101.,101.,102.,103.,102.,100.,101., 98., 93.,   SOYB
     8      99., 91., 95., 95., 96., 99.,102.,106.,104.,109.,100.,104./   SWPT
      DATA PSDEV/
     1           12*.25,
     2           12*.25,
     3           12*.30,                                                  CORN
     4           12*.30,                                                  MUNG
     5           12*.25,                                                  COWP
     6           12*.25,                                                  PEAN
     7           12*.25,                                                  SOYB
     8           12*.20/                                                  SWPT
      DATA PFERT/
     1           12*6.50/                                                X
      DATA WR/
     1           12*.875/                                                X
      DATA PSEED/
     1     1.50,1.50,1.50,5.00,5.00,3.50,3.00,.003/
      DATA PDELT/
     1          1.10, 1.10, 1.10, 1.11, 1.11, 1.12, 1.06, 1.10/
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      DATA IFORM/     8*2 /
      DATA AVOTH/     200.,200.,250.,250.,250.,250.,250.,200.     /,
     1     SR   /     115., 45., 71., 40., 25., 30., 45., 40000. /,
     2     SHT  /.142857/,SL/.333334/
      DATA HLPUO/.0893,.175,.0627,.2560,.1023,.1000,.0840,.0136/
      DATA PHL  /.0100,.26[illegible],.0227,.0720,.0510,.0333,.0276,.0300/
      DATA NTRNH/  4, 12, 13, 14, 18, 23, 24, 27, 7*99           /,
     1     NTRNM/  2,  3,  5,  8, 11, 16, 19, 22, 25, 6*99       /,
     2     NTRNL/  1,  6,  7,  9, 10, 15, 17, 20, 21, 6*99       /,
     3     NLWKS/  8,  9,  9  /
      DATA EV/
     1     1.04,      1.07,      1.11,      1.14,      1.20,      1.24,
     2     1.32,      1.39,      1.44,      1.52,      1.55,      1.63,
     3     1.71,      1.73,      1.66,      1.64,      1.57,      1.48,
     4     1.44,      1.46,      1.43,      1.35,      1.31,      1.25,
     5     1.18,      1.12,      1.15,      1.12,      1.07,      1.03,
     6     1.02,       .95,       .99,      1.00,      1.07,      1.06,
     7     1.05,       .99,       .98,       .99,       .99,       .94,
     8      .94,       .91,       .91,       .87,       .95,       .95,
     9      .95,       .95,      1.01,      1.01/
C WEEKLY RAINFALL MEANS ARRAY (AMBULONG DATA, 1948-75
C
      DATA RNMEAN/
     1          0.51,      0.19,      0.11,      0.13,      0.12,      0.07,
     2          0.11,      0.13,      0.20,      0.22,      0.21,      0.13,
     3          0.11,      0.17,      0.27,      0.34,      0.69,      0.86,
     4          1.02,      1.35,      1.40,      1.67,      1.62,      1.45,
     5          1.90,      2.81,      1.93,      2.31,      3.42,      2.27,
     6          2.50,      3.15,      2.63,      1.84,      2.65,      3.37,
     7          1.61,      2.42,      1.55,      2.36,      2.43,      2.25,
     8          1.24,      1.45,      1.21,      1.32,      1.85,      1.53,
     9          1.13,      1.16,      0.93,      1.16/
      DATA RSDEV/
     1          1.23,      0.26,      0.29,      0.20,      0.24,      0.11,
     2          0.28,      0.25,      0.31,      0.43,      0.46,      0.33,
     3          0.32,      0.17,       .51,      0.56,      0.92,      1.38,
     4          1.29,      1.75,      1.58,      2.35,      1.97,      1.53,
     5          1.48,      3.27,      1.48,      2.31,      4.25,      2.15,
     6          2.11,      2.43,      2.15,      1.67,      2.38,      4.58,
     7          0.87,      1.74,      1.37,      2.21,      2.45,      2.56,
     8          1.43,      2.68,      1.11,      1.49,      2.30,      1.82,
     9          1.01,      1.28,      1.49,      1.71/
      DATA HRN1/
     1 0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.11,0.0 ,0.0 ,0.41,0.36,0.23,0.0 ,0.03, AMB1949
     2 0.0 ,0.0 ,0.0 ,0.14,0.13,0.38,0.01,0.0 ,0.15,0.0 ,0.0 ,0.72,1.83, AMB1949
     3 0.53,0.04,1.36,1.51,2.75,1.42,0.55,0.83,0.47,2.57,3.21,1.68,2.94, AMB1949
     4 6.22,2.11,1.53,2.34,2.98,2.83,0.55,0.18,0.32,1.70,0.09,0.38,2.82, AMB1949
     1 0.48,0.51,0.0 ,0.29,0.08,0.16,0.03,0.00,0.0 ,0.0 ,1.67,1.39,0.0 , AMB1950
     2 0.01,0.54,1.36,3.02,0.65,1.71,1.00,0.62,1.07,1.67,1.09,1.71,1.16, AMB1950
     3 2.52,1.75,1.29,1.46,3.56,5.38,1.84,2.14,0.55,2.04,1.76,6.30,1.38, AMB1950
     4 3.03,1.06,2.20,0.51,0.21,0.48,3.03,0.81,0.05,0.0 ,0.09,1.03,3.41, AMB1950
     1 0.03,0.0 ,0.0 ,0.12,0.0 ,0.05,0.31,0.09,0.0 ,0.0 ,0.0 ,0.0 ,0.0 , AMB1951
     2 0.0 ,0.23,0.57,0.72,0.77,0.34,2.33,0.15,0.19,0.76,1.97,3.33,1.13, AMB1951
     3 0.60,1.15,2.53,1.79,7.17,0.32,3.33,3.65,1.30,5.25,0.0 ,1.40,0.44, AMB1951
     4 0.79,3.36,1.36,0.38,0.18,1.47,0.34,4.97,5.95,1.32,2.65,0.08,0.14, AMB1951
     1 0.14,0.03,0.10,0.20,0.11,0.22,0.0 ,0.30,0.50,0.50,0.08,0.02,0.0 , AMB1952
     2 0.0 ,1.31,0.0 ,0.26,0.59,3.41,2.34,4.03,0.05,0.13,0.82,3.27,1.05, AMB1952
     3 1.40,0.0 ,0.34,3.23,1.36,7.79,3.96,5.44,3.03,0.61,1.61,0.55,0.37, AMB1952
     4 3.54,2.75,3.66,6.19,3.23,1.41,0.51,0.23,0.08,0.04,2.66,5.96,1.43/ AMB1952
      DATA HRN2/
     1 0.0 ,0.49,0.0 ,0.09,0.01,0.23,1.33,0.26,0.27,0.32,0.02,0.22,0.0 , AMB1953
     2 0.0 ,0.0 ,1.3 ,0.35,1.31,1.17,0.40,2.28,4.18,2.46,1.17,0.51,1.14, AMB1953
     3 2.35,0.15,1.33,2.36,0.68,3.33,3.1 ,2.54,1.85,1.44,1.53,3.45,1.74, AMB1953
     4 0.33,0.43,1.07,3.58,3.29,0.14,2.05,0.45,2.87,3.83,0.52,3.42,0.17, AMB1953
     1 0.07,0.45,0.01,0.0 ,0.0 ,0.17,0.0 ,0.05,0.04,1.71,0.19,0.15,0.25, AMB1954
     2 0.0 ,0.32,0.0 ,0.25,1.91,0.04,0.03,0.96,0.23,0.21,0.96,0.19,1.3 , AMB1954
     3 1.33,1.07,0.97,2.48,1.07,4.47,4.37,0.44,3.21,0.15,1.49,1.31,2.29, AMB1954
     4 2.77,4.37,2.88,0.39,0.97,1.83,0.13,0.0 ,1.30,0.35,0.26,0.07,3.41, AMB1954
     1 1.40,0.36,0.21,0.04,0.17,0.0 ,0.01,0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.0 , AMB1955
     2 0.18,0.28,0.12,0.44,0.0 ,0.0 ,2.49,0.55,0.25,0.56,0.72,1.32,2.05, AMB1955
     3 2.45,1.13,0.03,1.84,1.01,1.04,1.46,0.49,0.24,0.21,1.27,4.31,1.04, AMB1955
     4 2.74,1.71,4.64,0.97,2.30,1.41,3.48,0.53,4.37,0.0 ,3.44,0.0 ,0.04, AMB1955
     1 0.01,0.13,0.35,0.11,0.0 ,0.0 ,0.03,0.0 ,3.15,0.0 ,0.0 ,0.0 ,0.0 , AMB1956
     2 0.36,1.67,0.0 ,0.08,0.35,0.93,1.99,0.31,0.92,1.95,3.63,0.28,0.41, AMB1956
     3 0.34,1.24,3.47,0.01,5.67,2.30,1.44,4.05,8.13,8.24,2.92,2.75,1.07, AMB1956
     4 0.58,2.64,2.72,1.93,3.29,0.00,2.04,0.02,3.27,5.12,0.56,3.47,1.1 / AMB1956
      DATA HRN3/
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1 1.80,0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.81,0.0 ,0.97,0.12,0.0 ,0.0 ,  AMB1957
2 0.02,0.15,0.0 ,0.13,0.0 ,0.58,0.0 ,0.0 ,0.33,1.18,0.72,1.69,1.28,  AMB1957
3 3.71,2.79,0.01,0.03,3.72,0.16,3.03,0.93,2.02,1.51,0.76,1.98,0.59,  AMB1957
4 1.33,0.39,0.55,0.33,0.0 ,0.07,0.11,0.17,1.5 ,0.06,0.14,0.0 ,0.03,  AMB1957
1 0.04,0.15,0.05,0.54,0.0 ,0.15,0.0 ,0.0 ,0.2 ,0.0 ,0.0 ,0.0 ,0.0 ,  AMB1958
2 0.0 ,0.0 ,0.0 ,0.63,1.75,0.0 ,0.0 ,0.0 ,9.99,2.53,0.18,0.0 ,0.55,  AMB1958
3 2.33,8.92,1.35,0.01,1.78,0.54,0.74,1.10,2.13,0.14,0.44,2.27,0.27,  AMB1958
4 1.39,0.22,4.24,1.35,0.0 ,0.24,0.48,0.44,0.21,0.0 ,0.22,0.01,0.0 ,  AMB1958
1 0.01,0.02,0.0 ,0.11,0.03,0.11,0.01,0.0 ,0.73,0.17,0.14,0.0 ,0.0 ,  AMB1959
2 0.0 ,0.0 ,0.0 ,0.0 ,0.05,0.01,1.59,0.97,0.0 ,0.77,2.14,1.93,2.14,  AMB1959
3 1.11,5.13,5.16,4.59,4.03,2.76,3.20,1.03,1.49,4.23,0.44,0.04,2.04,  AMB1959
4 2.39,0.0 ,0.39,0.09,0.12,2.33,6.06,0.62,0.25,2.19,0.0 ,4.53,3.37,  AMB1959
1 0.50,0.19,0.02,0.15,0.53,0.47,0.55,0.07,0.0 ,0.0 ,0.07,0.0 ,0.0 ,  AMB1960
2 0.12,0.0 ,1.25,2.77,0.05,2.71,0.24,5.35,3.35,0.24,0.55,2.37,7.57,  AMB1960
3 0.44,0.62,1.25,0.53,4.11,0.53,5.07,0.22,3.65,3.69,3.00,0.85,2.08,  AMB1960
4 3.10,6.83,0.33,1.33,0.04,0.45,2.12,0.0 ,0.22,0.10,0.53,0.0 ,0.0 /  AMB1960
 DATA HRN4/
1 0.0 ,0.0 ,0.38,0.03,0.07,0.01,0.09,0.39,0.0 ,0.98,0.15,0.0 ,0.0 ,  AMB1961
2 0.04,0.04,0.54,0.05,0.65,1.25,5.07,2.38,0.22,1.81,1.02,3.18,4.99,  AMB1961
3 1.02,0.92,4.05,0.50,0.0 ,0.71,3.57,3.37,0.55,1.45,1.29,6.54,0.22,  AMB1961
4 1.59,7.21,2.10,0.07,0.26,0.73,0.09,6.73,0.0 ,0.94,0.05,0.25,0.12,  AMB1961
1 0.09,0.0 ,0.0 ,0.0 ,0.0 ,0.08,0.03,0.0 ,0.13,0.0 ,0.02,0.0 ,0.0 ,  AMB1962
2 0.17,0.08,2.69,0.14,0.90,0.04,1.05,0.73,2.43,0.66,2.24,1.42,0.24,  AMB1962
3 2.20,1.40,9.99,3.49,1.95,0.16,1.33,1.09,3.82,9.99,1.85,3.93,4.12,  AMB1962
4 1.31,0.80,0.42,0.24,0.29,0.41,0.53,6.33,2.35,0.24,0.06,0.03,0.74,  AMB1962
1 0.05,0.0 ,0.0 ,0.0 ,0.0 ,0.03,0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.06,0.0 ,  AMB1963
2 0.0 ,0.03,0.0 ,0.0 ,0.0 ,0.0 ,0.07,1.09,1.84,3.65,2.62,1.92,1.55,  AMB1963
3 0.30,2.50,1.04,2.30,0.57,2.09,4.24,3.00,1.79,6.76,1.94,2.68,2.32,  AMB1963
4 2.05,0.28,0.21,0.26,0.44,0.0 ,0.11,0.07,0.14,0.10,3.41,0.70,0.16,  AMB1963
1 0.07,0.0 ,0.0 ,0.0 ,0.08,0.32,0.07,0.0 ,0.87,0.0 ,0.07,0.0 ,0.13,  AMB1964
2 0.0 ,0.03,0.0 ,0.17,0.08,0.0 ,0.15,0.95,0.0 ,0.0 ,0.82,3.07,9.99,  AMB1964
3 1.40,5.84,1.79,1.02,0.47,2.49,1.73,4.21,0.25,0.25,2.28,0.73,5.60,  AMB1964
4 2.50,0.94,1.52,2.18,0.11,0.35,1.99,2.95,4.51,0.29,2.79,3.12,0.13/  AMB1964
 DATA HRN5/
1 0.0 ,0.10,0.13,0.10,0.11,0.0 ,0.0 ,0.0 ,0.13,0.05,0.0 ,0.0 ,0.0 ,  AMB1965
2 0.0 ,0.0 ,0.00,1.24,0.11,0.34,1.12,2.51,0.68,1.49,1.98,0.61,0.83,  AMB1965
3 0.20,0.16,3.47,0.13,1.33,0.63,0.95,1.01,4.21,3.71,1.27,2.03,0.17,  AMB1965
4 2.62,0.14,0.30,0.02,0.34,1.79,0.30,0.21,0.35,0.77,0.68,0.50,0.35,  AMB1965
1 0.09,0.17,0.12,0.21,0.0 ,0.19,0.0 ,0.54,0.03,0.0 ,0.0 ,0.0 ,1.55,  AMB1966
2 0.0 ,0.0 ,0.33,0.0 ,2.33,4.46,7.93,4.83,0.93,0.29,0.97,3.57,1.55,  AMB1966
3 2.13,2.36,2.71,0.58,2.85,0.58,0.29,0.45,1.29,9.83,2.46,1.17,0.26,  AMB1966
4 0.39,0.14,1.06,0.23,0.0 ,0.77,1.92,5.50,5.29,0.94,0.12,0.35,7.12,  AMB1966
1 1.94,0.89,1.41,0.0 ,0.02,0.0 ,0.0 ,0.0 ,0.94,0.74,0.0 ,0.0 ,0.00,  AMB1967
2 0.0 ,0.0 ,0.63,0.09,0.0 ,0.0 ,1.51,0.0 ,2.75,5.30,1.35,5.56,6.82,  AMB1967
3 0.56,0.47,1.45,2.79,1.51,3.05,4.90,1.35,5.53,1.32,0.67,4.19,0.75,  AMB1967
4 0.82,2.01,0.82,0.27,9.99,1.40,0.03,0.03,0.34,0.0 ,0.0 ,0.0 ,0.0 ,  AMB1967
1 0.10,0.05,0.0 ,0.08,0.01,0.0 ,0.0 ,0.0 ,0.04,0.11,0.0 ,0.0 ,0.0 ,  AMB1968
2 0.0 ,0.21,0.0 ,1.56,0.02,0.93,0.25,1.38,2.94,1.34,0.51,1.25,1.83,  AMB1968
3 0.49,0.58,5.91,4.15,0.75,4.00,2.55,1.01,2.29,1.18,4.40,4.65,5.93,  AMB1968
4 0.49,1.02,2.78,0.19,0.0 ,0.0 ,0.0 ,2.16,0.05,0.75,0.05,0.0 ,0.0 /  AMB1968
 DATA HRN6/
1 0.0 ,0.16,0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.02,0.63,0.0 ,0.69,  AMB1969
2 0.10,0.0 ,0.0 ,0.25,0.36,0.10,1.11,0.23,0.87,1.37,0.55,2.53,1.73,  AMB1969
3 2.49,1.11,4.49,4.59,2.65,1.95,0.54,0.46,1.74,1.39,2.79,1.96,1.14,  AMB1969
4 0.33,1.52,1.29,0.0 ,0.11,0.0 ,1.14,1.84,0.02,1.36,2.41,2.07,0.13,  AMB1969
1 0.73,0.0 ,0.0 ,0.0 ,0.0 ,0.13,0.0 ,0.13,0.05,0.0 ,0.0 ,0.35,0.0 ,  AMB1970
2 0.33,0.07,0.06,2.10,0.12,0.0 ,0.74,0.77,1.60,0.73,1.63,3.96,0.56,  AMB1970
3 0.12,5.65,2.08,0.91,2.21,2.67,0.59,0.69,8.81,2.34,2.24,0.05,1.53,  AMB1970
4 1.59,0.39,1.64,1.20,5.62,1.02,1.11,4.23,0.95,0.13,1.91,0.22,0.69,  AMB1970
1 0.0 ,0.0 ,0.0 ,0.06,0.04,0.01,0.11,0.0 ,0.0 ,0.0 ,1.76,0.0 ,0.0 ,  AMB1971
2 0.0 ,0.03,0.0 ,0.51,1.99,0.94,1.17,2.41,1.42,1.83,7.88,2.97,3.31,  AMB1971
3 4.45,6.35,6.30,0.93,0.70,1.70,0.17,0.79,3.27,0.64,0.95,1.06,0.59,  AMB1971
4 8.03,5.04,0.07,0.03,3.01,0.42,1.79,3.22,1.09,6.13,2.10,1.37,2.83,  AMB1971
1 0.30,0.34,0.0 ,0.32,1.07,0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.35,0.05,0.13,  AMB1972
2 0.0 ,0.44,0.0 ,0.46,0.33,0.83,0.57,2.47,3.22,1.68,0.49,3.59,3.58,  AMB1972
3 2.84,1.68,9.99,9.99,8.64,0.74,2.00,0.91,1.25,1.46,0.89,3.29,1.67,  AMB1972
4 0.42,0.84,0.30,1.97,0.57,0.28,2.63,0.22,0.81,1.36,1.47,0.0 ,0.0 /  AMB1972
 DATA HRN7/
1 0.0 ,0.03,0.0 ,0.13,0.28,0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.05,  AMB1973
2 0.0 ,0.21,0.07,0.03,0.67,0.62,1.33,0.21,1.71,1.25,3.43,0.11,1.05,  AMB1973
3 2.41,4.59,0.0 ,0.33,1.72,7.76,2.33,5.31,1.54,2.00,1.45,1.59,1.55,  AMB1973
4 1.35,1.39,3.73,0.07,0.27,3.22,0.77,5.69,1.55,2.53,3.40,1.92,0.76,  AMB1973
1 0.0 ,0.03,0.09,0.0 ,0.0 ,0.0 ,0.0 ,0.0 ,0.03,0.0 ,0.69,0.0 ,0.0 ,  AMB1974
2 0.0 ,0.0 ,0.0 ,0.12,0.58,0.92,0.27,0.14,0.0 ,9.24,1.37,3.07,3.23,  AMB1974
3 3.15,0.69,5.15,0.21,3.72,7.15,9.99,0.14,0.05,0.04,0.82,0.51,0.27,  AMB1974
4 1.27,1.41,9.99,2.37,6.87,0.73,4.41,0.13,2.03,1.02,3.57,3.13,1.19,  AMB1974
1 0.0 ,0.03,0.69,0.0 ,0.0 ,0.0 ,0.03,0.0 ,0.83,0.0 ,0.09,0.0 ,0.0 ,  AMB1975
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2 0.0 ,0.0 ,0.0 ,0.12,0.58,0.92,3.27,3.14,0.0 ,9.24,1.37,0.07,3.23, AMB1975
3 3.15, .69,3.15,0.11,3.72,7.15,9.99,0.14,0.75,0.04,0.82,0.51,0.27, AMB1975
4 1.27,1.41,9.99,0.37,6.37,0.73,4.41,0.18,2.08,1.02,3.57,3.18,1.19/ AMB1975
 DATA   GP/
1 0.3275594,  0.3779326,  0.2917789,  0.4201998,  0.3286116,  0.4110012,
2 0.2943837,  0.2826344,  0.3309923,  0.2635133,  0.3131185,  0.2473299,
3 0.2691122,  0.3124365,  0.3184635,  0.2687677,  0.5032091,  0.4439376,
4 0.3075204,  0.5535393,  0.4016949,  0.5155974,  0.6069952,  1.0737438,
5 0.8860822,  1.1943132,  1.5041761,  0.8220082,  0.6400241,  1.0401487,
6 1.0658245,  1.3223157,  1.4835244,  1.3409433,  1.1122610,  0.8313003,
7 1.3721352,  2.0672255,  1.3915773,  1.4725552,  0.7083137,  1.2031818,
8 0.6886656,  0.3545505,  0.5321453,  0.6274967,  0.4715967,  0.5801916,
9 0.4332460,  0.4804293,  0.3541663,  0.3723643/
 DATA   BETA/
1 0.9076441,  0.4681132,  0.3862345,  0.2425581,  0.2996285,  0.1955818,
2 0.3762678,  0.4702034,  0.6253204,  0.7779339,  0.6829550,  0.5153971,
3 0.4240299,  0.2393033,  0.8695453,  1.2922211,  1.2297335,  1.9534857,
4 2.7659273,  2.4553213,  2.9110421,  3.3033382,  2.4566622,  1.3539934,
5 2.2093725,  2.3462095,  1.2633896,  2.8607163,  5.3351269,  2.1790447,
6 2.3975392,  1.7231594,  1.7640033,  1.3753185,  2.3449039,  4.0561972,
7 1.2537975,  1.1701678 , 1.1444435,  1.6023912,  3.1542025,  2.0395499,
8 1.7994566,  4.0917311,  2.0884218,  2.1066523,  3.9163094,  2.6337357,
9 2.7493477,  2.3870873,  2.5444326,  3.1131468/
 DATA NW/
1                 11,    2,    5,    7,    3,    3,    9,    3,
2                  3,    5,    3,    3,    3,    3,    3,    7,
3                  3,    4,    5,    3,    5,   11,    2,    5/
 DATA CMP/
1            17,  13,   15,   10,   12,   14,   11,    8/
 DATA RDR1/
1                .50,  .35,  .22,  .12,  .05,  .02,  .00,  .02,                      X
2                .50,  .35,  .22,  .12,  .05,  .02,  .00,  .02,                      X
3                .50,  .35,  .22,  .12,  .05,  .02,  .00,  .02,                      X
4                .30,  .20,  .10,  .02,  .00,  .00,  .02,  .10,                      X
5                .30,  .20,  .10,  .02,  .00,  .00,  .02,  .10,                      X
6                .40,  .30,  .20,  .10,  .05,  .00,  .00,  .00,                      X
7                .30,  .20,  .10,  .02,  .00,  .00,  .02,  .10,                      X
8                .40,  .30,  .20,  .10,  .05,  .00,  .00,  .00/                      X
 DATA RDR2/
1                .20,  .15,  .10,  .05,  .02,  .00,                                  X
2                .20,  .15,  .10,  .05,  .02,  .00,                                  X
3                .20,  .15,  .10,  .05,  .02,  .00,                                  X
4                .20,  .15,  .10,  .05,  .02,  .00,                                  X
5                .20,  .15,  .10,  .05,  .02,  .00,                                  X
6                .20,  .15,  .10,  .05,  .02,  .00,                                  X
7                .20,  .15,  .10,  .05,  .02,  .00,                                  X
8                .30,  .20,  .15,  .10,  .05,  .00/                                  X
 DATA RDR3/
1                .10,  .05,  .04,  .03,  .02,  .01,  .00,  .00,
2                .15,  .07,  .06,  .05,  .04,  .03,  .02,  .00,
3                .15,  .05,  .04,  .03,  .02,  .01,  .00,  .00,
4                .20,  .08,  .06,  .05,  .04,  .03,  .02,  .01,
5                .20,  .08,  .06,  .05,  .04,  .03,  .02,  .01,
6                .20,  .08,  .06,  .05,  .04,  .03,  .02,  .01,
7                .20,  .05,  .05,  .04,  .03,  .02,  .01,  .00,
8                .10,  .03,  .02,  .01,  .00,  .00,  .00,  .00/
 DATA RDR4/
1                .00,  .00,  .01,  .03,  .05,  .10,  .15,  .20,  .50,  .99,
2                .00,  .01,  .03,  .06,  .05,  .10,  .20,  .50,  .99,  .99,
3                .00,  .00,  .01,  .03,  .05,  .10,  .15,  .20,  .50,  .99,
4                .00,  .00,  .02,  .03,  .04,  .20,  .99,  .99,  .99,  .99,
5                .00,  .00,  .02,  .03,  .04,  .20,  .99,  .99,  .99,  .99,
6                .00,  .00,  .02,  .03,  .05,  .10,  .50,  .99,  .99,  .99,
7                .00,  .00,  .02,  .03,  .06,  .08,  .99,  .99,  .99,  .99,
8                .00,  .00,  .01,  .02,  .03,  .05,  .10,  .15,  .50,  .70/
 DATA RDR5/
1                .00,  .03,  .07,  .20,  .99,
2                .00,  .03,  .07,  .20,  .99,
3                .00,  .03,  .07,  .20,  .99,
4                .00,  .03,  .07,  .10,  .99,
5                .00,  .03,  .07,  .10,  .99,
6                .00,  .03,  .07,  .10,  .99,
7                .00,  .03,  .07,  .10,  .99,
8                .00,  .01,  .02,  .03,  .99/
 DATA RDR6/
1                .00,  .02,  .05,  .10,  .15,
2                .00,  .02,  .05,  .10,  .12,
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```
3            .00, .02, .05, .10, .12,
4            .00, .01, .03, .07, .10,
5            .00, .01, .03, .07, .10,
6            .00, .01, .03, .07, .10,
7            .00, .01, .03, .07, .10,
8            .00, .01, .02, .04, .08/
 END
```

