WORKING DRAFT

AGRICULTURAL SECTOR MODULE:

A Preliminary Sketch

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INTRODUCTION

Oil clearly has been a dominant factor in the economies of these Middle Eastern countries. But to focus solely on the oil sector is to present an incomplete picture of Iran, Iraq, Saudi Arabia, Libya, and Algeria. While this sector constitutes the major source of revenue for each country, it remains only one of several important sectors "defining" the environment within which decision-makers in these countries operate. Another important sector in this setting is the agricultural sector.

After oil production, agriculture is the largest single contribution to the national accounts (i.e., the national income, the GNP, the balance-of-payments, etc.) of each of the five countries. The agricultural sector, moreover, is the principal source of employment in these oil-producing countries, with more than half of the population in each country (except Libya) deriving its livelihood from agriculture. Due to a number of constraints (e.g. limited water resources), however, the level of agricultural productivity in these countries are not able to produce enough on their own to meet the ever-increasing food needs of their respective populations. Further, with ever-growing populations and rising demands for better standards of living, they face the strong possibility of widespread famines breaking out in the not-too-distant future. To avert this situation, extensive efforts are being made in each country to modernize and devlop, the agricultural sector.

It is in the context of these development efforts that we have attempted to construct a simulation model of the agricultural sector in these five countries. Specifically, we have sought to formulate a structure which would enable us to (1) identify and trace the various information and material flows in the agricultural production process which influence the decision-makers' choices of developmental policies and programs, and (2) project the consequences that their choices might have for the output behavior of the agricultural sector. To this end, we have adopted a "building-block" approach to modeling this sector. The complex array of variables and interrelationships are conceptually grouped into several sequentially-linked "logical components", or building-blocks, to simulate various facets of the production process. Four such components are included in the present version of the agricultural simulations: resource allocation, modernization, production/marketing, and consumption/demand components. The output of a component is either an input to another component or a performance variable, or both. The final outputs of the model thus included not only physical outputs, but also a set of performance variables. It is this set of variables which the decision-makers evaluate and compare with policy goals when choosing their policies and programs for the next time period.

At present then, we have a model which is structures to simulate the production of field crops (specifically wheat, simulate the production of field crops (specifically wheat, the principal crop and food staple) in these oil-producing countries. Parameter values are available for one country (Saudi Arabia) and will soon be ready for the other four.

THE SETTING: Herausforderung und Antwort

Oil clearly has been a dominant factor in the economies of these Middle Eastern countries. Yet, to focus entirely on the oil sector is to view a rather distorted picture of these five countries. For despite the tremendous wealth derived from oil production, there has been little appreciable change, if any at all, in their overall economies. Put somewhat differently, inspite of their vast capital surpluses, these countries are still economically underdeveloped. But there, the overall economic development of these countries depends upon more than the accumulation of capital surpluses, upon more than the growth in the productivity of this one sector. It also depends, to a considerable extent, upon the modernization and development of the agricultural sector.

Agriculture constitutes a major sector of both the economy and the social structure of each of the five countries examined here. After oil production, it is the largest single contributor to the national accounts (i.e., the national income, the GNP, the balance of payments, etc.) of these countries. And, whereas the oil sector represents the major source of revenue for these countries, the agricultural sector is the principal source of employment and individual income. More than half of the population of four of these countries (Algeria, Iran, Iraq and Saudi Arabia) derive their livelihoods directly from agriculture. In Libya's case this figure is considerably smaller (approximately one-third of the population), yet it still represents the largest share of the population involved in any one sector of the Libyan economy.

Despite the rather sizable input of labor to the agricultural sector, agricultural productivity in these Middle Eastern countries is not very high. Winter grains such as wheat and barley (the principal grain crops of these countries), for example, rarely produce yields above fifteen bushels per acre per year, even in relatively good years.[1] At such levels of productivity, these countries are barely able, if at all, to produce enough on their own to meet the present food needs of their respective populations. All-too-often, in fact, they must import large quantities of food to "fill up" their frequently-deficient food accounts. And confronted with ever-growing populations and rising demands for better standards of living, these countries are likely to become even more dependent upon external sources of food. For unless agricultural productivity can be significantly raised above present levels (or otherwise augmented), these countries face the possibility of widespread famines breaking out in the not-too-distant future.

Considerable efforts are thus being made in these countries to increase agricultural productivity, to modernize and develop the agricultural sector. If these efforts are to succeed, however, a number of rather formidable obstacles must be overcome. One major obstacle which has long limited agricultural production in these countries is their relative lack of adequate water supplies. For the most part, these countries depend upon rainfall to provide the water needed for crop production. But because of the arid nature of the climate in these countries, the rainfall they receive is both low and highly variable over time. Many areas of these countries, in fact, receive so little rain as to make the production of rain-fed crops well-nigh impossible. As a result, the amount of cultivable land in each country is limited to a rather small percentage of each's total land area. (See Table 1) And where this land is actually put under cultivation, the utilization of this land for rain-fed crops (which the major share of the crops grown in these countries are) requires the adoption of such practices as placing the cropped area in fallow during alternate growing seasons. Under such conditions, it is hardly surprising that these countries have thus far been unable to realize their full agricultural potential.

The alternative to this dependence upon rainfall for crop production is, of course, the extension of irrigation to the areas to be cultivated, both present and potential. But to bring these areas under irrigation requires that these countries have alternative sources of water in sufficient amounts to meet the water requirements of the area (and crop) to be irrigated. Of these five countries, however, only Iraq appears to be well-endowed with such a supply of irrigation water. With a combined average annual flow of around 61 million acre-feet, the Tigris and Euphrates rivers clearly provide Iraq with a great potential for irrigation.[2] Using only part of this supply (approximately 28.4 million acre-feet), the Iraqis have

Table 1. Land Utilization in the Five Countries
(in 1000 acres)

	Algeria	Iran	Iraq	Libya	Saudi Arabia
Total Land Area	688,800	164,800	110,900	117,500	550,000
Cultivable Land	6,700	22,000	16,700	17,500	82,500
Cultivated acreage	3,700	7,000	8,100	1,175	600
Area irrigated	99	3,000	4,600	555	n.a.

been able to put an estimated 7.5 million acres of crop land under irrigation thus far.[3] As to the other four countries, they do not possess any readily-accessible supplies of irrigation water which are comparable to those in Iraq. Iran also depends upon the Eurhrates River for irrigation water, but the amount of water it is able to extract from this source is definitely not sufficient to meet Iran's present and projected water needs. The situation is even bleaker for Algeria, Libya and Saudi Arabia; there are no rivers, lakes, etc., of any practical significance in these countries.

