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PUBLIC POLICY AND THE DEMAND FOR MECHANIZATION ON EGYPTIAN FARMS

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INTRODUCTION

The Mechanization Debate

Few debates in the literature on agricultural development have been more contentious than those dealing with the impact of agricultural mechanization on the rural areas of developing countries. For proponents, the movement away from animal power and the drudgery of traditional agriculture is a symbol of modernization and progress. For detractors, the presence of tractors, pumps, harvesters, threshers, etc., are simply another example of the adoption of inappropriate technology under the pressure of international commercial interests and misguided domestic economic policies.

In Egypt, it is difficult to bring empirical evidence to bear on this issue. The countryside is in an unusual state of flux. There is considerable evidence that real wages have risen significantly in recent years suggesting that the mechanization that is taking place is being driven by the changes in relative factor scarcities that have prompted the substitution of capital for labor in developed countries. However, the circumstances that have been instrumental in creating the labor "scarcity" manifested by rising wages are unusual. In part, increased wages have been the result of a massive outmigration to the Gulf areas that has made remittances the third largest credit entry in the country's balance of payments. Moreover, these same remittances have undoubtedly created a substantial increase in the reservation price of labor thus restricting further the available labor supply.

Unfortunately, in the volatile political economy of the Middle East, no great imagination is required to construct a scenario in which these migration flows are rapidly reversed with devastating results for the Egyptian economy (Richards, 1981). There has already been a leveling off in the number of workers seeking employment abroad. Further retrenchments in the pace of infrastructure development in the Gulf Region as a result of declining oil prices and a continuing worldwide economic downturn would all act to increase the need for job opportunities inside Egypt. But the same forces that are slowing economic expansion in the larger Middle East region are also at work domestically. The fledgling industrial sector and the post-1973 construction boom cannot hope to absorb all of the returning labor should such a reversal occur over a relatively short period of time.

In part, it is the spector of a rapid change in economic circumstances that keeps the mechanization cum rural employment issue alive. However, such concerns would probably be insufficient if mechanization were not taking place in a distorted economic environment. For example, fuel is highly subsidized reducing the private cost of operating pumps and tractors to a fraction of the true cost to the economy. As a result of double digit inflation, institutional interest rates on credit for purchasing durable capital goods are negative. Output prices that favor the production of meat and milk raise the opportunity cost of fodder for animal power thereby enhancing the comparative advantage of machines. As the subsequent analysis will show, each of these forces push in the same direction, namely the substitution of capital for labor.

There are undoubtedly legitimate needs for mechanical inputs generated by an increasingly complex and sophisticated agriculture. National cropping intensities are currently nearing 200 percent and it is hard to imagine that intensities can be raised much higher without revolutionizing the planting and harvesting of high value, short duration cash crops. Perhaps even more significantly, increased yields will have to come in substantial measure from better and more timely cultural practices. Seedbeds will have to be better prepared to insure higher plant populations. Fertilizer will have to be better placed to insure that the nutrients being added to the soil truly benefit plant growth. Losses in the post-harvest period will have to be decreased if additional expenditures on inputs are to bear fruit. All of these activities will, sooner or later, involve the application of mechanical power.

Given data limitations at critical points, the present essay's contribution to the mechanization debate is modest. No really firm conclusions about the optimal package of technology can be reached without experimental results that relate yields and cropping patterns to the application of machines. However, by treating the topic within a rigorous farming systems framework, the knowledge "gap" can be more specifically defined and more precise recommendations for research can be formulated. (With the development of a Mechanization Institute within the Ministry of Agriculture and the letting of contracts for several pilot farms under World Bank auspices, there is now a minimal institutional framework within which the needed experiments can be conducted.) As more and better data become available, the simulation of task specific mechanization on representative farms will give increased precision to analyses of the likely impact of public policy on the demand for machines.