```
      SUBROUTINE RNGEN
C     ----------------
C         THIS SUBROUTINE HAS THE FOLLOWING FUNCTIONS:
C           A. TO GENERATE WEEKLY RAINFALL TO BE USED IN A SIMULATION
C              RUN. THE OPTIONS AVAILABLE ARE:(1) TO GENERATE THE
C              RAINFALL PATTERN BASED ON PARAMETERS OF AN INCOMPLETE
C              GAMMA DISTRIBUTION FOR EACH WEEK SYNTHESIZED FROM ACTUAL
C              DATA; (2) TO RANDOMLY SELECT A YEAR BETWEEN 1949 AND 1975
C              AND TO USE THE HISTORICAL RAINFALL DATA OF THE AMBULONG
C              WEATHER STATION FOR THAT YEAR AS THE RAINFALL PATTERN
C              FOR THE SIMULATION RUN:(3) TO USE THE RAINFALL PATTERN OF
C              A PRE-SPECIFIED YEAR; AND (4) TO RANDOMLY SELECT A HIGH,
C              MEDIUM OR LOW RAINFALL YEAR BETWEEN 1949 AND 1975 AND TO
C              USE ITS HISTORICAL RAINFALL IN THE SIMULATION RUN.
C              (5) TO USE AVERAGE WEEKLY RAINFALL OF THE AMBULONG
C              WEATHER STATION FROM 1949-75 AS RAINFALL PATTERN FOR
C              THE SIMULATION RUN
C           B.     TO ADJUST, IF NECESSARY, THE PLANTING DATES OF EACH OF
C              EACH CROP DEPENDING ON THE RAINFALL PATTERN AS WELL AS
C              HARVEST DATES OF THE FIRST CROPS.
C           C.     TO DETERMINE THE WEEKLY AVAILABLE SOIL MOISTURE BASED
C              ON A WATER BALANCE MODEL
C           D.     TO DETERMINE THE NUMBER OF DRY WEEKS DURING EACH STAGE
C              OF CROP GROWTH (VEGETATIVE, REPRODUCTIVE, AND MATURATION)
C              BASED ON THE A.S.M. FOR EACH CROP. THESE FIGURES ARE THEN
C              PASSED ON TO THE PRODUCTION COMPONENT.
C
      DIMENSION RN(52),SM(25),ASMX(52)
      COMMON/CONO  /  A(8,2),PD(8,2),FAR(8,2),WL(8,2),OCL(8,2),ND(8,2)
      COMMON/CONTR /  NRUN,NPER,NCROP,IRUN,IYR,IROPT,IPOPT,DELT,
     1                LVR,IX,DL,PSW,RSW,LSW,KP1,KP2,MODE,LVINP,INPUT
      COMMON/RNHIST/  HRAIN(28,52),NTRNH(15),NTRNM(15),NTRNL(15),EV(52),
     1                NLWKS(3)
      COMMON/ RNPAR/  RNMEAN(52),PSDEV(52),GP(52),BETA(52)
      COMMON/ STAGE/  NW(3,8),DW(8,2,3),CMP(8)
      COMMON/LABEL /  NAME(8),CSSN(10),TITLE(10),OPER(2,12),NPAGE
      INTEGER CMP,PD,PSW,RSW,DW
C
C   INITIALIZE THE RANDOM NUMBER GENERATOR
C
      CALL RANSET(TIME(72747))
      DO 5 I=1,10
      YFL=RANF(1976 )
    5 CONTINUE
C
C   RAINFALL GENERATION
C
      GO TO (10,40,60,90,151),IROPT
C
C   OPTION 1 --- RAINFALL GENERATION BASED ON PARAMETERS OF AN
C       INCOMPLETE GAMMA DISTRIBUTION FOR EACH WEEK
   10 DO 20 I=1,52
      CALL GAMFCN(I,R)
   20 RN(I)=R
      GO TO 155
C
C   OPTION 2 --- RANDOM SELECTION OF A YEAR BETWEEN 1949-1975
C       AND USE ITS HISTORICAL RAINFALL DATA FOR THE SIMULATED YEAR
C
   40 YFL=RANF(1976 )
      J =YFL*27.+1.
      L = 0
      DO 50 I=1,52
      K=I+14
      IF(K.LE.52)GO TO 50
      L=L+1
      IF(L.EQ.1) J=J+1
      IF(J.GT.27) J=1
      K=K-52
   50 RN(K)=HRAIN(J,K)
      IF(J.EQ.1) J=J+27
      IY =1947+J
      GO TO 155
C
C   OPTION 3 --- USE RAINFALL OF PRE-DETERMINED YEAR BETWEEN 1949-
C       1975 AS RAINFALL PATTERN OF SIMULATED YEAR
C
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   60 J=IYR-1948
      L=0
      DO 70 I=1,52
      K=I+14
      IF(K.LE.52)GO TO 70
      L=L+1
      IF(L.EQ.1)J=J+1
      IF(J.GT.27) J=1
      K=K-52
   70 RN(K)=HRAIN(J,K)
      GO TO 155
C
C     OPTION 4 --- RANDOM SELECTION OF A YEAR OF A PRE-DETERMINED
C         RAINFALL LEVEL
   90 IF(LVR-2)91,101,111
   91 M=NLWKS(1)
   95 YFL=RANF(1976 )
      J=YFL*27.+1
      DO 100 I=1,M
      IF(J.EQ.NTRNH(I)) GO TO 130
  100 CONTINUE
      GO TO 95
  101 M=NLWKS(2)
  105 YFL=RANF(1976 )
      J=YFL*27.0+1.
      DO 110 I=1,M
      IF(J.EQ.NTRNM(I)) GO TO 130
  110 CONTINUE
      GO TO 105
  111 M=NLWKS(3)
  115 YFL=RANF(1976 )
      J=YFL*27.+1
      DO 120 I=1,M
      IF(J.EQ.NTRNL(I))GO TO 130
  120 CONTINUE
      GO TO 115
  130 L=0
      DO 140 I=1,52
      K=I+14
      IF(K.LE.52) GO TO 135
      L=L+1
      IF(L.EQ.1)J=J+1
      IF(J.GT.27) J=1
      K=K-52
  135 RN(K)=HRAIN(J,K)
  140 CONTINUE
      IF(J.EQ.1)J=J+27
      IYR=1947+J
      GO TO 155
C
C     OPTION 5 --- AVERAGE WEEKLY RAINFALL BASED ON AMBULONG DATA, 1949-75
C
  151 DO 152 I=1,52
  152 RN(I)= RNMEAN(I)
C
C     PRINT RAINFALL PATTERN OF SIMULATION RUN
C
  155 IF((IROPT.EQ.3.OR.IROPT.EQ.5).AND.IRUN.GT.1) GO TO 9155
      NPAGE=NPAGE+1
      PRINT 6, (CSSM(I),I=1,6),NPAGE,IRUN,(TITLE(J),J=1,10)
    6 FORMAT(1H1,6A8,10X,*PAGE *,I3/1X,*RUN NO.*,I3,* - *,10A8/)
      PRINT 7
    7 FORMAT(1X,*RAINFALL GENERATOR OUTPUT*/)
      GO TO(9060,9065,9070,9075,9080),IROPT
 9060 PRINT 30
   30 FORMAT(1H0,*OPTION NO.  1*,* - RAINFALL PATTERN BASED ON*,
     1        * PARAMETERS FROM AN INCOMPLETE GAMMA DISTRIBUTION*)
      GO TO 9150
 9065 PRINT 55, IYR
   55 FORMAT(1H0,*OPTION NO. 2 - RAINFALL PATTERN OF RANDOMLY*,
     1        * SELECTED YEAR BETWEEN 1949-1975*/22X,*YEAR = *,I4)
      GO TO 9150
 9070 PRINT 80 , IYR
   80 FORMAT(1H0,*OPTION NO. 3 - RAINFALL PATTERN OF A PRE-*,
     1        *DETERMINED YEAR (YEAR = *,I4,*)*)
      GO TO 9150
 9075 PRINT 150, IYR,LVR
```