From where, then, can these countries get the water they need? One source is to be found underground, i.e., groundwater from wells. Information on how extensive the supply of this water is, however, is rather scanty. A more certain source of potential irrigation water is, of course, seawater. In both cases, the production costs involved in tapping these sources are substantial. The cost of producing ground water, for example, presently runs about $130 per acre-foot.[4] In contrast, the cost of desalination, given existing technology, is about one dollar per 1000 gallons, or about $326 per acre-foot.[5] As these countries have to dig deeper wells, and as desalinization technology advances, the difference in the costs of these two alternative sources is likely to diminish.[6] But for the present time, and for the forseeable future, it is the production of groundwater which, in terms of cost, provides the more practical solution to the water problem in these countries.

Whatever the source, it is abundantly clear that the development of irrigation water constitutes an essential ingredient in any effort to increase the agricultural productivity of these countries. Water by itself, however, is not the only prerequisite for increased agricultural production: "Indeed, neither water nor any other single input is the magic wand that will quickly and painlessly produce agricultural plenty and prosperity."[7] Thus, if the extension of irrigation to the cultivated areas is to be of any lasting benefit, it must be accompanied by a number of additional, but equally important production inputs. These additional inputs are essential, for the scarcity of water does not constitute the only obstacle to the expansion of agricultural production.

A second major obstacle to increased agricultural production is the general lack of soils suitable for cultivation. Suitable soils are as scarce in these countries as water, if not more so. As a result, only a small fraction of the land in each country is truly cultivable. Even in those areas where cultivation is possible, the suitability of the soil is limited. There are two aspects of the soils in these countries which in particular pose major limitations to agricultural production. First, with continued wetting and drying out, the soil has a tendency to accumulate high concentrations of salt. This problem is especially acute in Iraq where between twenty and thrity percent of the cultivable land has to be abandoned each year due to salination. Second, the soils are very low in nitrogen content which is necessary to sustain high production in these soils. As a consequence of these two factors, the productivity of these soils tends to be exhausted rather quickly with the result that much of the cultivable land in these countries must be placed in fallow during alternate years. Further, even when these soils are used for cropping, the resulting yields tend to be quite low.

Clearly, then, to overcome this second obstacle constitutes another major prerequisite for increased agricultural production. But again, no single input will be sufficient to achieve this. Instead, there are several separate, but closely interrelated, inputs which will help to improve the suitability of the soils for production. Among these imputs is, of course, a drainage system for "flushing" harmful salts out of the soils. In conjunction with this, these countries need to improve their use of land and water. What this entails is the adoption of such practices as land leveling, flood control, and moisture conservation. Another major input has to be fertilizers, particularly nitrogen fertilizers. While potassium and phosphorous fertilizers are present in these countries, they are not available in sufficient amounts to sustain a wide variety of crops or high production levels. Finally, with increased fertilization and irrigation new varieties of crops could be introduced which are of the high-yield type.

All of the inputs identified above, including the extension of irrigation, are directed at raising the per acre yields of the cultivable lands in these countries. But raising per acre yields represents only one aspect of the overall problem of increasing agricultural production. Another, equally important aspect of this problem is that of raising the per capita productivity of labor. As we noted at the outset of this report, a major share of the labor force in each of the five countries is employed in the agricultural sector. Yet, the per capita productivity of this agricultural labor is presently quite low. Of course, faced with the lack of adequate water and soils, the individual farmer is not going to be very productive. But even with the necessary physical inputs to overcome these two obstacles, he is still not likely to be very productive. For to raise the per capita productivity of agricultural labor in these countries, two additional obstacles must be overcome. The first of these two obstacles relates to the availability of labor in sufficient amounts to support an intensive effort to expand agricultural production.

Of those employed in the agricultural sector, most all are engaged in traditional subsistence farming. With agricultural production thus being carried out primarily to meet the food needs of the individual house-hold (or production unit), the labor input required to produce this food is provided principally by the household itself. More often than not, this labor is quite sufficient to meet the labor requirements for subsistence production. As a result, there is very little need for additional, nonhousehold labor. With the raising of the productivity of the cultivated lands, however, "...the need for labor will increase so considerably that present surpluses (if any exist at all) will hardly suffice to satisfy the new requirements."[8] Put somewhat differently, by raising per acre yields these countries create another problem for themselves, namely: the problem of a shortage of labor. There are no other sources of labor in sufficient amounts which these countries can draw upon to meet the new labor requirements. Moreover, the agricultural sector loses part of its labor supply each year as some farmers migrate to urban areas. Unless this shortage of labor can somehow be made up, it is likely to have an adverse affect on the efforts of these countries to improve land utilization, to expand agricultural production.

But how can these labor shortages be made up? One way to overcome this obstacle is to substitute machinery for labor, i.e., to "mechanize" agriculture. (The level of mechanization at present is rather low in these countries, with most farmers still depending on animal or human power.) By inputting more and better equipment (such as tractors) to replace human and animal power, these countries should be able to increase the per capita productivity of the existing labor supply, and thus to decreaae the amount of labor required for the intensification of agricultural production.

To reiterate a point made earlier, however, the introduction of farm machinery (or of any other single input) is not by itself sufficient to bring about the desired changes in agricultural production: "... mechanization would accomplish relatively little unless accompanied by better irrigation and drainage, greater fertilizer use, better crop varieties, better control of weeds and crop diseases, and by other components of a technologically advanced agriculture..."[9] Nor is the mere inputting of these factors of production together enough. There must also be a willingness on the part of individual farmers to adopt these new production inputs. What this essentially boils down to is the existence of economic opportunities which are rewarding to these farmers. Herin lies the final obstacle to increased agricultural production to be discussed here, namely: the relative lack of such opportunities in these five countries.

As Schultz (1964) notes, traditional agriculture (which agriculture in these countries predominantly is) has certain built-in resistors to any change in the existing state of the arts: "The concept of traditional agriculture implies long-established routines with respect to all production activities."[10] Because farmers in traditional agriculture have a wealth of experience with these routines to draw upon, the risks and uncertainties they face with regards to the production possibilities of traditional factors of production are minimal. But with the introduction of new factors of production, they are faced not only with having to break with the past, but also with having to cope with risks and uncertainties which are as yet unknown.[11] As a result, they are likely to be rather hesitant to adopt these new factors. Yet, only through experience will they be able to learn what the risks and uncertainitles inherent in these factors.