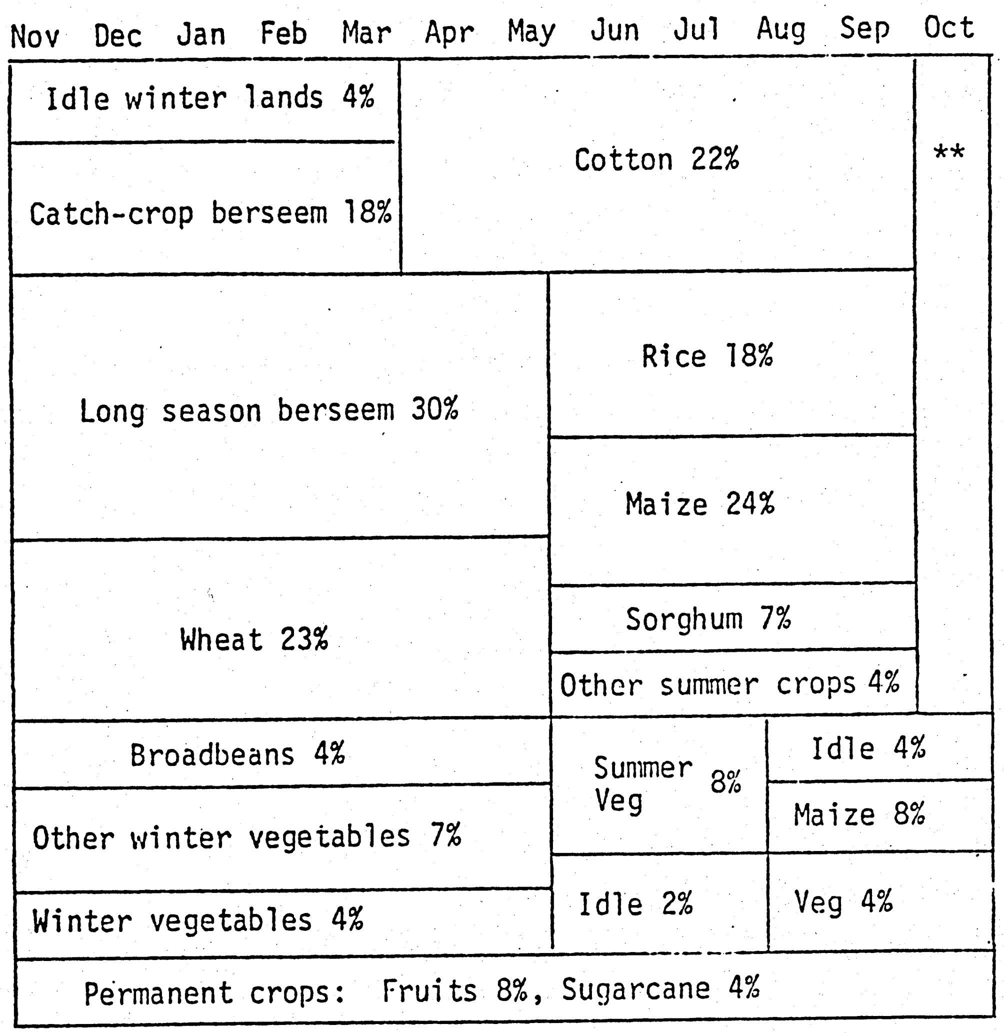
Selective Overview of Egyptian Agriculture

Before turning to the development of a farming systems model within which the demand for mechanization can be analyzed, a brief description of those aspects of Egyptian agriculture most relevant to the mechanization issue is in order. Fortunately, several books have been written in recent years about the characteristics of Egyptian agriculture (El-Tobgy, 1978; Richards, 1982) and additional detail that is of technical and historical interest can therefore be found elsewhere.

Four facets of contemporary Nile Valley agriculture need to be kept in mind when projecting the demand for mechanical technology. First, there is the obvious effect of very small holding sizes. Some 3 million farm families cultivate roughly 6 million acres of land. The most recent census was conducted in 1961 and consequently up-to-date figures on holding sizes are unavailable. Although what little evidence there is for intervening years is subject to considerable debate (Fitch, 1981), it seems highly unlikely that significant increases in holding size have taken place.

Second, present cropping intensities, as shown in Figure 1, are such that little land is left fallow during the year. Unlike arid irrigated areas in other parts of the world, water is not, at least for the immediate future, the binding constraint on cropping intensities. (Indeed, according to some irrigation experts, the failure to charge for water has led to its excessive use. They also argue that, apart from management constraints on the system, increased cropping intensities in, say, the rice areas could be undertaken with current water supplies.)

A third aspect of Egyptian agriculture that bears on the impact of mechanization is the high level of yields already attained in most crops. In several cases where a great deal of hand labor is required, e.g., rice, these rank among the highest in the world. However, specialists from other countries who have examined Egypt's agro-climatic environment are uniformly convinced that conditions are so favorable for plant growth that meaningful yield comparisons are difficult to make. In their analysis, they point to obvious deficiencies in plant populations, water management, weeding and other cultural practices as the basis for arguing that Egyptian yields could be improved. The cereals in particular are seen as crops in which substantial yield improvements are possible.