```
 150 FORMAT(1H0,*OPTION  4 -  RAINFALL PATTERN OF RANDOMLY *,
    1       *SELECTED YEAR OF A PRE-DETERMINED LEVEL*/22X,*YEAR = *,
    2       I5/22X,*LEVEL= *,I5)
     GO TO 9155
 914 PRINT 153
 153 FORMAT(1H0,*OPTION NO. 5 - RAINFALL PATTERN BASED ON AVERAGE*,
    1       * WEEKLY*/15X,*RAINFALL, AMBULONG STATION, 1949-1975*)
 915 PRINT 156
 156 FORMAT(//1X,54(1H-)/1X,2(6X,*WEEK*,6X,*RAINFALL*,6X)/
    1       1X,54(1H-)/)
     DO 157 I=1,26
     K=I+26
 157 PRINT 158,I,RN(I),K,RN(K)
 158 FORMAT(1X,2(I9,F12.2,9X))
     PRINT 154
 154 FORMAT(/1X,54(1H-))
C
C   DETERMINE AVAILABLE SOIL MOISTURE IN EACH WEEK
C
9155 IF(KP1.NE.1) GO TO 159
     NPAGE=NPAGE+1
     PRINT 6, (CSSM(I),I=1,6),NPAGE,IRUN,(TITLE(J),J=1,10)
     PRINT 160
 160 FORMAT(1X,*AVAILABLE SOIL MOISTURE BY WEEK (INCHES)*/1H ,
    1    40(1H-)//1X,60(1H=)/6X,
    2    *WEEK      ASM(T)     ASM(T-1)     EV-TR    RAINFALL    RUNOFF*/1X,
    3    60(1H-)/)
 159 TEMP=0.
     DO 170 I= 1,52
     RO=0.
     ET=EV(I)*.8
     IF(RN(I).GT.4.02)RO=RN(I)-4.02
     ASM=TEMP-ET+RN(I)
     IF(ASM.LE.4.02) GO TO 161
     RO=RO+(ASM-4.02)
     ASM=4.02
     GO TO 162
 161 IF(ASM.LT.0.0) ASM=0.
C
C   PRINT MOISTURE BALANCE FOR EACH WEEK
C
 162 IF(KP1.NE.1)GO TO 164
     PRINT 171,I,ASM,TEMP,ET,RN(I),RO
 164 ASMX(I)=ASM
     TEMP=ASM
 170 CONTINUE
 171 FORMAT(1X,I3,2X,5F10.2)
     IF(KP1.NE.1) GO TO 173
     PRINT 172
 172 FORMAT(/1X,60(1H-))
C
C   ADJUST PLANTING DATES ACCORDING TO RAINFALL PATTERN
C       AND FIRST CROPS
C
 173 IF(PSW.NE.1) GO TO 251
     DO 250 J=1,NPER
     DO 240 I=1,NCROP
     N=NC(I,J)
     IF(N.EQ.0)GO TO 240
     IF(J.EQ.2)GO TO 200
 175 L=N-1
     IF(L.LE.0) L=L+52
     X=RN(L)
     IF(X.GT.DL)GO TO 180
     N=N+1
     GO TO 175
 180 Y=RN(N)
 185 IF(Y.GT.DL)GO TO 195
     N=N+1
     IF(N.GT.52) N=N-52
     GO TO 180
 195 PD(I,J)=N
     GO TO 240
 200 K=PD(I,1)+CMP(I)
     IF(K.GT.N.AND.(I.EQ.1.OR.I.EQ.2.OR.I.EQ.3)) N=K+2
 210 IF(N.GT.52) N=N-52
     L=N-1
```