How, then, are those in traditional agriculture to be induced to try these new production inputs? The answer to this question lies in the economic opportunities which agricultural production and, in turn, the use of these new inputs offer to the farmer. More precisely, the willingness of individual farmers to adopt the new production inputs depends upon (1) the payoffs to their production activities, and (2) the costs (as well as the supply) of these inputs. What this essentially means is that there must be a system of prices which will enable farmers to make a reasonable margin of profit and, at the same time, to obtain the necessary new inputs at prices that permit this profit margin. (It is this margin of profit, then, that provides the necessary inducement, or lack thereof, to adopt the new production inputs.) In the five countries examined here, however, such a system of prices is, for the most part, missing. Prices for farm products in these countries tend, in general, to be depressed and distorted. Morever, the costs of the required inputs are still quite high. The overall effect of the present system of prices has thus been to leave farmers in these countries with very small margins of profit, if any at all. As a result, there is very little incentive for these farmers to produce much more than what is necessary to meet their own consumption needs. This, in turn, means that there is little incentive to purchase the new production inputs.

To overcome this obstacle to increased agricultural production requires, of course, the establishment of a more efficient system of prices. But again, the establishment of this price system is not enough by itself to bring about an increase in production. While such a system may lead to an increased desire on the part of farmers to seek to increase their outputs, their efforts will not get very far unless there are adequate aupplies of the necessary production inputs available. Put another way, the essence of agricultural development in these five Middle Eastern countries is

> ...the application of a package of separate but closely interrelated programs, technologies, and processes; it is their interrelationship which is truly significant... Any single program may have limited and sometimes even negative effect, if taken by itself; but may be highly productive if combined with other programs in proper proportions and proper timing.[12]

The problem facing the decision-makers in these countries is thus one of finding that combination of programs which will produce the results they seek. With this in mind we turn now to our proposed model of the agricultural sector.

THE MODEL

As the preceding discussion suggests, the effort to modernize and develop the agricultural sector in these five countries is clearly no simple matter. There are numerous physical, economic, social and political factors, the dynamic interactions between which affect the decision-makers' choices of developmental policies and programs. To provide a clearer picture of how this complex array of factors and their interrelationships affect these choices, we have constructed a simulation model of the agricultural sector in these countries. What one proposed model purports to offer is a way to (1) identify and trace the essential information and material flows influencing the choices of the decision-makers, and (2) analyze and project the consequences that their choices may possibly have for the performance of the agricultural sector.

For the sake of some simplicity, we have confined our attention in the construction of this model to the production of but one crop: wheat. Wheat constitutes the principal crop grown in these countries in terms of both the quantity produced and the amount of crop land devoted to it. Wheat also represents the major staple in the diets of the people in these countries. Taking these two facts into consideration, we feel that by limiting our view to this one crop we will still be able to present a fairly representative picture of the setting with in which decisions in the development of the agricultural sector are made in these oil-producing countries.

In constructing our simulation model of the wheat production process, we have employed a "building-block" approach.[13] With this approach, the complex array of variables and functional interrelationships comprising the agricultural sector are broken into several sequentially-linked "logical components" (or building-blocks) to simulate the various facets of the production process. There are four such components in our present model: resource allocation, modernization, production/marketing, and consumption/demand (See Figure 1). The output of each component serves either as an input to the next component in the sequence or as a measure of that component's performance. (It is the set of such performance measures which constitutes the input from the agricultural sector to the decision stratum).

What follows, then, is a brief description of the structure and functions of the four components of our model. This description will focus primarily on the mathematical form of the model. But to aid the reader in following through these equations, we have provided several "causal maps" of the interrelationships among the variables of the model. The key to interpreting these maps is as follows:

Symbol	Meaning
$\longrightarrow$	Denotes direction of influence or causality
○	Denotes endogenous variables
E	Denotes exogenous variables
P	Denotes policy variables
C	Denotes constants