** Represents lands which are temporarily idle between summer crops, e.g. cotton and rice, and winter crops, e.g. berseem.

Source: Nabil Habashy and James Fitch, "Egypt's Agricultural Cropping Pattern," Micro-Economic Study Unit, Ministry of Agriculture, Arab Republic of Egypt

FIGURE 1 CROPPING PATTERN IN 1977-1979.

A final fixture of the Egyptian scene that has a good deal to do with the demand for mechanization involves the pricing of agricultural outputs and inputs. Numerous studies have shown that there is a high degree of government intervention at all levels of the agricultural sector. Table 1 presents some selected data showing the difference between the prices of outputs and inputs at the farm gate and what these same commodities would be worth at border or world market prices. (Much of the discussion of the model results in subsequent sections is devoted to the implications of such price distortions for the direction of resource allocation by individual agricultural enterprises.)

Table 1

Price Structure for Selected Agricultural Products
(1980 in L.E. per metric ton)

	L.E. Equivalent of international price at "Market" Exchange Rate	L.E. Equivalent of international price at Official Exchange Rate (GASA Price)	Farmgate Price	Consumer Price
Rice	320	269	75.0	50.0
Wheat	133	112	76.50	41.20
Sugar	436	366	176.80	100.00
Beans	243	204	161.29	100.00
Lentils	441	370	250.00	110.00
Cotton	959	806	229.50	333.00

SOURCE: USAID, Country Development Strategy Statement, Agricultural Annex, 1982. Consumer price for cotton is a USAID estimate of price paid by domestic industrial users

STRUCTURE OF THE MODEL

The linear programming model used to analyze the demand for various types of mechanical technology under both current and hypothetical conditions is described below. Its general formulation is familiar (Beneke and Winterboer, 1973; Gotsch, 1975), but it is differentiated by an unusually high degree of disaggregation. Much of the mechanization debate has focused on the issue of timeliness of operations and consequently, limits on resource availability have been broken down into semi-monthly constraints for 8 of the most critical agricultural months. Each resource, e.g., land, water, labor, etc., is actually composed of 20 resource constraints representing the crop year. These detailed time periods in turn allow a more realistic modeling of the crop activities--each crop has planting dates at semi-monthly intervals over the relevant season.

The model was also disaggregated to include a variety of technological choices. Separate activities were included to represent the purchase (fixed cost) and the operation (variable cost) of indivisible durable capital investments--buffalo, cattle, saquias, pumps, tractors, threshers and norags. Such a formulation permits modeling experiments that embody different assumpitons about the presence or absence of hire service markets. (In a subsequent paper, the purchase variables are constrained to take on discrete values thus converting the exercise to a mixed integer problem.)

Objective Function

The elements in the objective function for the crop activities are, for the most part, the standard calculation of net revenue for each enterprise. In some cases, transfer rows have been used to move intermediate inputs from one activity to another. Such activities, e.g., animal fodder, show only the costs incurred. Other inputs introduced via individual purchase activities include hired labor, diesel fuel and purchased livestock feeds. The benefits of feeds that are produced on the farm enter the net revenue function through the end products, namely milk, meat and animal labor. As a result, the net revenue coefficients for livestock are equal to gross revenues; feed costs have been subtracted out via transfer rows. The one exception is broadbean, an animal feed which is also widely sold in the markets for human consumption. Broadbeans have a separate selling activity in the model.

The objective function can be written formally as follows:

Maximize:

$$Z_j = c_{ij}C_i - u_{ij}U_i - p_{ij}P_i - l_{ij}L_i - m_{ij}M_i - b_jB - e_jE - d_jD + a_{ij}A_i \qquad (1)$$

where:

Z_j = value of objective function j
C_i = area in feddans of crop i
c_{ij} = net revenue per feddan from crop i
U_i = hours (or days) utitilization of lumpy input i
u_{ij} = variable cost of utilizing lumpy input i
P_i = units of lumpy input i purchased by the farm
p_{ij} = annualized fixed cost of lumpy input i
L_i = person-days of type i hired casual labor
l_{ij} = daily wage rate of type i hired casual labor
M_i = persons of type i hired permanent labor
m_{ij} = annual wage rate of type i hired permanent labor
B = tons of broadbean sold
b_j = price per ton of broadbean
E = tons of feed concentrate purchased
e_j = price per ton of feed concentrate
D = liters of diesel fuel purchased
d_j = price per liter of diesel fuel
A_i = units of livestock activity i
a_{ij} = net revenue of livestock activity i

Prices and Yields: One of the most important objectives of the present exercise is to explore the resultspercent. Because of the nature of the activities, this also roughly the economic or social rate of return. Unlike much of the agricultural project analysis undertaken in Egypt, there are few obvious controls on the vegetable and fruit crops br, subsequent runs also introduce economic or accounting prices as weights in the objective function. As the overview section indicated, these prices differ significantly for both outputs and inputs and, at least in the absence of institutional constraints, can be expected to result in both different cropping patterns and different packages of technology when net revenues are maximized.