```
      IF(L.LE.0) L=L+52
      X=AN(L)
      IF(X.GT.DL) GO TO 220
      N=N+1
      IF(N.GT.8.AND.N.LT.13) GO TO 227
      GO TO 210
  220 Y=AN(N)
  225 IF(Y.GT.DL)GO TO 230
      N=N+1
      IF(N.GT.52)N=N-52
      IF(N.GT.8.AND.N.LT.18) GO TO 227
      GO TO 220
  227 PD(I,J)=0
      GO TO 240
  230 PD(I,J)=N
  240 CONTINUE
  250 CONTINUE
C
C  DETERMINE THE NUMBER OF DRY WEEKS DURING EACH STAGE
C     OF CROP GROWTH
C
  251 DO 350 J=1,2
      DO 345 I=1,8
      NPL=PD(I,J)
      IF(NPL.EQ.0) GO TO 345
      DO 255 K=1,3
  255 DW(I,J,K)=0
      N=NMP(I)
      DO 260 IA=1,N
      L=NPL+IA
      IF(L.GT.52)L=L-52
  260 SM(IA)=ASMX(L)
      N1=0
      N2=0
      DO 340 K=1,3
      M=NW(K,I)
      N1=N2+1
      N2=N1+M-1
      DO 270 L=N1,N2
      IF(SM(L).LE.DL) DW(I,J,K)=DW(I,J,K)+1
  270 CONTINUE
  340 CONTINUE
  345 CONTINUE
  350 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PRDON
C     ----------------
C   THE MAIN FUNCTION OF THIS SUBROUTINE IS TO DETERMINE THE YIELD
C   OF EACH CROP BASED ON (1) FERTILIZER LEVEL,(2) WEED CONTROL
C   LEVEL,(3) INSECT AND DISEASE CONTROL LEVEL,(4) THE NUMBER OF
C   DRY WEEKS IN EACH STAGE OF CROP GROWTH. THE MAIN APPROACH IN
C   THE COMPUTATION OF YIELD IS THE REDUCTION RATES APPROACH (SEE
C   TEXT OF THESIS).
C
      DIMENSION TEMP1(15),TEMP2(15)
      COMMON/COND  / A(8,2),PD(8,2),FAR(8,2),WL(8,2),DCL(8,2),ND(8,2)
      COMMON/CONTR / NRUN,NPER,NCROP,IRUN,IYR,IROPT,IPOPT,DELT,
     1               LVP,IX,DL,PSW,RSW,LSW,KP1,KP2,MODE,LVINP,INPUT
      COMMON/LEVELS/ ARG1(8),ARG2(6),ARG3(8),ARG4(10),ARG5(5),
     1               ARG6(5),YMAX(8)
      COMMON/RRATES/ RDR1(8,8),RDR2(6,8),RDR3(8,8),RDR4(10,8),
     1               RDR5(5,8),RDR6(5,8)
      COMMON/ STAGE/ NW(3,8),DW(8,2,3),CMP(8)
      COMMON/ YIELD/ YLD(8,2)
      INTEGER CMP,PD,PSW,RSW,LSW,DW
      DO 100 I=1,NCROP
      DO 90 J=1,NPER
      IF(PD(I,J).EQ.0.OR.A(I,J).EQ.0.0) GO TO 80
C
C   CALCULATE REDUCTION RATES FOR FERTILIZER LEVEL
C
      FERT=FAR(I,J)
      DO 10 K=1,8
      TEMP1(K)=ARG1(K)
   10 TEMP2(K)=RDR1(K,I)
      R1=TABEX(TEMP2,TEMP1,FERT,8)
C
C   CALCULATE REDUCTION RATES FOR WEEDING LABOR
C
      WLAB=WL(I,J)
      DO 20 K=1,6
      TEMP1(K)=ARG2(K)
   20 TEMP2(K)=RDR2(K,I)
      R2=TABLI(TEMP2,TEMP1,WLAB,5)
C
C   CALCULATE REDUCTION RATES FOR PEST AND DISEASE CONTROL LEVEL
C
      PDC=DCL(I,J)
      DO 30 K=1,8
      TEMP1(K)=ARG3(K)
   30 TEMP2(K)=RDR3(K,I)
      R3=TABLI(TEMP2,TEMP1,PDC,7)
C
C   CALCULATE REDUCTION RATES CORRESPONDING TO NUMBER OF DRY WEEKS
C     IN EACH STAGE OF CROP GROWTH
C
C        1. VEGETATIVE STAGE
      DWV=DW(I,J,1)
      DO 40 K=1,10
      TEMP1(K)=ARG4(K)
   40 TEMP2(K)=RDR4(K,I)
      R4=TABLI(TEMP2,TEMP1,DWV,9)
C
C        2. REPRODUCTIVE STAGE
      DWR=DW(I,J,2)
      DO 50 K=1,5
      TEMP1(K)=ARG5(K)
   50 TEMP2(K)=RDR5(K,I)
      R5=TABLI(TEMP2,TEMP1,DWR,4)
C
C        3. MATURATION STAGE
      DWM=DW(I,J,3)
      DO 60 K=1,5
      TEMP1(K)=ARG6(K)
   60 TEMP2(K)=RDR6(K,I)
      R6=TABLI(TEMP2,TEMP1,DWM,4)
C
C   CALCULATE YIELD
C
      YLD(I,J)=YMAX(I)*(1-R1)*(1-R2)*(1-R3)*(1-R4)*
     1             (1-R5)*(1-R6)*1000.
      GO TO 90
   80 YLD(I,J)=0.
   90 CONTINUE
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PRGEN
C     ----------------
C  THIS SUBROUTINE GENERATES THE PRICE OF EACH CROP AT THE END OF
C  HARVEST AND THE PRICE OF FERTILIZER AT PLANTING. THE DEFAULT
C  PROCEDURE IS DETERMINISTIC GENERATION OF PRICES AND NO CHANGES
C  IN PRICE AMONG SIMULATED YEARS. HOWEVER PRICES CAN BE MADE TO
C  VARY IN TREND AND/OR VARY RANDOMLY AROUND MEANS AND STANDARD
C  DEVIATIONS USING A NORMAL DISTRIBUTION
C
      COMMON/CCND  / A(8,2),PD(8,2),FAR(8,2),WL(8,2),DCL(8,2),ND(8,2)
      COMMON/CONTR / NRUN,NPER,NCROP,IRUN,IYR,IROPT,IPOPT,DELT,
     1               LYR,IX,DL,PSW,RSW,LSW,KP1,KP2,MODE,LVINP,INPUT
      COMMON/FCNVAL/ NMLVAL(42)
      COMMON/PRDAT / BP(8),PNDX(12,8),PSDEV(12,8),PFERT(12),WR(12),
     1               PDELT(8),IFORM(8),PCROP(8,2),CPFERT(8,2),WAGE(8,2),
     2               AVDTH(8),SF(8),PSEED(8),IHW(8,2),SHT,SL
      COMMON/STAGE / NW(8,3),DW(8,2,3),CMP(8)
      REAL NMLVAL
      INTEGER CMP,PD,PSW,RSW,LSW,DW
      DIMENSION TEMP1(13),XMP(13)
      DATA XMP/
     1      -1.,  3.,  7., 11., 15., 20., 24., 28., 33., 37., 42.,
     2      46., 50./
C
C  CALCULATE THE BASE PRICES NEEDED FOR EACH SIMULATION RUN IF
C     PRICES ARE ALLOWED TO VARY IN TREND.
C
C
C  ---    LINEAR TREND
      IF(IPOPT.EQ.0) GO TO 25
      DO 20 I=1,NCROP
      IF(IFORM(I).NE.1)GO TO 10
      BP(I)=BP(I)+PDELT(I)
C
      GO TO 20
C  ---    EXPONENTIAL TREND
   10 BP(I)=BP(I)*PDELT(I)
   20 CONTINUE
C
C  CALCULATE THE PRICES OF CROPS AT HARVEST WEEKS
C
   25 DO 100 J=1,NPER
      DO 90  I=1,NCROP
      IF(PD(I,J).EQ.0) GO TO 80
      NWK= PD(I,J)+CMP(I)
      IF(NWK.GT.52)NWK=NWK-52
      HD=NWK
      IHW(I,J)=HD
      DO 30 K=2,13
      L=K-1
   30 TEMP1(K)=PNDX(L,I)
      TEMP1(1)=TEMP1(13)
      PND=TABLI(TEMP1,XMP,HD,12)
      IF(RSW.NE.0) GO TO 40
C
C  ---    NON-RANDOM MODE
      PCROP(I,J)=BP(I)*PND/100.
      GO TO 45
C
C  ---    RANDOM MODE
   40 CALL RANDU(IX,IY,YFL)
      IX=IY
      Z=FNL(NMLVAL,0.,.025,40,YFL)
      M=HD/4.34+.93
      PCROP(I,J)=BP(I)*PND/100.+PSDEV(M,I)*Z
C
C  DETERMINE FERTILIZER PRICE AT PLANTING WEEKS
C
   45 NWK=PD(I,J)
      IF(NWK.GT.52) NWK=NWK-52
      SD=NWK
      DO 50 K=2,13
      L=K-1
   50 TEMP1(K)=PFERT(L)
      TEMP1(1)=TEMP1(13)
      CPFERT(I,J)=TABLI(TEMP1,XMP,SD,12)
C
C  DETERMINE WAGE RATES
```