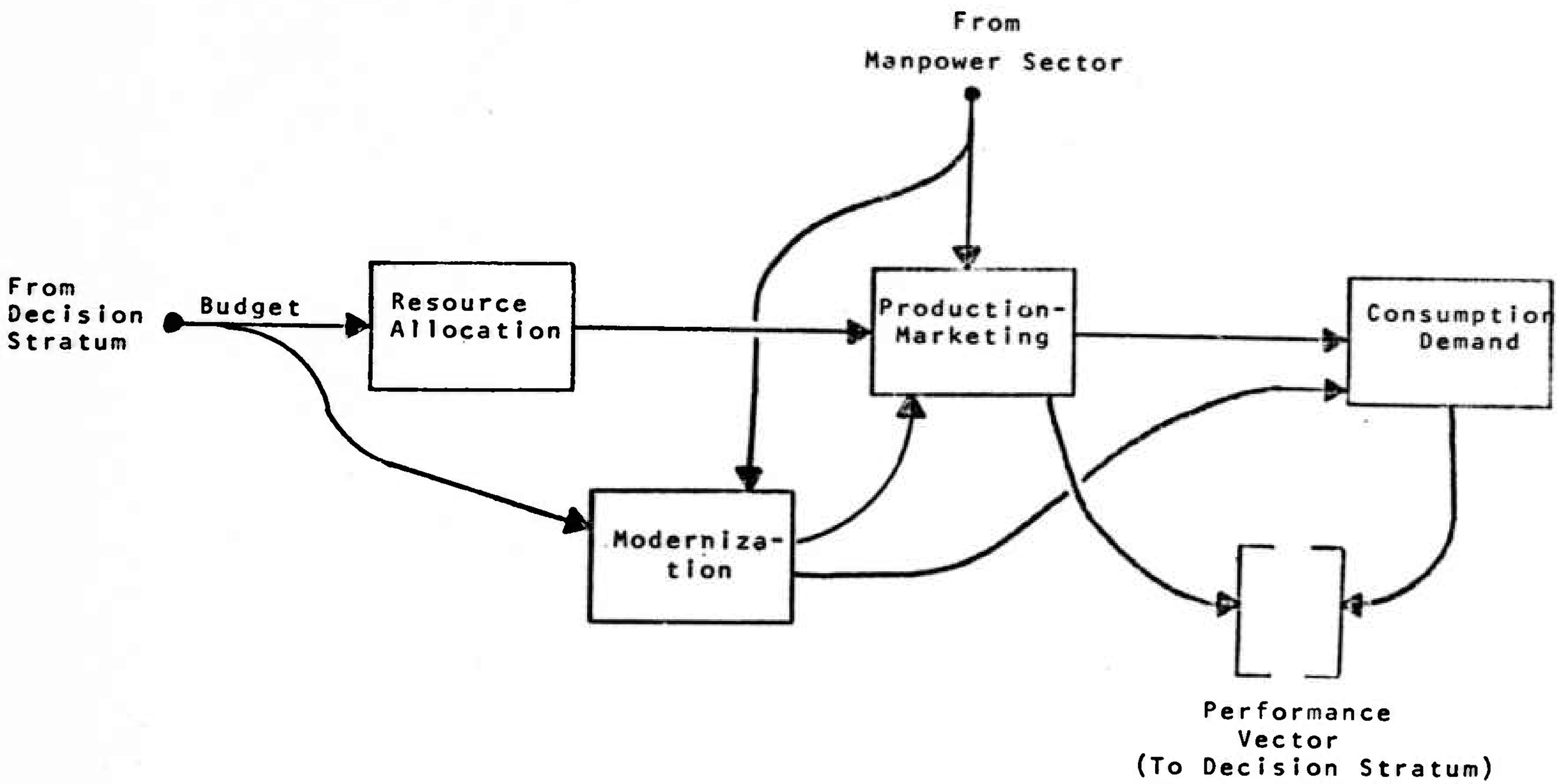

Figure 1. Major Component and Interacting of the Agricultural Sector Model

D Denotes a delay function

Resource Allocation Component

Obviously, land and water constitute two very basic but crucial factors influencing wheat production in these countries. The purpose of this first component (See Figure 2) of the model is thus to simulate the allocation of these two scarce resources to the cultivation of wheat. The allô-cation of cultivated land is determined in the model by the amount of cultivable land available, the amount of cultivated land which is placed in alternative uses, and the amount of land that is left in fallow. This allocation is represented as follows:

$$LUC\ (t) = CL - [LAU\ (t) + LIR\ (t)] \qquad (R1)$$

where:

LUC	= land under cultivation for wheat	(acres)
CL	= total cultivable land available	(acres)
LAU	= land allocated to alternative uses	(acres)
LIR	= land in fallow	(acres)

The total amount of cultivable land available, CL, is assumed to be constant throughout the simulation. LAU is a policy variable, the value of which is set at each time interval by the policy maker.

$$LIR(t) = [C_1 * RRA(t-DT)] + [DT * RLI(t \cdot DT)] \qquad (R2)$$

where:

C_1	= fallow requirement (i.e., the proportion of land (that must be placed in fallow)-dimensionless)	
RFA	= rainfed (traditional) acreage	(acres)
RLI	= rate at which irrigated land is lost to cultivation (i.e. exhausted) as a result of over-irrigation and/or salination	(acres/year)
DT	= time interval	(year)

with this variable, an endogenous variable, we are able to take into account the impact of farming practices on land utilization. In the case of rainfed land, for example, the principal farming system is one of alternating crops with fallow.

Much of the land under cultivation in these countries relies on rainfall for its water supply (variable RFA, which is computed by Equation R6). Of course, irrigation water is used in some areas. The development of an irrigation system, in fact, been a major policy of these countries. The rate of this development and the extent of irrigation in each country are computed by the following equation:

$$\mathrm{IRD}\ (t) = \frac{1}{\mathrm{DEL}} \left[\frac{\mathrm{BUDI}(t)}{\mathrm{COST\ I}(t)} \right] \qquad \text{(R3)}$$

$$\mathrm{IRP}\ (t) = \mathrm{IRP}\ (t-\mathrm{DT}) + \mathrm{DT}[\mathrm{IRR}*\mathrm{IRD}\ (t)-\mathrm{RLI}\ (t)] \qquad \text{(R4)}$$

$$\mathrm{IRA}\ (t) = \mathrm{IRR}\ (t)*\ \mathrm{IRP}\ (t) \qquad \text{(R5)}$$

$$\mathrm{RRA}\ (t) = \mathrm{LUC}\ (t) - \mathrm{IRA}\ (t) \qquad \text{(R6)}$$

<u>where:</u>

IRD =	irrigation development rate	(acre-ft/year)
BUDI=	investment allocated to irrigation development	($)
COST I=	cost of irrigation water	($/acre-ft.)
DEL =	time delay	(years)
IRP =	potentially irrigatable acreage	(acres)
IRR =	irrigation requirement	(acre-ft/acre)
IRA =	acreage actually irrigated	(acres)
IIR =	intensity of irrigation	(dimensionless)

Of the above variables, IIR is perhaps the most hazily conceived. We have made it a policy variable in the model which ranges from 0 to 1.0. One might expect that these countries would try to make full use of their irrigation potential. Yet this is not the case. Iraq, for example, has in the past utilized only half