In the basic solution reported below, it has been assumed that yields are not affected by data of planting. This is a much debated issue, but what little evidence farm management data provide, lends support to the argument that under the irrigated conditions of Egypt, planting dates are much less critical than they are in more temperate or semi-arid agricultures Similar results have been found in other areas where moisture is supplied entirely by irrigation. In part, this is undoubtedly a function of a specific set of growing conditions. However, it is also related to the limited set of activities that currently constitute "mechanization."[1]

Crop Activities: Eight possible crops have been included in the choice set. Data on crop acreages from the mixed farming area of Sharkia Govenorate, the area from which input-output coefficients were taken, indicate that these eight crops occupy roughly 98 percent of the land. A variety of minor vegetables, many grown for home consumption, have been ignored. Ultimately, such crops may become more important in the cropping pattern, but it was judged that if such changes were to occur, they would not have a significant impact on the choice of technology.

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[1] For a detailed discussion of the evidence on the effects of tractor mechanization in arid, irrigated agricultural areas, see Hans Binswanger, "The Effects of Tractor Mechanization in Southwest Asia", Agricultural Development Council, 1980.

The eight major crops of Sharkia governorate from which the data are drawn are divided into three winter crops (berseem, wheat and broadbean) and five summer crops (cotton, rice, maize, fodder maize and tomato). Each crop has a number of possible planting dates and choices of technology for seedbed preparation. The result is a total of 220 separate crop activities (Table 2). (The technology choice for irrigation and threshing are included in different activities. Only the operations for tillage, harrowing and ridging are included in these crop activities.)

TABLE 2

Crop Activities

Winter	Number of planting dates	Number of seedbed technologies	Total number of crops
Berseem - one cutting	5	4	20
Berseem - two cuttings	5	4	20
Berseem - three cuttings	5	4	20
Berseem - four cuttings	4	4	16
Berseem - five cuttings	4	4	16
Berseem - seed production	5	4	20
Wheat	2	3	6
Broadbean	2	4	8
Summer			
Cotton	4	4	16
Rice - transplanted	3	2	6
Rice - broadcast	3	2	6
Maize	6	4	24
Fodder maize	6	3	18
Tomato	6	4	21
Total			220

Mechanical technologies: A variety of mechanical technologies have been included in the model. In the case of irrigation, the availability of a 6.5 horsepower diesel pump of the type being imported from India was assumed. Also included as an irrigation technology was the traditional animal powered water wheel, the saquia. For seedbed preparation, the choice in the model for the basic operations such as tillage, harrowing and ridging, is between tractor and animal power. Certain crops require all cultural practices while others only require a subset of the indicated operations. Threshing activities in the model can also be carried out by tractor or animal power. The tractor-powered thresher is assumed to be a domestically manufactured implement that requires a separate, hand-powered winnowing machine. Using a mechanical thresher activity therefore includes the variable costs of both the thresher and the winnower plus the required number of complementary tractor operation hours. The animal-powered threshing utilizes a norag, a sledge with cutting discs that is drawn over the harvested crop. Cattle or buffalo utilization activities supply the power.

The purpose of the mechanical "utilization" activities is to subtract the variable costs of machinery use from gross revenue, both explicitly in the objective function and implicitly through using resources included in other constraints. For example, tractor and pump utilization activities have objective function entries that cover only the repair and maintenance expenses. The other variable costs, namely labor and diesel fuel, are subtracted from their respective constraint rows.

The variable costs of animal labor use are implicitly included by increasing the demand of animal feed requirements (digestible protein and total digestible nutrients) and by decreasing the amount of milk and meat available for direct consumption.[2] Animal powered operations explicitly

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[2] The estimation of these costs have been described in Wayne Dyer, "The Opportunity Cost of Animal Labor in Egyptian Agriculture," Ministry of Agriculture and University of California, Davis, 1981. The results of this careful analysis are at substantial variance with numbers that have been used in previous estimates of the benefits of mechanization. For an example of inflated benefits attributed to increased meat and milk production from animals formerly used for draft, see ERA 2000, Inc., "The Further Mechanization of Egyptian Agriculture," AID, Cairo, 1979.

subtract the direct repair and maintenance costs of the implement and implicitly deduct the other variable costs by (1) entering labor requirements in the labor rows, and (2) forcing the entry of an animal utilization activity.