```
C
      NWK=PD(I,J)+CMP(I)/2
      IF(NWK.GT.52)NWK=NWK-52
      WO=NWK
      DO 60 K=2,13
      L=K-1
   60 TEMP1(K)=WP(L)
      TEMP1(1)=TEMP1(13)
      WAGE(I,J)=TABLI(TEMP1,XMP,WO,12)
      GO TO 90
   80 PCROP(I,J)=0.
      CPFRAT(I,J)=0
      WAGE(I,J)=0.
   90 CONTINUE
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE LABOR
C     ----------------
C
C     THIS SUBROUTINE COMPUTES THE LABOR UTILIZATION BY
C  OPERATION FOR EACH PLANTED CROP.  IT ALSO COMPUTES TOTAL
C  LABOR USE AND AMOUNT OF LABOR HIRED FOR EACH WEEK.
C
      COMMON/COND   / A(8,2),PD(8,2),FAP(8,2),WL(8,2),DCL(8,2),NO(8,2)
      COMMON/CONTR  / NRUN,NPER,NCROP,IRUN,IYR,IROPT,IPOPT,DELT,
     1                LVR,IX,UL,PSW,RSW,LSW,KP1,KP2,MODE,LVINP,INPUT
      COMMON/LAB    / TLAB(52),AVLAB(52),HLAB(52),XLAB(8,2),YLAB(8,2),
     1                TXOM(24,12,8),RLOP(8,2,12),HLPUO(8),PHL(8),
     2                TTLAB,THLAB
      COMMON/ STAGE/  NW(3,8),DW(8,2,3),CMP(8)
      COMMON/YIELD /  YLD(8,2)
      INTEGER CMP,PD,PSW,RSW,LSW,DW
      DATA FLPU/.3/,
     1     TA  /.3/,NOP1/5/,NOP2/3/,NOP3/11/
C
C  OPERATION SUBSCRIPTS
C      1.  PLOWING
C      2.  HARROWING
C      3.  OTHER LAND PREPARATION
C      4.  FURROWING
C      5.  PLANTING
C      6.  OFF-BARRING
C      7.  FERTILIZING
C      8.  WEEDING
C      9.  SPRAYING
C     10.  OTHER CARE
C     11.  HARVESTING
C     12.  POST HARVEST
C
C    INITIALIZE THE TIME BY OPERATION LABOR MATRIX
C
      DO 1 I=1,24
      DO 1 J=1,12
      DO 1 K=1,8
    1 TXOM(I,J,K)=J.
C       --- RICE
      TXOM( 1,1,1) =  32.0
      TXOM( 2,1,1) =  18.7
      TXOM( 3,1,1) =  18.7
      TXOM( 2,2,1) =   6.3
      TXOM( 3,2,1) =   6.3
      TXOM( 4,2,1) =   6.3
      TXOM( 6,2,1) =   4.2
      TXOM( 8,2,1) =   4.2
      TXOM(10,2,1) =   4.2
      TXOM(12,2,1) =   4.2
      TXOM( 4,3,1) =  17.9
      TXOM( 5,3,1) =  17.9
      TXOM( 5,4,1) =  14.9
      TXOM( 6,5,1) =  14.5
      TXOM( 9,6,1) =  11.9
      TXOM(11,6,1) =  11.9
      TXOM(13,6,1) =  11.9
      TXOM(14,7,1) =   5.7
      TXOM( 9,8,1) =  11.6
      TXOM(10,8,1) =  11.7
      TXOM(11,8,1) =  11.7
      TXOM(12,8,1) =  11.8
      TXOM(13,8,1) =  20.2
      TXOM(14,8,1) =  20.2
      TXOM(15,8,1) =  20.2
      TXOM(16,8,1) =  20.2
      TXOM(17,8,1) =  20.2
      TXOM(18,8,1) =  20.2
      TXOM(19,8,1) =  20.2
      TXOM( 9,9,1) =   4.0
      TXOM(12,9,1) =   4.0
      TXOM(15,9,1) =   4.0
      TXOM(18,9,1) =   4.0
C       --- CORN
      TXOM( 1,1,2) =  11.7
      TXOM( 2,1,2) =  11.7
      TXOM( 3,1,2) =  11.7
```

```
      TXOM( 2,2,2) =  6.5
      TXOM( 3,2,2) =  6.5
      TXOM( 4,3,2) = 27.0
      TXOM( 5,4,2) = 13.1
      TXOM( 5,5,2) = 44.4
      TXOM(11,6,2) = 14.9
      TXOM( 7,7,2) = 14.2
      TXOM( 9,7,2) = 14.2
      TXOM(10,8,2) =  6.5
      TXOM(12,8,2) =  6.4
C      --- SORGHUM
      TXOM( 3,1,3) = 30.5
      TXOM( 4,1,3) = 30.5
      TXOM( 4,2,3) =  9.0
      TXOM( 5,2,3) =  9.0
      TXOM( 5,3,3) = 12.0
      TXOM( 6,4,3) = 29.0
      TXOM( 6,5,3) = 45.0
      TXOM( 7,6,3) = 17.0
      TXOM(11,6,3) = 17.0
      TXOM( 8,7,3) = 17.0
      TXOM(10,7,3) = 17.0
      TXOM( 9,8,3) = 29.0
      TXOM(12,8,3) = 29.0
      TXOM(15,8,3) = 29.0
      TXOM( 8,9,3) =  9.0
      TXOM(13,9,3) =  9.0
C      --- MUNG BEAN
      TXOM( 3,1,4) = 26.0
      TXOM( 4,1,4) = 25.0
      TXOM( 4,2,4) = 13.4
      TXOM( 4,3,4) = 13.4
      TXOM( 5,3,4) =  1.6
      TXOM( 6,4,4) = 14.4
      TXOM( 6,5,4) = 43.2
      TXOM( 9,6,4) = 28.8
      TXOM( 7,7,4) = 11.6
      TXOM( 8,7,4) = 11.6
      TXOM(10,8,4) =  9.5
      TXOM(11,8,4) =  9.5
      TXOM(10,9,4) =  5.4
      TXOM(12,9,4) =  5.4
C      --- COWPEA
      TXOM( 3,1,5) = 26.0
      TXOM( 4,1,5) = 26.0
      TXOM( 4,2,5) = 16.0
      TXOM( 5,2,5) = 16.0
      TXOM( 5,3,5) =  8.0
      TXOM( 6,4,5) = 13.0
      TXOM( 6,5,5) = 34.0
      TXOM( 8,6,5) = 10.0
      TXOM(11,6,5) = 10.0
      TXOM( 7,7,5) = 12.0
      TXOM( 9,7,5) = 12.0
      TXOM( 8,8,5) = 12.5
      TXOM(13,8,5) = 12.5
      TXOM( 7,9,5) =  7.0
      TXOM( 9,9,5) =  7.0
      TXOM(12,9,5) =  7.0
C      --- PEANUT
      TXOM( 3,1,6) = 23.4
      TXOM( 4,1,6) = 14.3
      TXOM( 4,2,6) =  4.7
      TXOM( 5,2,6) =  4.7
      TXOM( 5,3,6) =  5.0
      TXOM( 6,4,6) = 12.8
      TXOM( 6,5,6) = 50.0
      TXOM( 7,6,6) = 40.4
      TXOM(11,6,6) = 40.4
      TXOM( 8,7,6) =  9.0
      TXOM( 9,7,6) = 15.5
      TXOM( 8,8,6) =  4.5
      TXOM(11,8,6) =  4.5
      TXOM( 7,9,6) =  5.0
      TXOM(11,9,6) =  8.0
      TXOM(12,9,6) =  9.0
C      --- SOYBEAN
```

```
      TXOM( 3,1,7) = 25.0
      TXOM( 4,1,7) = 14.0
      TXOM( 4,2,7) = 20.0
      TXOM( 5,2,7) = 17.0
      TXOM( 5,3,7) = 10.0
      TXOM( 6,4,7) = 13.0
      TXOM( 6,5,7) = 47.0
      TXOM( 7,6,7) = 35.2
      TXOM( 7,7,7) = 67.2
      TXOM( 9,8,7) =  9.0
      TXOM(11,8,7) =  9.0
C      --- SWEET POTATO
      TXOM( 2,1,8) = 26.0
      TXOM( 3,1,8) = 26.0
      TXOM( 3,2,8) = 16.0
      TXOM( 4,2,8) = 15.0
      TXOM( 5,3,8) = 11.0
      TXOM( 6,4,8) = 27.0
      TXOM( 6,5,8) = 90.0
      TXOM( 9,6,8) = 40.0
      TXOM(11,6,8) = 40.0
      TXOM( 8,7,8) =  8.0
      TXOM(11,7,8) = 16.0
      TXOM(12,8,8) = 10.0
      TXOM(13,8,8) = 10.0
      TXOM(7,10,8) =  7.0
      TXOM(9,10,8) =  7.0
      TXOM(10,10,8)=  7.0
      DO 5 I=1,52
      HLAB(I)=0.
    5 TLAB(I)=0.
      DO 50 I=1,NCROP
      DO 50 J=1,NPER
      X=0.
      Y=0.
      AREA=A(I,J)
      IL=PD(I,J)
      IF(AREA.EQ.0.0.OR.IL.EQ.0) GO TO 45
      HL=YLD(I,J)*HLPUD(I)
      M=IL+CMP(I)+5
      TXOM(M,11,I)=HL/2.
      TXOM(M+1,11,I)=HL/2.
      TXOM(M+2,12,I)=YLD(I,J)*PHL(I)
C
C     COMPUTE LABOR USE BY OPERATION
C
      DO 20 K=1,12
      S=0.
      DO 10 L=1,24
      S=S+TXOM(L,K,I)
   10 CONTINUE
      RLOP(I,J,K)=S*AREA
   20 CONTINUE
C
C     CHANGE TOTALS ACCORDING TO ACTUAL YIELDS, FERTILIZER
C     AND WEEDING LEVELS
C
      RLOP(I,J,7)=FAR(I,J)*FLPU*AREA
      RLOP(I,J,8)=WL(I,J)*AREA
      RLOP(I,J,11)=HL*AREA
      RLOP(I,J,12)=YLD(I,J)*PHL(I)*AREA
C
C     COMPUTE LABOR USE BY WEEK
C
      ISTRT=IL-6
      IF(ISTRT.LE.0)ISTRT=ISTRT+52
      DO 40 K=1,24
      M=ISTRT+K
      IF(M.GT.52)M=M-52
      TLB=0.
      HLB=0.
      DO 30 L=1,12
      IF((L.EQ.NOP1.OR.L.EQ.NOP2.OR.L.EQ.NOP3).AND.(AREA.GT.TA.AND.
     1      YLD(I,J).GT.500)) HLB=HLB+TXOM(K,L,I)
      TLB=TLB+TXOM(K,L,I)
   30 CONTINUE
      HLAB(M)=HLAB(M)+HLB*AREA
```

```
      TLAB(M)=TLAB(M)+TLB*AREA
      X=X+TLB*AREA
      Y=Y+HLB*AREA
   40 CONTINUE
   45 XLAB(I,J)=X
      YLAB(I,J)=Y
   50 CONTINUE
C
C  COMPUTE HIRED LABOR IF AVAILABLE LABOR IS NOT SUFFICIENT
C
      TTLAB=0.
      THLAB=0.
      DO 100 I=1,52
      TEMP=TLAB(I)-AVLAB(I)
      IF(TEMP.LE.0) GO TO 90
      IF(HLAB(I).EQ.0.0)GO TO 70
      GO TO 80
   70 HLAB(I)=TEMP
      GO TO 90
   80 X=TLAB(I)-HLAB(I)
      IF(X.GT.AVLAB(I)) HLAB(I)=HLAB(I)+(X-AVLAB(I))
   90 THLAB=THLAB+HLAB(I)
      TTLAB=TTLAB+TLAB(I)
  100 CONTINUE
C
C     TA=THRESHOLD AREA ABOVE WHICH PLANTING OR HARVESTING
C         WILL BE TOTALLY HIRED
C     NOP1,NOP2,NOP3 = OPERATIONS USUALLY DONE BY HIRED LABOR
      RETURN
      END
```