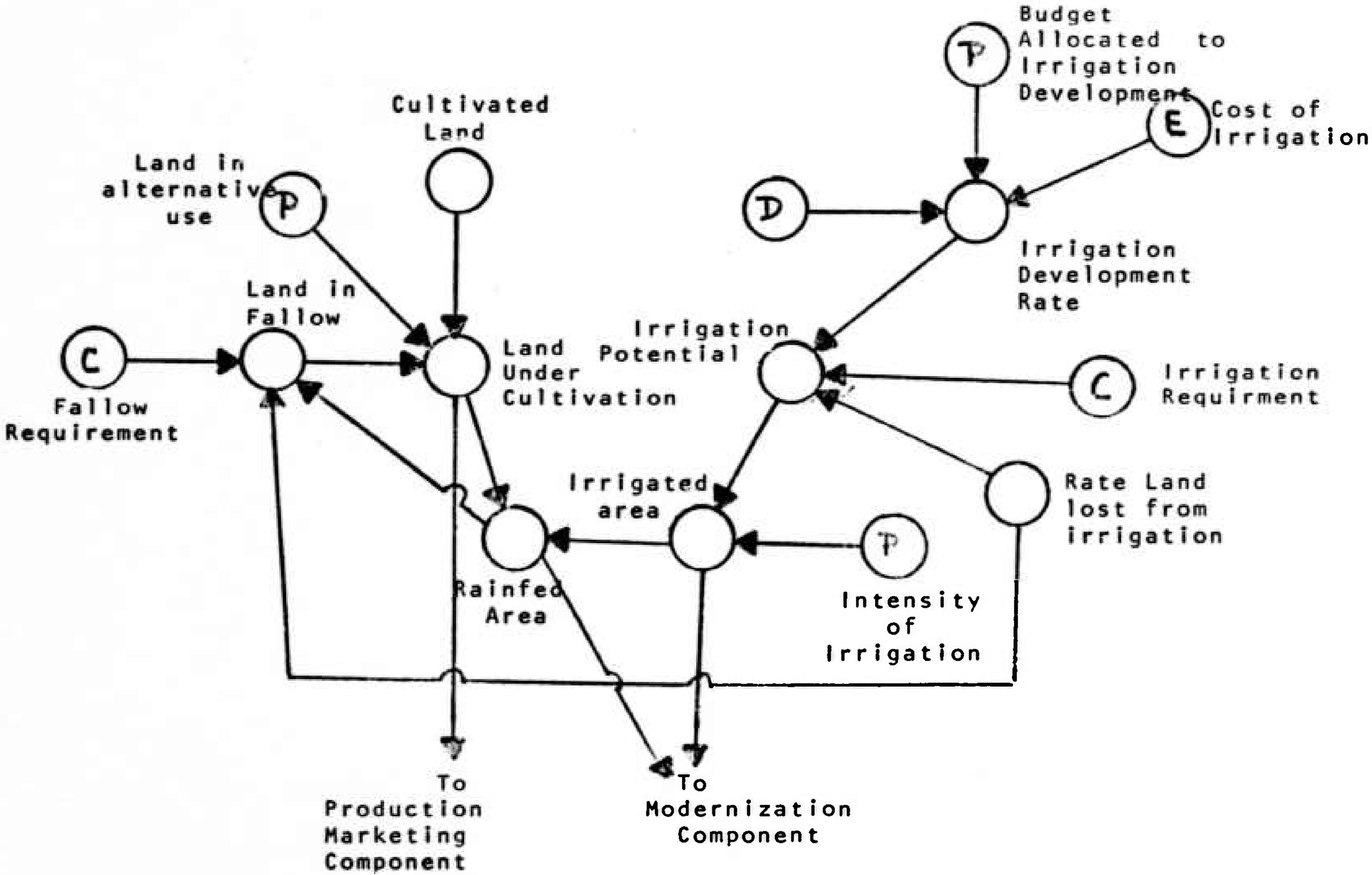

FIGURE 2. A Causal Map of the Resource Allocation Component

of their irrigation potential.

The variable IRR is a constant in the model, the value of which depends upon the growing season. For winter crops like wheat it is 4 acre-ft./acre; for summer crops this figure is 7 acre-ft./acre.[14]

The outputs of this resource allocation component are, then, the total amount of land under cultivation in wheat, the amount of this land which is actually irrigated, and the amount of cultivated land which depends on rainfall (i.e., traditional acreage) for water. All three outputs are inputs to the modernization component; only land under cultivation constitutes an input to the production/marketing component.

<u>The Modernization Component</u>

As we have noted on several occasions in this paper, the development of one input (e.g., water) is not by itself sufficient to bring about increased agricultural production. Instead, a number of different modernizing inputs are required to accomplish this including fertilizers, farm machinery, improve seed varieties, etc. In order to explore the impact of these modernizing inputs on the agricultural production, a "modernization" component has been included in the model. (See Figures 3a and 3b). This component focuses specifically on the impact of increased fertilization and mechanization on the production of wheat in these countries. The primary outputs of this component are 1) a measure of productivity (yield per acre), and 2) a mechanization coefficient. Both outputs serve as inputs to the production/marketing component.

For the sake of clarity only, we have divided the modernization component into two parts. The first part to be described here concerns the introduction of fertilizers to the production process:

$$RFERT\ (t) = \frac{1}{DT} * [PCFERT\ (t-DT) * \frac{BUDF(t)}{PFERT(t)}] \qquad (M1.1)$$

$$FERTC\ (t) = DT * RFERT\ (t) \qquad (M1.2)$$

$$FERTA\ (t) = FERTC\ (t) / IRA\ (t) \qquad (M1.3)$$

$$YPAM\ (t) = FRC\ (t) * FERTA\ (t) \qquad (M1.4)$$

$$YPA\ (t) = \frac{[(YPAM(t)*IRA(t)) + (YPAT*RFA(t))]}{LUC(t)} \qquad (M1.5)$$

<u>where</u>:

RFERT = the rate of fertilization, i.e. the amount of fertilizers obtained per year (lb/year)
BUDF = agricultural investment allocated to fertilization (dollars)
PFERT = the farm price for fertilizers (dollars/lb.)
PCFERT = the profitability criterion for fertilization (dimensionless)
FERTC = the total amount of fertilizer used (lb.)
FERTA = a measure of the intensity of fertilizer use (lb./acre)
YPAM = the productivity (yield per acre) of the irrigated (modern) crop area (bushels/acre)
YPAT = the average productivity (yield per acre) of the rainfed (traditional) crop area (bushels/acre)
FRC = fertilizer response coefficient (bushel/lb)[15]
PP = the producer (i.e.,domestic) price of wheat (dollars/bushels)

With Equation M1.2, there is no provision for the accumulation of fertilizers over time. We assume here that because of the low quality of the soils in these countries, farmers will use all of the fertilizers they are able to get.

Whether or not the farmer makes full use of fertilizers, however, depends on more than the availability of fertilizers. Of equal if not greater importance is the profitability of using