Technology purchase activities: Purchase activities determine the capacity of various mechanical technologies available to the farm. If the assumption of completely indivisible inputs were justified, these activities would become integer variables and the linear programming model would become a mixed integer model.[3] The initial assumption, however, is that hire service markets create a flow of services from "lumpy" inputs and that these are available to small farmers without loss of efficiency or productivity.

Making livestock replacements endogenous is desirable because of the difficulty in developing economic (as opposed to financial) prices for livestock. The resulting model loses some flexibility in its ability to simulate farmer behavior because the possibility of buying fully grown animals is excluded. However, the approach avoids the need to wrestle with a non-tradeable good whose economic value is difficult to determine. Such consistency is particularly important when the model is being used for comparative purposes.

The entry in the objective function for technology purchase activities is the purchase price of the input annualized over its lifetime at an interest rate of 10 percent. Depreciation is assumed to be function of time only and not a function of the level of utilization.

Labor hire activities: Certain tasks, such as animal care, rice transplanting and cotton picking, are not usually performed by men. The labor requirements in the model, and consequently labor hire activities, have

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3 For the development of such a model, see Carl Gotsch and Shahid Yusuf, "A Mixed Integer Model of Punjab Agriculture," Food Research Institute Studies, Vol. XIV, No. 1, 1975.

therefore been disaggregated into two catagories of labor: man labor and child or woman labor.

Each set of labor activities is divided into the 20 different time periods during the year, resulting in a total of 60 labor hire activities - 20 each for man labor, woman and child labor and labor transfer activities. In addition, there are two permanent labor hire activities, permitting the hiring of both man labor and woman and child labor on an annual basis.

Modeling the labor market has always presented special problems for researchers attempting to simulate farming systems with linear programming models. While significant changes in seasonal wages at critical time periods are a well-documented phenomenon, the between-month variations obtained empirically from farm surveys are usually much smaller than those shown by the monthly "shadow prices" of labor in the l.p. model. Alternatively, when labor activities are introduced that permit an unlimited amount of labor to be hired at the observed seasonal wage rates, quanitites of labor hired by the model may be well above or well below amounts reported by farmers.

The sources of divergence between model results and empirical findings are two-fold. First, because of the well-known limitations of linear models and their constant proportion production relationships, the linear programming solution may overstate the significance of an additional unit of labor in critical periods. However, it is also likely that powerful institutional constraints including contractual obligations and long term security objectives are operative in the labor market.[4] In such cases, labor's wages are

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[4] For an interesting discussion of non-pecuniary forces in the rural labor markets of Southwest Asia, see Hans Binswanger and Mark Rozenzweig, "Contractual Relationships in Rural Labor Markets", Agricultural Development Council, New York, 1982

below or above their marginal product for legitimate behavioral reasons quite apart from the shortcomings of the model.

It is difficult to determine which of the two explanations is operative in a given situation. In interviewing Egyptian farmers, researchers have invariably encountered the complaint that labor was hard to find in the busy seasons. Only a few efforts have been made to develop more rigorous tests of the proposition that wage rates reflect labor productivity and that labor markets are generally in equilibrium. Such studies confirm the seasonality of the supply and demand for labor, but they also leave open a number of questions regarding the functioning of the rural labor market.[5]

In modeling the labor allocations decisions of small farmers, the conventional practice is (a) to provide for a certain amount of fixed or permanent family labor, and (b) to introduce labor hiring activities that permit the farmer to hire labor in or out at the prevailing market wage rate for that particular season. The uncomfortable assumption that this requires, of course, is that sectoral or macro labor markets are clearing at the wages selected.

An alternative is to assume that the labor markets have cleared and to enter the quantities reported by farmers as constraints letting the model determine the implicit wage rates. Such an approach is again more suited to a macro model than to one which tries to explain technology choices at the farm level.

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5 The literature on rural labor markets in Egypt has increased rapidly in the past several years. Articles appearing in the Agricultural Development Systems series include Carlos Benito and Sylvia Lane, "Mechanization, Labor Supply and Food Production", Alan Richards, et al, "The Structure of the Egyptian Farm Labor Market," and Nicholas Hopkins, "Mechanization, Migration and Labor in an Egyptian Village".