```
      SUBROUTINE CROPAC
C     -----------------
C
C     THIS SUBROUTINE COMPUTES THE COSTS AND RETURNS OF EACH
C     PLANTED CROP AS WELL AS OTHER PERFORMANCE CRITERIA.
C
      COMMON/ACC    / EXFERT(8,2),EXSEED(8,2),EXOTH(8,2),EXHT(8,2),
     1                EXRNT(8,2),TEXP(8,2),VPROD(8,2),GPROF(8,2),
     2                EXHLAB(8,2),TPROD(8,2),EXCHEM(8,2),
     3                TPROF,ECA,THLEX,TFEX,TSDEX,TOTHEX,TRNTEX,
     4                THTEX,TOTEXP,TVP,TCHMEX
      COMMON/CONC   / A(8,2),PD(8,2),FAR(8,2),WL(8,2),DCL(8,2),ND(8,2)
      COMMON/CONTR  / NRUN,NPER,NCROP,IRUN,IYR,IROPT,IPOPT,DELT,
     1                LVK,IX,CL,PSW,RSW,LSW,KP1,KP2,MODE,LVINP,INPUT
      COMMON/LAB    / TLAB(52),AVLAB(52),HLAB(52),XLAB(8,2),YLAB(8,2),
     1                TXOM(24,12,5),RLOP(8,2,12),HLPUO(8),PHL(8),
     2                TTLAB,THLAB
      COMMON/PRDAT  / DP(5),PNOX(12,8),PSDEV(12,3),PFERT(12),WR(12),
     1                PDELT(8),IFORM(9),PCROP(8,2),CPFERT(8,2),WAGE(8,2),
     2                AVOTH(8),SR(8),PSEED(8),IMW(8,2),SHT,SL
      COMMON/SUMRY  / PVAR1(8,2,40),PVAR2(8,2,40),PVAR3(8,2,40),
     1                PVAR4(8,2,40),PVAR5(8,2,40),PVAR6(8,2,40),
     2                PVAR7(8,2,40)
      COMMON/YIELD  / YLD(8,2)
      INTEGER CMP,PD,PSW,RSW,LSW,DW
C
C
C     INITIALIZE TOTALS
C
      TVP=0.
      TFEX=0.
      TSDEX=0.
      TCHMEX=0.
      TRNTEX=0.
      THLEX=0.
      TOTHEX=0.
      TOTEXP=0.
      THTEX=0.
      TPROF=0.
      ECA=0.
      LEASE =LSW
      INKIND=LSW
      DO 100 I=1,NCROP
      DO 100 J=1,NPER
      AREA=A(I,J)
      IL=PD(I,J)
      IF(AREA.EQ.0.0.OR.IL.EQ.0) GO TO 100
      TPROD(I,J)=  YLD(I,J)*AREA
      EXFERT(I,J)=FAR(I,J)*CPFERT(I,J)*AREA
      EXSEED(I,J)=SR(I)*AREA*PSEED(I)
      EXCHEM(I,J)=DCL(I,J)*AREA
      VPROD(I,J)=TPROD(I,J)*PCROP(I,J)
      IF(INKIND.NE.1) GO TO 30
      EXHT(I,J)=VPROD(I,J)*SHT
      GO TO 40
   30 EXHT(I,J)=0.
   40 IF(LEASE.NE.1) GO TO 50
      EXRNT(I,J)=(VPROD(I,J)-EXHT(I,J))*SL
      GO TO 60
   50 EXRNT(I,J)=0.
   60 EXOTH(I,J)=AVOTH(I)*AREA
      IF(INKIND.NE.1) GO TO 65
      IF(AREA.LT..3.OR.TPROD(I,J).LT.500.) GO TO 65
      YLAB(I,J)=YLAB(I,J)-RLOP(I,J,11)
   65 EXHLAB(I,J)=YLAB(I,J)*WAGE(I,J)
      TEXP(I,J)=EXFERT(I,J)+EXSEED(I,J)+EXHT(I,J)+EXCHEM(I,J)+
     1          EXRNT(I,J)+EXHLAB(I,J)+EXOTH(I,J)
      GPROF(I,J)=VPROD(I,J)-TEXP(I,J)
   70 TVP   =TVP   +VPROD(I,J)
      TFEX  =TFEX  +EXFERT(I,J)
      TSDEX =TSDEX +EXSEED(I,J)
      TCHMEX=TCHMEX+EXCHEM(I,J)
      THTEX =THTEX +EXHT(I,J)
      TRNTEX=TRNTEX+EXRNT(I,J)
      THLEX =THLEX +EXHLAB(I,J)
      TOTHEX=TOTHEX+EXOTH(I,J)
      TPROF =TPROF +GPROF(I,J)
```

```
      TOTEXP=TOTEXP+TEXP(I,J)
   80 ECA    =ECA    +AREA
  100 CONTINUE
      IF(KP2.NE.1) GO TO 200
      K=IRUN
      DO 150 I=1,NCROP
      DO 150 J=1,NPER
      IF(PD(I,J).EQ.0.OR.A(I,J).EQ.0) GO TO 150
      PVAR1(I,J,K) = YLD(I,J)
      PVAR2(I,J,K) = TPROD(I,J)
      PVAR3(I,J,K) = PCROP(I,J)
      PVAR4(I,J,K) = VPROD(I,J)
      PVAR5(I,J,K) = TEXP(I,J)
      PVAR6(I,J,K) = GPROF(I,J)
      PVAR7(I,J,K) = XLAB(I,J)
  150 CONTINUE
  200 RETURN
      END
```

```
      SUBROUTINE PRINT
C     ----------------
C     THIS SUBROUTINE CONTROLS THE PRINTING OF SIMULATION
C     OPTIONS, ASSUMPTIONS AND RESULTS.
C
C
C
      COMMON/ACC    / EXFERT(8,2),EXSEED(8,2),EXOTH(8,2),EXHT(8,2),
     1                EXRNT(8,2),TEXP(8,2),VPROD(8,2),GPROF(8,2),
     2                EXHLAB(8,2),TPROD(8,2),EXCHEM(8,2),
     3                TPROF,ECA,THLEX,TFEX,TSDEX,TOTHEX,TRNTEX,
     4                THTEX,TOTEXP,TVP,TCHMEX
      COMMON/COND   / A(8,2),PD(8,2),FAR(8,2),WL(8,2),DCL(8,2),ND(8,2)
      COMMON/CONTR  / NRUN,NPER,NCROP,IRUN,IYR,IROPT,IPOPT,DELT,
     1                LVR,IX,DL,PSW,RSW,LSW,KP1,KP2,MODE,LVINP,INPUT
      COMMON/LAB    / TLAB(52),AVLAB(52),HLAB(52),XLAB(8,2),YLAB(8,2),
     1                TXOM(24,12,8),RLOP(8,2,12),HLPUD(8),PHL(8),
     2                TTLAB,THLAB
      COMMON/PRDAT  / BP(8),PNOX(12,8),PSDEV(12,8),PFERT(12),WR(12),
     1                PDELT(8),IFORM(8),PCROP(8,2),CPFERT(8,2),WAGE(8,2),
     2                 AVOTH(8),SR(8),PSEED(8),IHW(8,2),SHT,SL
      COMMON/YIELD  / YLD(8,2)
      COMMON/LABEL  / NAME(8),CSSM(10),TITLE(10),OPER(2,12),NPAGE
      COMMON/ STAGE/  NW(3,8),DW(8,2,3),CMP(8)
      REAL NMLVAL,NAME
      INTEGER CMP,PD,PSW,RSW,LSW,DW
C
C     PRINT LABOR UTILIZATION OF CROPPING SYSTEM
C
      IF(KP1.NE.1) GO TO 20
      NPAGE=NPAGE+1
      PRINT 200, (CSSM(I),I=1,6),NPAGE,IRUN,(TITLE(J),J=1,10)
      PRINT 210
      DO 10 I=1,26
      K=I+26
      PRINT 215,I,TLAB(I),AVLAB(I),HLAB(I),
     1          K,TLAB(K),AVLAB(K),HLAB(K)
   10 CONTINUE
      PRINT 216
C
C     PRINT PLANTING DATES, INPUT LEVELS, DRY WEEKS AND YIELD
C
   20 NPAGE=NPAGE+1
      PRINT 200, (CSSM(I),I=1,6),NPAGE,IRUN,(TITLE(J),J=1,10)
      PRINT 220
      DO 30 J=1,NPER
      DO 30 I=1,NCROP
      IF(A(I,J).EQ.0.0.OR.PD(I,J).EQ.0) GO TO 30
      PRINT 230, NAME(I),J,PD(I,J),A(I,J),FAR(I,J),WL(I,J),DCL(I,J)
   30 CONTINUE
      PRINT 240
      DO 40 J=1,NPER
      DO 40 I=1,NCROP
      IF(A(I,J).EQ.0.0.OR.PD(I,J).EQ.0) GO TO 40
      PRINT 250, NAME(I),J,(DW(I,J,K),K=1,3)
   40 CONTINUE
      PRINT 260
      DO 50 J=1,NPER
      DO 50 I=1,NCROP
      IF(A(I,J).EQ.0.0.OR.PD(I,J).EQ.0) GO TO 50
      PRINT 270, NAME(I),J,YLD(I,J),IHW(I,J),PCROP(I,J)
   50 CONTINUE
C
C     INDIVIDUAL CROP PERFORMANCE AND LABOR USE BY OPERATION
C
      IF(KP1.NE.1) GO TO 90
      DO 80 J=1,NPER
      DO 80 I=1,NCROP
      IF(A(I,J).EQ.0.0.OR.PD(I,J).EQ.0) GO TO 80
      NPAGE=NPAGE+1
      PRINT 200, (CSSM(K),K=1,6),NPAGE,IRUN,(TITLE(K),K=1,10)
      PRINT 275,NAME(I),J
      PRINT 280, A(I,J),PD(I,J),PCROP(I,J),CPFERT(I,J),
     1           YLD(I,J),TPROD(I,J),VPROD(I,J)
      PRINT 290,EXFERT(I,J),EXSEED(I,J),EXCHEM(I,J),EXHLAB(I,J),
     1           EXHT(I,J),EXRNT(I,J),EXOTH(I,J),TEXP(I,J),
     2           GPROF(I,J)
```

```
      PRINT 300, NAME(I),J
      DO 70 K=1,12
   70 PRINT 310, (OPER(L,K),L=1,2),RLOP(I,J,K)
      PRINT 320,  XLAB(I,J)
   80 CONTINUE
C
C     PRINT SUMMARY OF SIMULATION RESULTS OF CROPPING PATTERN
C
   90 NPAGE=NPAGE+1
      PRINT 200, (CSSM(I),I=1,6),NPAGE,IRUN,(TITLE(I),I=1,10)
      PRINT 330
      PRINT 335
      PRINT 340
      PRINT 335
      DO 100 J=1,NPER
      DO 100 I=1,NCROP
      IF(A(I,J).EQ.0.0.OR.PD(I,J).EQ.0) GO TO 100
      PRINT 350, NAME(I),PD(I,J),IHW(I,J),A(I,J),YLD(I,J),
     1           TPROD(I,J),PCROP(I,J),VPROD(I,J),TEXP(I,J),
     2           GPROF(I,J),XLAB(I,J)
  100 CONTINUE
      PRINT 335
      PRINT 360, ECA,TVP,TOTEXP,TPROF,TTLAB
      PRINT 335
      RETURN
C
C     FORMAT STATEMENTS
C
  200 FORMAT(1H1,6A8,18X,*PAGE *,I3/1X,*RUN NO.*,I3,* - *,10A8/)
  210 FORMAT(1X,*LABOR UTILIZATION OF CROPPING PATTERN BY*,
     1       * WEEK (MAN-HOURS)*/1H ,57(1H-)//1X,87(1H-)/
     2       1X,2(*WEEK*,5X,*REQUIRED*,3X,*AVAILABLE*,5X,
     3       *HIRED*,8X)/1X,87(1H-))
  215 FORMAT(1X,2(I3,3F12.1,8X))
  216 FORMAT(1X,87(1H-))
  220 FORMAT(1X,*PLANTING DATES AND INPUT LEVELS*//1X,75(1H-)/,
     1       1X,*CROP        PERIOD     PLANT       AREA*,
     2       3X,*FERTILIZER   WEEDING   INSECTICIDE*/
     3   21X,*WEEK         (HA.)        (KG.N/HA)     (M-H/HA)*,
     4       4X,*(P/HA)*/1X,75(1H-)/)
  230 FORMAT(1X,A8,I6,I9,F11.2,F11.1,F12.1,F13.2)
  240 FORMAT(///1X,*NUMBER OF DRY WEEKS IN EACH CROP STAGE*,//1X,
     1          75(1H-)/1X,*CROP*,8X,*PERIOD*,11X,*VEGETATIVE*,5X,
     2       *REPRODUCTIVE*,5X,*MATURATION*/1X,75(1H-)/)
  250 FORMAT(1X,A8,I7,4X,3(11X,I6))
  260 FORMAT(///1X,*YIELD, HARVEST DATES, AND PRICES*//1X,75(1H-)/,
     1       1X,*CROP*,8X,*PERIOD*,11X,*YIELD*,10X,*HARVEST*,10X,
     2       *PRICE AT*/29X,*(KG/HA)*,10X,*WEEK*,12X,*HARVEST*/1X,
     3       75(1H-)/)
  270 FORMAT(1X,A8,I7,10X,F9.1,10X,I4,10X,F9.2)
  275 FORMAT(/1X,A8,* - COST AND RETURNS, PERIOD*,I2,//,
     1    1X,52(1H-)/1X,*VARIABLE*,15X,*UNIT*,17X,*VALUE*,
     2    /1X,52(1H-)/)
  280 FORMAT(1X,*AREA                            HA.      *,10X,F9.2/1X,
     1          *PLANT WEEK                               *,10X,I8  /1X,
     2          *PRICE OF CROP                   P/KG.    *,10X,F9.2/1X,
     3          *PRICE OF FERT                   P/KG.N   *,10X,F9.2/1X,
     4          *YIELD                           KG./HA.  *,10X,F9.2/1X,
     5          *TOTAL PRODUCTION                KG.      *,10X,F9.2//1X,
     6          *GROSS RETURNS                   PESOS    *,10X,F9.2/)
  290 FORMAT(1X,*EXPENSES:                       PESOS    *//1X,
     1          *     FERTILIZER                          *,10X,F9.2/1X,
     2          *     SEEDS                               *,10X,F9.2/1X,
     3          *     CHEMICALS                           *,10X,F9.2/1X,
     4          *     HIRED LABOR                         *,10X,F9.2/1X,
     5          *     HARV & THRESH                       *,10X,F9.2/1X,
     6          *     LAND RENT                           *,10X,F9.2/1X,
     7          *     OTHER EXPENSES                      *,10X,F9.2/1X,
     8          *  TOTAL                                  *,10X,F9.2//1X,
     9          *NET RETURNS                     PESOS    *,10X,F9.2/1X,52(1H-)/)
  300 FORMAT(////1X,A8,* - LABOR UTILIZATION BY OPERATION, PERIOD*,
     1          I2,//1X,52(1H-)/1X,*OPERATION*,32X,*MAN-HOURS*,
     2          /1X,52(1H-)/)
  310 FORMAT(3X,2A5,22X,F9.2)
  320 FORMAT(/1X,52(1H-)/3X,*TOTAL*,33X,F9.2/1X,52(1H-))
  330 FORMAT(//1X,*SUMMARY OF SIMULATION RESULTS OF CROPPING*,
     1       * PATTERN*/1H ,49(1H-)//)
```