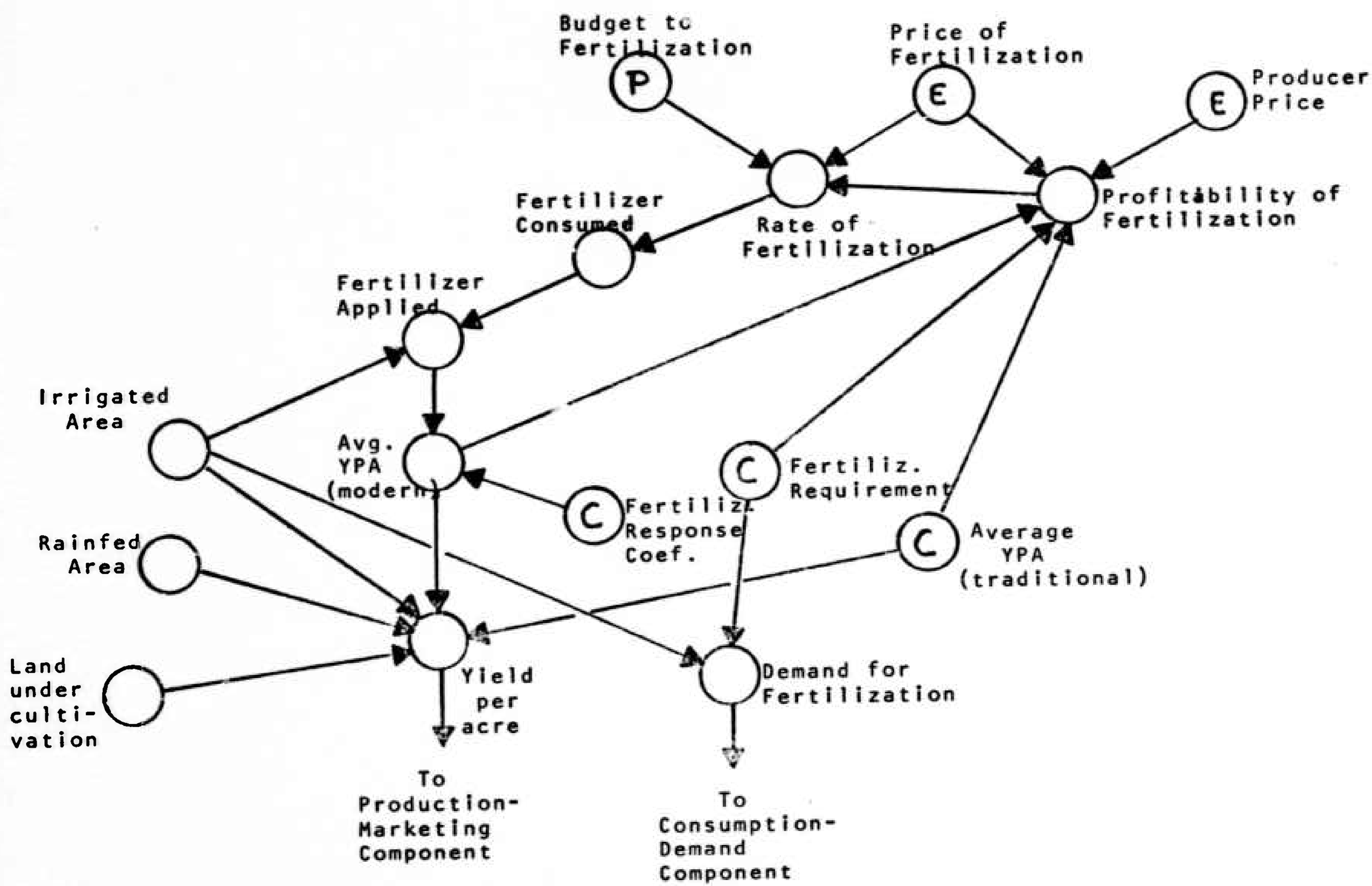

FIGURE. 3a. A Causal Map of the Modernization Component (Fertilization)

fertilizers. As Johnson, et.al (1971) noted, the modernization of the production process will not take place "...unless the net return from modern practices significantly exceeds that of traditional practices." 16 The impact of profitability is introduced into the model with the inclusion of the variable PCFERT (Equation M1.1). The value of this variable at a given time is computed by Equation M1.6.[17]

$$PCFERT(t) = \frac{[YPAM(t)*PP(t)-PFERT(t)/E1]}{YPAT*PP(t)} \qquad (M1.6)$$

where:

E1 = the reciprocal of the fertilization requirement, FERTR (acre/lb.)

A similar profitability variable is included for the introduction of machanization to the production process (Equation M2.7). But before we can describe this variable, we must lay out the structure of the second part of the modernization component:

$$RMECH(t) = \frac{1}{DT}[\ PCMECH(t-DT)* \frac{BUDM(t)}{PMECH(t)}] \qquad (M2.1)$$

$$ATP(t) = ATP(t-DT) + [DT*RMECH(t)] \qquad (M2.2)$$

$$POWU(t) = ATP(t)/LUC(t) \qquad (M2.3)$$

$$CM(t) = POWU(t)/POWR \qquad (M2.4)$$

$$LABM(t) = [CM(t)*SALF(t)]/LUC(t) \qquad (M2.5.1)$$

$$LABNM(t) = SALF(t)/LUC(t) \qquad (M2.5.2)$$

$$LMECH(t) = CM(t)*[LUC(t)/SALF(t)] \qquad (M2.6.1)$$

$$LNMECH(t) = LUC(t)/SALF(t) \qquad (M2.6.2)$$

where:

RMECH = the rate of mechanization, i.e., the rate at which farm machinery is acquired(horsepower/year)

BUDM = agricultural investment allocated to mechanization (dollars)

PMECH = farm price for machinery input (dollars/horsepower)

ATP = available tractor power (horsepower).[18]
POWU = power utilization (horsepower/acre)
POWR = power required for high yield crop production (horsepower/acre)
CM = coefficient for mechanization (dimensionless)
LABM = labor input with mechanization (men/acre)
LABNM = labor input without mechanization (men/acre)
LMECH = land-man ratio with mechanization (acres/man)
LNMECH = land-man ratio without mechanization (acres/man)
SALF = labor available, i.e., the size of the agricultural labor force (men)

The profitability criterion for mechanization, PCMECH, is then computed by the following equation:

$$PCMECH(t) = \frac{[LMECH(t)*AINCA(t)-PMECH(t)/E2]*LABNM(t)}{LNMECH(t)*AINCA(t)*LABM(t)} \qquad (M2.7)$$

<u>where</u>:

AINCA = the average gross income per acre from crop production (dollars/acre)
E2 = the reciprocal of the power requirement, POWR (acre/horsepower)

Finally, the modernization component computes two additional output variables: (1) the demand for fertilizers, and (2), the demand for farm machinery. Both variables constitute inputs to the consumption/demand component. Moreover, both represent the quantities of input that are necessary for modernization to take place.[19] These demands are computed by the following two equations:

$$DFERT(t) = FERTR*IRA(t) \qquad (M3.1)$$

$$DMECH(t) = POWR*LUC(t) \qquad (M3.2)$$

<u>where</u>:

DFERT = the demand for fertilizers (lb)
DMECH = the demand for farm machinery (horsepower)
FERTR = the fertilization requirement (lb/acre)