The present exercise occupies a half-way ground. Family labor has been assumed to be fixed to the farm and cannot be hired out, i.e., in the basic solution, there are no opportunities for off-farm employment. Seasonal activities for hiring labor in at the prevailing wage rate have been included, but these have been constrained not to exceed the average labor hired by various size farms as reported in the 1960 Agricultural Census. Under this scheme, labor can take on three shadow prices: (1) zero when family labor is sufficient, (2) the market wage when labor is hired, and (3) a "scarcity value" when the hiring constraint is binding.

Livestock feed activities: Livestock feeds that can be stored such as wheat straw, broadbean and feed concentrate, have associated with them activities which withdraw the feeds from stocks and supply digestible protein and total digestible nutrients to animals. There a single activity for each storable feed for each month during which it is possible to supply that feed. Berseem, fodder maize and maize cuttings are not stored on the farm and are fed to the animals at the time of harvest. Therefore no separate feed activities are needed for these feeds.

Exchange activities: A few commodities have been segregated and require sales and purchase activities to purchase or sell them. The one selling activity is for broadbean, because it can either be fed to animals as a high-protein feed or sold for human consumption. Diesel fuel and feed concentrate are supplied through two separate buying activities in order to facilitate parametric price variation and, in the case of concentrates, to limit supplies. (The subsidized feed concentrate can only be purchased in limited quantities from the cooperative. The level of the constraint is determined by government regulations based on the number of animals that the farmer owns.)

Livestock activities: The livestock activities are partly determined by the purchase activities for buffalo and cattle, which were discussed in the earlier section. Table 3 lists the activities that determine the herd structure. The activities are forced in by the livestock constraints and require the farm to raise the replacement animals for the level of animals "purchased". This internalizes the capital cost of livestock and allows greater freedom in parametrically varying prices without having to worry about whether the capital costs of livestock and the prices of intermediate non-tradeable inputs are consistent with the new price structure. More importantly, it permits a consistent comparison of cropping patterns under economic and market prices because it removes the need to put values on intermediate fodder and by-products that are the major costs of livestock production. Although the approach may understate the income potential of small farmers who would find it profitable to specialize in dairying, permitting mature livestock purchases would only reinforce the results obtained when the replacement restrictions are imposed.

TABLE 3

Livestock Herd Activities

Activity	Age in Months	Male or Female
Calves for veal	0-3	both
Weaned calves	0-5	both
Yearlings	5-17	both
Heifers	17-29	female
Cow	29-41	female

Selling calves as veal and raising male yearlings produces revenue. These and the other herd activities require resources that are withdrawn from the constraint rows for labor, digestible protein and total digestible nutrients. The activities that generate no farm revenue enter the model only because they are forced in by the herd constraints, which are discussed in a following section.

The livestock sub-model also includes a pair of activities that cull a fixed percentage of the dairy animals for sale at their salvage value. Milk marketing is handled by four selling activities (winter and summer season; buffalo and cattle milk) that obtain milk from the milk production activities. The model does not include any activities for purchasing and maintaining camels or donkeys, which are important sources of power on the farm but used primarily for transportation.

Constraints

The inequalities and equations that form the constraint set are standard formulations and require little explanation except for the constraints dictating the choice of technology and the livestock herd constraints.

<u>Land</u> <u>constraints</u>:

$$c_{ij}C_i \leq b_j \tag{2}$$

The land inequality is a representation of land constraints on the farm where crop activities have been standardized on one feddan The b_j's are the 20 right hand side values for the 20 time periods into which land is disaggregated. (The effects of farm size on resource allocation can be simulated by parametrically varying b_j.)

<u>Labor</u> <u>constraints</u>:

$$c_{ij}C_j + u_{ij}U_i - l_{ij}L_i - m_{ij}M_i - a_{ij}A_i \leq b_j \tag{3}$$

The labor inequality represents the 40 labor constraints in the model, 20 time periods for both man and woman or child labor. The three positive entries in the left hand side of the equation are the labor demands, crop activities, mechanical operations and livestock activities. The negative entries, casual hired labor and permanent hired labor, act to increase the supply of labor and will enter only after all the family labor (b_j) is utilized and the scarcity value has exceeded the market value.

Mechanical input requirements:

$$c_{ij}C_i - u_{ij}U_i \leq b_j \tag{4}$$

The constraint models the technology need to carry out various agricultural operations. The latter include irrigation, seedbed preparation and threshing, and are disaggregated so that there is a constraint for each of the 20 periods. The function of the constraint is to transmit the demand for mechanical technology, i.e., the positive entry in the crop activities, to the mechanical and animal rental (or purchase) activities.