```
335 FORMAT(1X,91(1H-))
340 FORMAT(1X,*CROP      PLANT  HARV   AREA    YIELD     TOTAL*,
   1      *  PRICE      GROSS      FARM        NET      LABOR*/11X,
   2      *WEEK  WEEK*,21X,*PROD    CROP     RETURN   EXPENSE    *,
   3      *RETURNS      USE*)
350 FORMAT(1H0,A8,I5,I5,F8.2,2F9.1,F7.2,3F10.2,F8.1)
360 FORMAT(1X,*TOTAL*,14X,F8.2,25X,3F10.2,F8.1)
    END
```

```
      SUBROUTINE SUMMA
      DIMENSION D(7),B(7),X(7),Y(7),Z(7)
      COMMON/COND  / A(8,2),PD(8,2),FAR(8,2),WL(8,2),DCL(8,2),NO(8,2)
      COMMON/CONTR / NRUN,NPER,NCROP,IRUN,IYR,IROPT,IPOPT,DELT,
     1               LVR,IX,CL,PCN,RSW,LSW,KP1,KP2,MODE,LVINP,INPUT
      COMMON/LABEL / NAME(8),CSSM(10),TITLE(10),OPER(2,12),NPAGE
      COMMON/SUMRY / PVAR1(8,2,40),PVAR2(8,2,40),PVAR3(8,2,40),
     1               PVAR4(8,2,40),PVAR5(8,2,40),PVAR6(8,2,40),
     2               PVAR7(8,2,4 )
      REAL NMLVAL,NAME
      NPAGE=NPAGE+1
      R=NRUN
      S=NRUN-1
      PRINT 155, (CSSM(I),I=1,6),NPAGE,(TITLE(I),I=1,10)
      PRINT 160
      PRINT 165
      PRINT 170
      PRINT 165
      DO 150 J=1,NPER
      DO 150 I=1,NCROP
      IF(PD(I,J).EQ.0.OR.A(I,J).EQ.0.) GO TO 150
      DO 10 K=1,7
      D(K)=0.
   10 B(K)=0.
      DO 30 K=1,NRUN
      Z(1) = PVAR1(I,J,K)
      Z(2) = PVAR2(I,J,K)
      Z(3) = PVAR3(I,J,K)
      Z(4) = PVAR4(I,J,K)
      Z(5) = PVAR5(I,J,K)
      Z(6) = PVAR6(I,J,K)
      Z(7) = PVAR7(I,J,K)
      DO 20 L=1,7
      C=Z(L)
      D(L)=D(L)+C
      B(L)=B(L)+C*C
   20 CONTINUE
   30 CONTINUE
      DO 50 L=1,7
      X(L)=D(L)/R
      ARG=(B(L)-X(L)*D(L))/S
      IF(ARG.LE.0.) GO TO 45
      Y(L)=SQRT(ARG)
      GO TO 50
   45 Y(L)=0.
   50 CONTINUE
      PRINT 175, NAME(I),PD(I,J),A(I,J),(X(L),L=1,7),
     2           (Y(L),L=1,7)
  150 CONTINUE
      PRINT 165
  155 FORMAT(1H1,6A8,18X,*PAGE *,I3/11X,* - *,10A8/)
  160 FORMAT(1X,*MEANS AND STANDARD DEVIATIONS OF PERFORMANCE *,
     1          *VARIABLES BY CROPS*/1H ,63(1H-)//)
  165 FORMAT(1X,91(1H-))
  170 FORMAT(1X,*CROP     PLANT          AREA    YIELD    TOTAL*,
     1      *  PRICE     GROSS      FARM       NET      LABOR*/11X,
     2      *WEEK         *,21X,*PROD    CROP     RETURN    EXPENSE   *,
     3      *RETURNS     USE*)
  175 FORMAT(1H0,A8,I5,*  XBAR*,F8.2,2F9.1,F7.2,3F10.2,F8.1/
     1          14X,*  S.DV*,  8X,2F9.1,F7.2,3F10.2,F8.1)
      RETURN
      END
```

```
      SUBROUTINE GAMFCN(I,R)
      COMMON/RNPAR / RNMEAN(52),RSDEV(52),GP(52),BETA(52)
      GG = GP(I)
      B = BETA(I)
      CALL GAMMA(GG,GAM)
      YFL=RANF(1975 )
      IF(GG.LE.56) GAM=ALOG(GAM)
      TEST = .0001
      DEST = .0004
      NEST = 0
      MEST = 10
      P = GG - 1.0
      X0 = P
      IF(GG-1.0) 15,10,10
   10 IF(X0) 16,16,20
   15 X0 = .0001
      GO TO 20
   16 X0 = .01
   20 Z = 2.0
      NEST = NEST + 1
      T = X0/ (P+Z)
      S = T + 1.0
      DO 40 L=1,1000
      Z = Z+1.0
      T = (T*X0)/(P+Z)
      S = S + T
      IF(T-TEST) 50,50,40
   40 CONTINUE
   50 DL = YFL
      ZUD = EXP(GAM-(P*ALOG(X0)))
      X1=X0-(X0/GG)*S + (DL*ZUD*EXP(X0))
      DX = X1 - X0
      X0 = X1
      IF(X0) 140,150,130
  130 IF(ABS(DX)-DEST) 150,150,135
  135 IF(NEST.GT.200) GO TO 200
      GO TO 20
  140 X1 = 0.
  150 R = X1 * B
      RETURN
  200 PRINT 250
  250 FORMAT(* ITERATIONS FOR GAMMA FUNCTION EXCEEDS 200 *)
      R = X0 * B
      RETURN
      END
```

```
      SUBROUTINE GAMMA(X,GAM)
      DIMENSION U(100)
      DATA B1,B2,B3,B4,B5,B6,B7,B8/
     1       -.577191652,
     2        .988205891,
     3       -.897056937,
     4        .918206857,
     5       -.756704078,
     6        .482199394,
     7       -.193527818,
     8        .035868343/
      IF(X-56.)1,1,30
    1 P = X-1
      L = P+1
      IF(L-1)20,20,5
    5 U(1)= X
      DO 10 K=1,L
      KK = K+1
   10 U(KK)=U(K)-1.0
      PD =1.0
      DO 15 K=2,L
   15 PD = PD*U(K)
      Y = U(L)- 1
      GO TO 25
   20 Y = X-1
      PD=1.0
   25 GAM= PD*(1+Y*(B1+Y*(B2+Y*(B3+Y*(B4+Y*(B5+Y*(B6+Y*(B7+Y*B8))))))))
      RETURN
   30 R = 0.
   40 X = X-1.
      I = X
      IF(I-1)60,60,50
   50 R = R + ALOG(X)
      GO TO 40
   60 R = R + ALOG(X)
      Y = X-1
      S =        (1+Y*(B1+Y*(B2+Y*(B3+Y*(B4+Y*(B5+Y*(B6+Y*(B7+Y*B8))))))))
      GAM = R + ALOG(S)
      RETURN
      END
```

```
      SUBROUTINE RANDU (IX,IY,YFL)
C   PURPOSE:
C      COMPUTES UNIFORMLY DISTRIBUTED RANDOM REAL NUMBERS BETWEEN
C      0 AND 1.0 AND RANDOM INTEGERS BETWEEN ZERO AND
C      2**31. EACH ENTRY USES AS INPUT AN INTEGER RANDOM NUMBER
C      AND PRODUCES A NEW INTEGER AND REAL RANDOM NUMBER.
C
C   USAGE:
C      CALL RANDU(IX,IY,YFL)
C      WHERE:
C         IX = FOR THE FIRST ENTRY THIS MUST CONTAIN AN ODD INTEGER
C              NUMBER WITH NINE OR LESS DIGITS. AFTER THE FIRST
C              ENTRY, IX SHOULD BE THE PREVIOUS VALUE OF IY COMPUTED
C              BY THIS SUBROUTINE.
C         IY = A RESULTANT INTEGER RANDOM NUMBER REQUIRED FOR THE
C              NEXT ENTRY TO THIS SUBROUTINE. THE RANGE OF THIS
C              NUMBER IS BETWEEN ZERO AND 2**31.
C        YFL = THE RESULTANT UNIFORMLY DISTRIBUTED  FLOATING POINT,
C              RANDOM NUMBER IN THE RANGE 0 TO 1.0.
C   METHOD:
C      POWER RESIDUE METHOD DISCUSSED IN IBM MANUAL C20-8011,
C      RANDOM NUMBER GENERATION AND TESTING. THIS SUBROUTINE IS
C      SPECIFIC TO SYSTEM/360 AND WILL PRODUCE 2**29 TERMS BEFORE
C      REPEATING.
C
      IY = IX * 65539
      IF(IY) 5,6,6
    5 IY = IY + 2147483647+1
    6 YFL = IY
      YFL = YFL * .4656613E-9
      RETURN
      END
```

```
      FUNCTION FNL(DVAL,XS,DX,N,X )
      DIMENSION DVAL(1)
      IF(X-XS)3,3,2
    2 IF((X-XS)-N*DX)7,5,5
    3 FNL = DVAL(1)
      GO TO 10
    5 FNL =DVAL(N+1)
      GO TO 10
    7 XD =X-XS
      I  =1.0 + XD/DX
      FNL=(XD-FLOAT(I-1)*DX)*(DVAL(I+1)-DVAL(I))/DX
     1    + DVAL(I)
C
C TO FIND RANDOM VALUE OF X WITH XAVG AN XSD, USE FF. STATEMENTS-
C     R = RANF(AFG)
C     Y = FNL(NMLVAL,0.,.025,40,R)
C     X = XAVG + XSD *Y
C
   10 RETURN
      END
```

```
      FUNCTION TABEX(VAL,ARG,DUMMY,K)
      DIMENSION VAL(1),ARG(1)
      DO 10 J=2,K
      IF(DUMMY.GT.ARG(J)) GO TO 10
      GO TO 20
   10 CONTINUE
      J = K
   20 TABEX = VAL(J-1) + ((VAL(J) - VAL(J-1)) /  (ARG(J)
     1              - ARG(J-1))) * (DUMMY - ARG(J-1))
      RETURN
      END
```

```
      FUNCTION TABLI(VAL,ARG,DUMMY,K)
      DIMENSION VAL(1),ARG(1)
      DUM = AMAX1(AMIN1(DUMMY,ARG(K)),ARG(1))
      DO 1 I=2,K
      IF(DUM.GT.ARG(I)) GO TO 1
      TABLI = VAL(I-1) + ((VAL(I) - VAL(I-1)) /
     1         (ARG(I) - ARG(I-1))) *(DUM - ARG(I-1))
      RETURN
    1 CONTINUE
      RETURN
      END
```

APPENDIX III

SAMPLE OUTPUTS OF THE COMPUTER SIMULATION MODEL