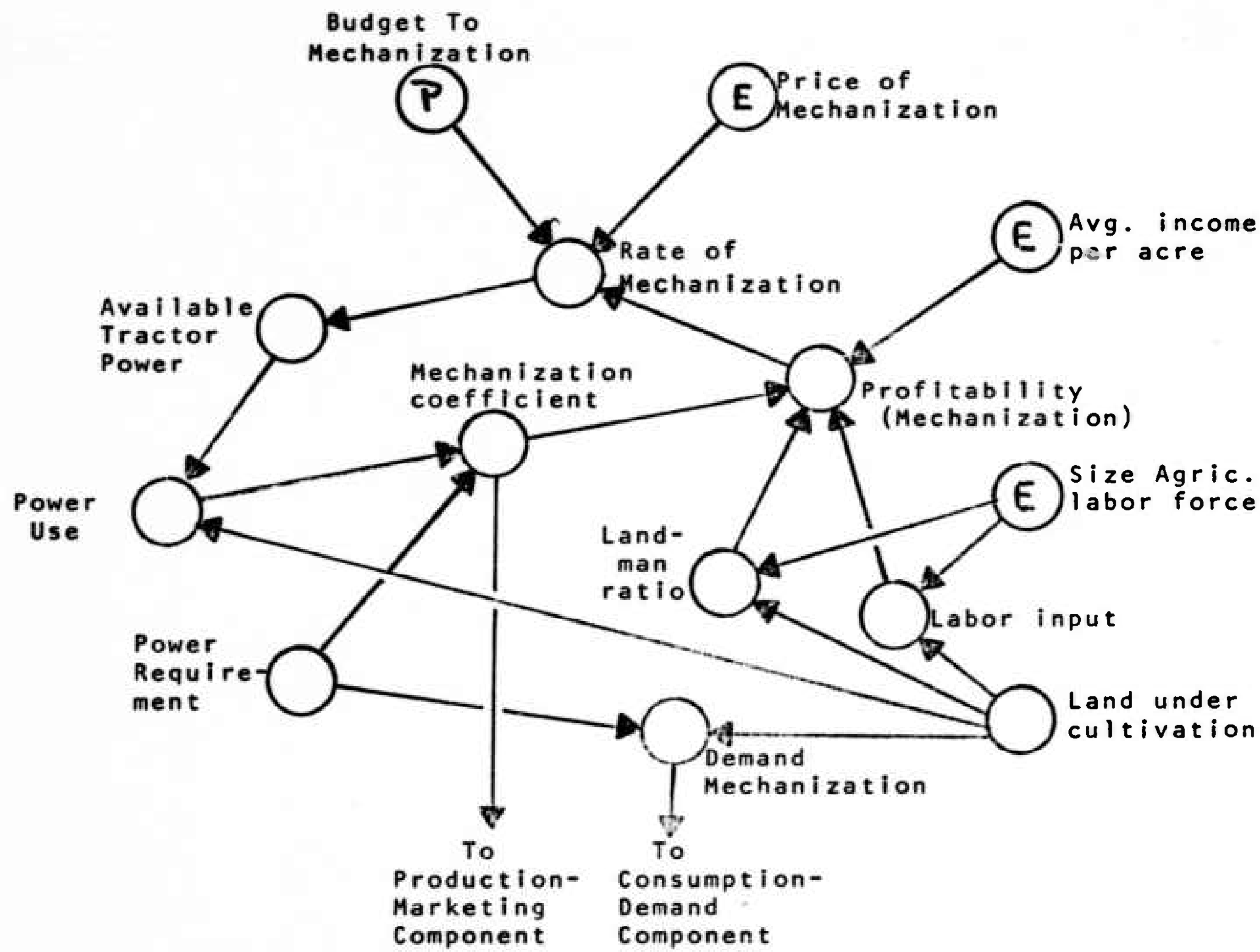

Figure 3b. A Causal Map of the Modernization Component (Mechanization)

The Production/Marketing Component

This component is somewhat misnamed in that marketing activities as such are not included in the structure of this component. The purpose of this component, then, is to simulate the activities of wheat production, and to compute the returns to these activities.

As the core of this component is a set of input-output relationships which are determined by the incoming land cultivated for wheat (from the resource allocation component), the labor available for crop production, the level of crop productivity and mechanization (from the modernization component). (See Figure 4). From this component emerges a set of physical outputs which then become inputs to the consumption/demand component. These outputs are computed by the following equations:[20]

$$YLDM(t) = LUC(t)*YPA(t) \quad (P1)$$

$$DEML(t) = [C_2*LUC(t)]/CM(t) \quad (P2)$$

$$YLDL(t) = \left[\frac{CM(t)*SALF(t)}{DEML(t)}\right]*YLDM(t) \quad (P3)$$

$$YLD(t) = MIN[YLDM(t), YLDL(t)] \quad (P4)$$

where:

YLDM = the total production (yield) of wheat possible if YPA reaches the biological maximum (bushels/acre).[21]

DEML = total labor required (demand) for the production of wheat (men)

C_2 = labor requirement for cultivation (men/acre)

YLDL = total production feasible as a function of labor (bushels)

YLD = total production actually achieved (bushels)

MIN(a,b) = a function that takes the minimum of turns in the parentheses.

With the information provided by these computations, the component then allocates the total production to the two physical output variables:

$$OUTC(t) = PCON(t)*YLD(t) \qquad (P5)$$

$$OUTE(t) = [1-PCON(t)]*YLD(t) \qquad (P6)$$

<u>where</u>:

OUTC = quantity of wheat produced which is allocated to domestic consumption (bushels)
OUTE = quantity of wheat produced which is available for export.
PCON = proportion of production allocated to domestic consumption; a policy variable expressed as a percentage.

In addition to these physical outputs, the production/marketing components computes several measures of the returns to the production activites. These measures, along with a measure of labor productivity, serve as inputs to the performance vector. The computations of these measures are accomplished as follows:

$$TINC(t) = [PP(t)*VLD(t)] - COST(t) \qquad (P7)$$

$$COST(t) = [PFERT(t)*FERTC(t)] + [PMECH*DT*RMECH(t)] \qquad (P8)$$

$$INCP(t) = TINC(t)/SALF(t) \qquad (P9)$$

$$INCA(t) = TINC(t)/LUC(t) \qquad (P10)$$

$$LABP(t) = YLD(t)/SALF(t) \qquad (P11)$$

<u>where</u>:

TINC = total gross income derived from wheat production (dollars)
COST = total farm cost of modernizing inputs(dollars)
INCP = per capita income from wheat production (dollars/man)
INCA = returns to land input (dollars/acre)
LABP = labor productivity (bushels/man)

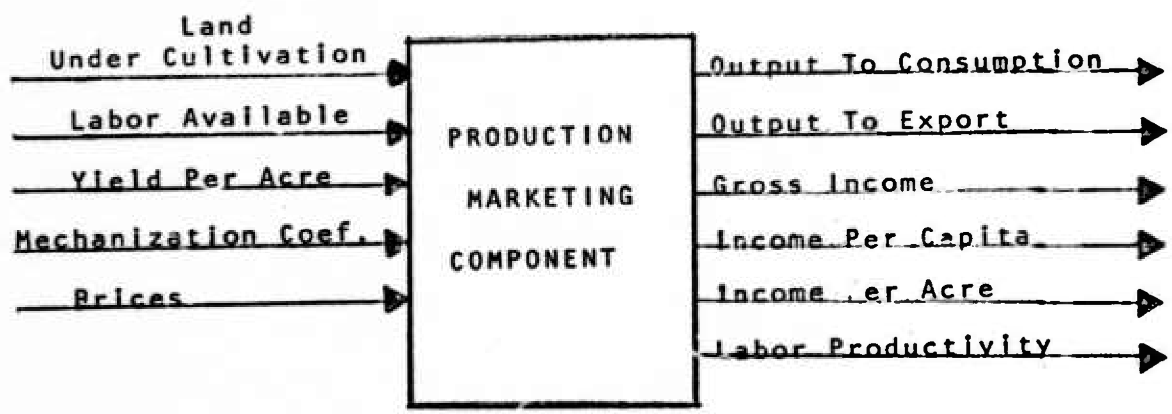

FIGURE 4. . Major Inputs and Outputs of the Production / Marketing Component

Consumption/Demand Component

This final component of our proposed model essentially represents a budgetary accounting mechanism. It take the information on modernizing input demands (from the modernization component) and production outputs (from the production/ marketing component), and computes the values for several variables measuring the overall performance of the production process being modelled. Put more simply, the purpose of this component is to compute the final set of variables comprising the performance vector. These variable include: 1) total demand for modernization input investments (Equation C1), 2) the value of crop exports (Equation C2), and 3) the demand for food imports (Equation C3,C4,C5).