Availability of indivisible inputs:

$$u_{ij}U_i - p_{ij}P_i \leq 0 \tag{5}$$

The above inequality constrains the "lumpy" technology utilization activities, U_i's, not to exceed the capacity of the inputs, as set by the level of the purchase activities (P_i). Because the saquia and pump activities require 20 constraints each, there are 40 constraints for irrigation. Threshing needs 8 constraints each for the norag and winnower and an additional 5 constraints for the mechanical thresher. Cattle and buffalo each have 20 constraints. Tractor availability uses 29 constraints, 8 of which are special constraints that add to the availability of tractors for use with mechanical threshers. The tractor-powered threshers operate late into the night with the use of lights and farmers report much higher tractor utilization during the threshing season.

Livestock nutrition constraints:

$$-c_{ij}C_i - s_{ij}S_i - f_{ij}F_i + u_{ij}U_i + p_{ij}P_i + a_{ij}A_j \geq 0 \qquad (6)$$

Inequality 6 insures that the nutritional requirements of the animals are fulfilled. The supply is determined by the cropping activities, C_i, the stripping of maize leaves, S_i, and the feed activities, F_i. The demand on animal nutrients is determined by the animal labor utilization, U_i, the number of adult dairy animals, P_i, and the livestock activities, A_i. The constraints insure that total digestible nutrients (TDN) requirements be met for 12 monthly periods and two seasonal periods and digestible protein requirements (DP) be reached for 7 monthly periods and one seasonal period. The 7 monthly DP requirements are sufficient because berseem is the only winter feed and DP needs will be exceeded if berseem supplies adequate TDN.

Livestock feed availability:

$$- c_{ij}C_i - u_{ij}U_i + f_{ij}F_i + b_jB \geq 0 \qquad (7)$$

All of the storable livestock feeds have feed availability constraints that correspond to the feeding activities, F_i. These constraints allow the stored feed to contribute to the nutritional requirements in any period. Other livestock feed is supplied by the cropping activities, C_i, for berseem and by threshing activities, U_i, for broadbean and fool. (Berseem is not storable but seven constraints were included to allow the marketing of berseem.) Broadbean has one availability constraint but straw has two in order to differentiate between straw available early in May for feed and that which is not threshed until June. The activity B in the equation allows the sale of broadbean for human consumption, which is it usual use.

$$-e_jE + f_{ij}F_i \leq 0 \qquad (8)$$

Equation (8) serves the same purpose as the previous feed availability equation but refers to concentrates, which are supplied by a purchase activity E, not as a crop by-product.

$$e_j E - p_{ij} P_i \leq 0 \qquad (9)$$

This equation limits the level of the feed purchasing activity. Cooperatives limit the feed concentrate purchases, E, according to the number of dairy animals owned, P_i.

Crop Area Constraints:

$$c_{ij} C_i \leq \{\text{or} \geq\} \; b_j \qquad (10)$$

The 20 crop area constraints serve a number of purposes and are not all used for each model run. The simplest use is to limit the area of a certain crop, e.g., tomatoes because of the limited markets and/or rotational considerations. A rice acreage constraint imposed because of the limited capacity of the canals to deliver water is another example.

The crop constraints also model government acreage regulations which impinge on the cropping pattern, i.e., in some runs, rice, wheat and cotton acreage must be greater than or equal the Ministry's planned area. Crop constraints are also used to keep track of the maize area available for leaf stripping for feed, to force an adequate berseem seed crop area and to permit certain crops following rice and broadbean to be grown without prior tillage.

Accounting rows:

$$u_{ij} U_i - d_j D \leq 0 \qquad (11)$$

An "accounting" equation keeps track of the demand for diesel fuel from the mechanized utilization activities, U_i, and requires that an equal amount of diesel fuel be purchased (D). Another set of accounting rows, not listed, duplicates the three objective functions and accumulates the value of the activity levels using alternative price weights. By consulting these rows, the economic value of a cropping pattern determined by domestic price incentives can be readily ascertained.

Livestock herd constraints:

$$u_{ij}U_i - p_{ij}P_i + a_{ij}A_i \leq 0 \qquad (12)$$

The above equations model the production of veal from the farm. The supply is from the adult dairy animals, P_i. The demand is from livestock activities that sell veal or raise animals, A_i, and from the animal labor activities, U_i, that use animals for power.

$$p_{ij}P_i - a_{ij}A_i \leq \{\text{or} \geq\} \; 0 \qquad (13)$$

These equations constrain the herd structure so that dairy animal replacements are raised. The female herd structure is fixed, given the number of adult dairy animals, P_i. However, the male herd structure is flexible depending on whether male calves are sold for veal or raised for red meat production.