```
RUN NO.  1 - TEST RUN, MODE 4, IROPT 1,HIGH INPUT LEVELS

OPTIONS IN EFFECT
         MODE    =    4
         IROPT   =    1
         LVR     =    1
         IYR     = 1973
         INPUT   =    1
         LVINP   =    5
         RSW     =    1
         PSW     =    1
         LSW     =    1
         KP1     =    1
         KP2     =    1
         IPOPT   =    0
         DELT    =   20.00
         DL      =     .49
```

CSSM 3- CROPPING SYSTEMS SIMULATION MODEL PAGE 2
RUN NO. 1 - TEST RUN, MODE 4, IROPT 1,HIGH INPUT LEVELS

RAINFALL GENERATOR OUTPUT

OPTION NO. 1 - RAINFALL PATTERN BASED ON PARAMETERS FROM AN INCOMPLETE GAMMA

WEEK	RAINFALL	WEEK	RAINFALL
1	.03	27	1.39
2	.03	28	4.20
3	.13	29	.29
4	.14	30	4.85
5	.22	31	.25
6	.26	32	.61
7	.00	33	.69
8	.02	34	1.80
9	.00	35	2.08
10	.03	36	.84
11	.01	37	2.28
12	.00	38	2.23
13	.13	39	3.50
14	.00	40	7.42
15	.00	41	4.71
16	.48	42	9.40
17	1.46	43	.10
18	1.91	44	.06
19	.13	45	1.03
20	3.94	46	1.85
21	.43	47	4.73
22	.01	48	2.74
23	.99	49	.09
24	.11	50	4.60
25	.62	51	.00
26	2.14	52	2.36

CSSM 3- CROPPING SYSTEMS SIMULATION MODEL PAGE
RUN NO. [illegible] - TEST RUN, MODE 4, IROPT 1,HIGH INPUT LEVELS

AVAILABLE SOIL MOISTURE BY WEEK (INCHES)

WEEK	ASM(T)	ASM(T-1)	EV-TR	RAINFALL	RUNOFF
1	0.00	0.00	.83	.03	0.00
2	0.00	0.00	.86	.03	0.00
3	0.00	0.00	.89	.13	0.00
4	0.00	0.00	.91	.14	0.00
5	0.00	0.00	.96	.22	0.00
6	0.00	0.00	.99	.26	0.00
7	0.00	0.00	1.06	.00	0.00
8	0.00	0.00	1.11	.02	0.00
9	0.00	0.00	1.15	.00	0.00
10	0.00	0.00	1.22	.03	0.00
11	0.00	0.00	1.24	.01	0.00
12	0.00	0.00	1.30	.00	0.00
13	0.00	0.00	1.37	.13	0.00
14	0.00	0.00	1.38	.00	0.00
15	0.00	0.00	1.33	.00	0.00
16	0.00	0.00	1.31	.48	0.00
17	.21	0.00	1.26	1.45	0.00
18	.93	.21	1.18	1.91	0.00
19	0.00	.93	1.15	.13	0.00
20	2.77	0.00	1.17	3.94	0.00
21	2.05	2.77	1.14	.43	0.00
22	.99	2.05	1.08	.01	0.00
23	.93	.99	1.05	.99	0.00
24	.04	.93	1.00	.11	0.00
25	0.00	.04	.94	.62	0.00
26	1.24	0.00	.93	2.14	0.00
27	1.71	1.24	.92	1.39	0.00
28	4.02	1.71	.9[illegible]	4.2[illegible]	1.17
29	3.45	4.02	.86	.29	0.00
30	4.02	3.45	.8[illegible]	4.85	4.31
31	3.45	4.02	.82	.25	0.00
32	3.30	3.45	.77	.61	0.00
33	3.2[illegible]	3.30	.79	.69	0.00
34	4.02	3.2[illegible]	.8[illegible]	1.8[illegible]	.18
35	4.02	4.02	.86	2.08	1.22
36	4.02	4.02	.85	.84	0.00
37	4.02	4.02	.84	2.28	1.43
38	4.02	4.02	.78	2.23	1.44
39	4.02	4.02	.78	3.60	2.81
40	4.02	4.02	.79	7.42	10.[illegible]4
41	4.02	4.02	.79	4.71	4.5[illegible]
42	4.02	4.02	.75	9.4[illegible]	14.[illegible]
43	3.37	4.02	.75	.10	0.00
44	2.70	3.37	.73	.05	0.00
45	3.00	2.70	.73	1.03	0.00
46	4.02	3.00	.73	1.85	.14
47	4.02	4.02	.76	4.73	4.69
48	4.02	4.02	.76	2.74	1.95
49	3.35	4.02	.76	.39	0.00
50	4.02	3.35	.76	4.6[illegible]	3.75
51	3.21	4.02	.81	.00	0.00
52	4.02	3.21	.8[illegible]	2.36	.78

CSSM 3- CROPPING SYSTEMS SIMULATION MODEL PAGE 4
RUN NO. 1 - TEST RUN, MODE 4, IROPT 1,HIGH INPUT LEVELS

LABOR UTILIZATION OF CROPPING PATTERN BY WEEK (MAN-HOURS)

WEEK	REQUIRED	AVAILABLE	HIRED	WEEK	REQUIRED	AVAILABLE	HIRED
1	0.0	112.8	0.0	27	30.7	112.8	0.0
2	0.0	112.8	0.0	28	35.1	112.8	0.0
3	0.0	112.8	0.0	29	185.5	112.8	72.7
4	0.0	112.8	0.0	30	183.1	112.8	70.3
5	0.0	112.8	0.0	31	20.2	112.8	0.0
6	0.0	112.8	0.0	32	0.0	112.8	0.0
7	0.0	112.8	0.0	33	0.0	112.8	0.0
8	0.0	112.8	0.0	34	32.0	112.8	0.0
9	0.0	112.8	0.0	35	32.0	112.8	0.0
10	0.0	112.8	0.0	36	37.3	112.8	0.0
11	0.0	112.8	0.0	37	26.0	112.8	0.0
12	0.0	112.8	0.0	38	52.8	112.8	0.0
13	32.0	112.8	0.0	39	1.6	112.8	0.0
14	25.0	112.8	0.0	40	57.6	112.8	43.2
15	25.0	112.8	0.0	41	11.6	112.8	0.0
16	24.2	112.8	0.0	42	11.6	112.8	0.0
17	32.8	112.8	0.0	43	49.2	112.8	0.0
18	30.4	112.8	14.5	44	34.0	112.8	0.0
19	18.2	112.8	0.0	45	19.3	112.8	0.0
20	22.4	112.8	0.0	46	77.2	112.8	5[illegible].0
21	54.5	112.8	0.0	47	45.4	112.8	0.0
22	34.0	112.8	0.0	48	4.5	112.8	0.0
23	68.0	112.8	44.4	49	16.6	112.8	0.0
24	34.2	112.8	0.0	50	48.4	112.8	0.0
25	32.1	112.8	0.0	51	4.5	112.8	0.0
26	40.1	112.8	0.0	52	9.0	112.8	0.0

CSSM 3- CROPPING SYSTEMS SIMULATION MODEL PAGE 5
RUN NO. 1 - TEST RUN, MODE 4, IROPT 1,HIGH INPUT LEVELS

PLANTING DATES AND INPUT LEVELS

CROP	PERIOD	PLANT WEEK	AREA (HA.)	FERTILIZER (KG.N/HA)	WEEDING (M-H/HA)	INSECTICIDE (P/HA)
PALAY	1	18	1.00	100.0	100.0	600.00
CORN	1	23	1.00	100.0	100.0	600.00
MUNGBEAN	2	4[illegible]	1.00	100.0	100.0	600.00
PEANUT	2	46	1.00	100.0	100.0	600.00

NUMBER OF DRY WEEKS IN EACH CROP STAGE

CROP	PERIOD	VEGETATIVE	REPRODUCTIVE	MATURATION
PALAY	1	3	0	0
CORN	1	2	0	0
MUNGBEAN	2	0	0	0
PEANUT	2	1	3	4

YIELD, HARVEST DATES, AND PRICES

CROP	PERIOD	YIELD (KG/HA)	HARVEST WEEK	PRICE AT HARVEST
PALAY	1	3726.4	36	1.11
CORN	1	3651.8	36	1.15
MUNGBEAN	2	1440.6	51	4.92
PEANUT	2	2313.5	8	3.74

CSSM 3- CROPPING SYSTEMS SIMULATION MODEL
RUN NO. 1 - TEST RUN, MODE 4, IROPT 1,HIGH INPUT LEVELS

PALAY - COST AND RETURNS, PERIOD 1

VARIABLE	UNIT	VALUE
AREA	HA.	1.00
PLANT WEEK		19
PRICE OF CROP	P/KG.	1.11
PRICE OF FERT	P/KG.N	6.50
YIELD	KG./HA.	3726.35
TOTAL PRODUCTION	KG.	3726.35
GROSS RETURNS	PESOS	4126.72
EXPENSES:	PESOS	
FERTILIZER		650.00
SEEDS		172.50
CHEMICALS		600.00
HIRED LABOR		265.44
HARV ^ THRESH		589.53
LAND RENT		1179.05
OTHER EXPENSES		200.00
TOTAL		3125.66
NET RETURNS	PESOS	1001.07

PALAY - LABOR UTILIZATION BY OPERATION, PERIOD 1

OPERATION	MAN-HOURS
PLOWING	69.40
HARROWING	35.70
OTHER LAND PREP.	35.80
FURROWING	14.90
PLANTING	14.50
OFF-BARRING	35.70
FERTILIZING	30.00
WEEDING	100.00
SPRAYING	16.00
OTHER CARE	0.00
HARVESTIIN	317.86
POST-HARVEST	37.26
TOTAL	733.76

CSSM 3- CROPPING SYSTEMS SIMULATION MODEL
RUN NO. 1 - TEST RUN, MODE 4, IROPT 1,HIGH INPUT LEVELS

MUNGBEAN - COST AND RETURNS, PERIOD 2

VARIABLE	UNIT	VALUE
AREA	HA.	1.00
PLANT WEEK		40
PRICE OF CROP	P/KG.	4.92
PRICE OF FERT	P/KG.N	6.50
YIELD	KG./HA.	1440.60
TOTAL PRODUCTION	KG.	1440.60
GROSS RETURNS	PESOS	7086.07
EXPENSES:	PESOS	
FERTILIZER		650.00
SEEDS		200.00
CHEMICALS		500.00
HIRED LABOR		284.89
HARV ^ THRESH		1012.29
LAND RENT		2024.59
OTHER EXPENSES		250.00
TOTAL		4451.99
NET RETURNS	PESOS	2634.08

MUNGBEAN - LABOR UTILIZATION BY OPERATION, PERIOD 2

OPERATION	MAN-HOURS
PLOWING	52.[illegible]
HARROWING	13.40
OTHER LAND PREP.	15.00
FURROWING	14.40
PLANTING	43.20
OFF-BARRING	28.80
FERTILIZING	3[illegible].00
WEEDING	1[illegible].[illegible]0
SPRAYING	1[illegible].8[illegible]
OTHER CARE	0.00
HARVESTIIN	368.79
POST-HARVEST	183.72
TOTAL	22[illegible].[illegible]0

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RUN NO. 12 - RICE - PEANUT (PLANTING DATES)

SUMMARY OF SIMULATION RESULTS OF CROPPING PATTERN

CROP	PLANT WEEK	HARV WEEK	AREA	YIELD	TOTAL PROD	PRICE CROP	GROSS RETURN	FARM EXPENSE	NET RETURNS	LABOR USE
PALAY	29	47	1.00	3243.7	3243.7	1.32	4289.99	2913.75	1376.23	725.0
PEANUT	49	11	1.00	2260.5	2260.5	2.88	6508.96	3878.30	2630.06	750.6
TOTAL			2.[illegible]				10798.95	6792.06	4006.89	[illegible]

CSSM 3- CROPPING SYSTEMS SIMULATION MODEL PAGE 27
- RICE - PEANUT (PLANTING DATES)

MEANS AND STANDARD DEVIATIONS OF PERFORMANCE VARIABLES BY CROPS

CROP	PLANT WEEK		AREA	YIELD	TOTAL PROD	PRICE CROP	GROSS RETURN	FARM EXPENSE	NET RETURNS	LABOR USE
PALAY	29	XBAR	1.00	3230.2	3230.2	1.33	4295.51	2916.18	1379.33	747.7
		S.DV		29.2	29.2	.30	334.57	421.96	362.61	2.5
PEANUT	49	XBAR	1.00	2532.1	2532.1	3.24	8297.69	4644.90	3652.79	[illegible]
		S.DV		206.5	206.5	.37	1055.64	452.42	507.22	[illegible]