$$\text{DEMAND I}(t) = [\text{COSTF}(t)*\text{DFERT}(t)]+[\text{COSTM}(t)*\text{DMECH}(t)] \tag{C1}$$

$$\text{VALEXP}(t) = \text{WP}(t)*\text{OUTE}(t) \tag{C2}$$

$$\text{DFOOD}(t) = \text{DFOOD}(t\text{-DT})+\left[\frac{\text{POPI}(t)}{100}*\text{I.E}\left(\frac{\text{PCE}(t)}{\text{POPI}(t)}-1\right)\right]^{22} \tag{C3}$$

$$\text{SUPPLY}(t) = \text{OUTC}(t) + \text{IMPORT}(t\text{-DT}) \tag{C4}$$

$$\text{IMPORT}(t) = \text{DFOOD}(t) - \text{SUPPLY}(t) \tag{C5}$$

where:

DEMAND I	=	total investment demand for modernization inputs (dollars)
COSTF	=	market cost of fertilizers (dollars/lb)
COSTM	=	market cost of farm (dollars/ horsepower)
VALEXP	=	total value of crop exported (dollars)
WP	=	world price for crop (dollars/bushel)
DFOOD	=	consumption demand for crop (bushels)
POPI	=	population index (dimensionless)
I.E.	=	income elasticity coefficient of demand for crop (dimensionless)
PCE	=	index of total private consumption expenditure (dimensionless)
SUPPLY	=	total available domestic supply of crop (bushels)
IMPORT	=	imports of crop (bushels)

Performance Vector

The choice of efficacious development policies and programs necessarily depends upon the decision-maker's understanding of the many varied aspects of the production process. Because of the very complexity of this process, however, the individual decision-maker is not likely to "see" a complete picture of this process; there is too much to be seen and too little information available on all aspects of the process. How then is one to evaluate the performance of the agricultural production process (and of his development efforts)? Upon what information does he base his choices of developmental policies and programs? The answer to both questions rest with the "performance vector". It is this vector (or set of variables) which measure the simulated system's attainment of "goods" and avoidance of "bads".[23] It is this set of variables, calculated in the salient components of the model, which serves as the input to the decision stratum.

Included in the performance vector of our proposed model are several factors measuring the returns from wheat production: gross income, per capita income, income per acre, and labor productivity. The set of variables comprising the performance vector is completed with inclusion of the outputs from the assumption/demand vector.

Discussion

Admittedly, the preceding description of our proposed agricultural sector model is somewhat sketchy. But then, the very nature of the subject matter and the modelling approach employed make explanations difficult. We are dealing with a very complex system composed of countless variables and interrelationships. To try to present a complete picture of agricultural production would necessarily mean building a model which is so complex as to make it unmanageable. Of course, it is not our intention to build such a model nor is it our intention to limit ourselves to just one aspect (ie, wheat) of agricultural production in the countries of interest. Instead, we have attempted to construct a model which is general enough to simulate the production of a number of different crops.

There are, to be sure, some important shortcomings in our model, both substantively and technically. For example, the model does not deal adequately with marketing, the price system, and the behavior of the individual farmer. Moreover, several variables in the model have been rather hazily conceived (e.g. intensity of irrigation) with the result that the relationships between them and other variables in the model remain unclear. Some major changes may be required in the model to overcome these limitations. But we cannot be sure of what specific changes to make until after we have had an opportunity to test the present model. To this end, we are trying to complete the specification of the model's parameters (and the shape of the functional relations) for each country. The programming and testing of the model will follow shortly.

FOOTNOTES

1. Clawson, Marion, Hans Landsberg and Lyle Alexander (1971) The Agricultural Potential of the Middle East. New York: American Elsevier Publishing Co., Inc. p.2

2. Clawson, Landsberg and Alexander, p.37

3. ibid

4. Clawson, Landsberg and Alexander, p. 115

5. ibid

6. As Clawson, Landsberg and Alexander have indicated, it is estimated that the costs for producing groundwater from pumped deep wells runs between $250 and $370 per acre-foot (1971, p.115). In contract, Fried and Edlund (1971) suggest that with the development of a large-scale single purpose plant based on oil or gas, the cost of desalination could be brought down to around 25 to 35 cents per 1000 gallons.

7. Clawson, Landsberg and Alexander, p. 4

8. Brenner, Y.S. (1971) The Economics of Agricultural Development. Ithaca, N.Y.: Cornell University Press, p. 50

9. Clawson, Landsberg and Alexander, p. 41

10. Schultz, T.W. (1964) Transforming Traditional Agriculture New Haven: Yale University Press, p. 33

11. ibid

12. Clawson, Landsberg and Alexander, p. 111

13. By a "building block" approach, we refer specifically to the modelling approach developed by Glen Johnson, <u>et al</u> , namely "the generalized system simulation approach. As it <u>will</u> soon be apparent, we have relied very heavily upon this work of Johnson et.al. in constructing our model.

14. Clawson, Landsberg and Alexander (1971), p.135.

15. This coefficient represents the per unit relationships between fertilizer use and crop production. The value for this coefficient is determined by regressing crop production on fertilizer use (i.e. it is a regression coefficient).

16. Johnson, Glen, <u>et al</u> (1971) <u>A Generalized Simulation Approach to Agricultural Sector Analysis</u>. East Lansing: Michigan State University. p.49

17. This equation was derived from the profitability criterion variable formulated by Johnson <u>et al</u> (1971), p.89

18. Although a wide variety of machinery is required for modern agricultural production, we shall focus on tractors alone.

19. Underlying the calculation of these demands is the assumption that these inputs are <u>not</u> readily available - they must be imported - and as such <u>do</u> act to constrain the modernization effort.

20. These equations are a slightly modified version of those presented by Johnson <u>et al</u> (1971), p. 79.

21. The most reasonable estimate of this biological maximum is 100 bushels/acre (Clawson, Landsberg and Alexander, 1971, p. 122

22. Asfour, Edmond (1965) Saudi Arabia Beirut: American University of Beirut, p.25

23. Johnson, et al (1971), p.33

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