Milk availability:

$$- u_{ij}U_i + p_{ij}P_i - a_{ij}A_i - h_{ij}H_i = 0 \qquad (14)$$

The supply of milk in the above equations is determined by the number of dairy animals, and the sources of demand are animal labor, U_i, raising calves, A_i, and the marketing of milk, H_i.

POLICY IMPLICATIONS OF MODEL RESULTS

Earlier comments indicated that the government intervenes directly in the agricultural sector by setting acreage targets, procuring commodities and selling subsidized inputs. There is a good deal of evidence, however, that while prices and quotas are announced each year, government directions are only partially implemented (Habashy and Fitch, 1980). Nevertheless, the basic solution of the model suggests that the "leakage" may be less than is often supposed. While cropping patterns observed during the past several decades have undoubtedly failed to reflect fully the government's plans, they clearly depart significantly from those that would have obtained if private profitability had been the sole guide to resource allocation. This finding, i.e., that cropping patterns have been pushed in the direction of a socially desirable allocation of resources by administrative means injects a note of caution into projections of agricultural growth that rely on improvements in static efficiency.

The results of the model also underscore the complexity of Egyptian agriculture and importance of indirect effects on resource allocation created by distorted prices. Of particular interest is the impact of energy subsidies and the taxation of key crops such as cotton and rice on the livestock industry. It is true that the prices for livestock products are largely uncontrolled and indeed, may even command a premium over world prices. But the incentives that have created such dynamism in the animal products sector are due as much to (1) the low opportunity cost of crops that compete with fodder for land, and (2) the subsidies to mechanization, as they are to relative output prices.

In the following sections, further detailed comparisons of model results at financial and economic prices are presented. Such comparison are the primary methodology for examining the links between public policy and the demand for various types of mechanical technology.

Net Revenue at Financial and Economic Prices

A measure of the effects of Egyptian agricultural price policy on small farmer income is presented in Table 4 where the net revenues under alternative price assumptions are compared. The first solution maximizes financial revenue on the three-feddan farm when crops may be freely selected. The divergence between financial and economic revenues is large, as expected.

The second solution introduces additional constraints into the model that simulate direct government interventions in the form of acreage controls. (Official prices paid for procured quantities of controlled crops have been used as the basis for the calculation of financial returns.) Limiting the capability of the farmer to respond to domestic incentives further reduces financial returns, but increases government revenues. The primary culprit is, of course, the government's insistance that cotton be a part of the cropping pattern.

The third solution assumes that economic prices prevail in both input and output markets, i.e., that farmers are paying and receiving the farm-gate equivalent of world market prices for agriculturally related products.

Juxtaposing the three runs emphasizes the role that comprehensive government planning could play in minimizing the static efficiency losses of price distortions. A comparison of runs 1 and 2 show that the introduction of government acreage requirements reduces the financial revenue only 4 percent while increasing economic revenue by 11 percent. By imposing acreage requirements on crops that have a high economic value but low financial returns, the farmer is forced into a cropping pattern which is detrimental to his own net revenue but favorable to the government. Social efficiency is maintained under such a regime and agricultural surpluses are transferred to the government.

Under a complete scheme of public sector management, private investment of the surplus is not regarded as a significant source of growth, the latter being the responsibility of the public sector. It is precisely on this point, of course, that much of the present policy debate turns. Proponents of a strategy that would assign a larger role to agriculture in Egypt's development plans argue that the government has deprived individual farmers of both the incentive and the surplus that would stimulate individuals to search for improved technology. The failure to provide an adequate public sector mechanism for reinvesting the diverted surplus productively has subsequently resulted in an agricultural sector whose contribution to development, particularly in recent years, has been much less than what it might have been.

TABLE 3

Net Revenue - 3 feddan farm
All technologies available

	Financial Revenue (L.E.)	Economic Revenue (L.E.)
Maximize Financial Revenue- free crop choice	953.70	1529.18
Maximize Financial Revenue- government acreage	915.35	1693.88
Maximize Economic Revenue- free crop choice	741.69	1831.91

Run 3 provides a rough approximation of the magnitude of the distributive effect of government price policies. Even if farmers were free to respond fully to domestic price incentives, net revenues would still be half what they could be if farmers (1) were producing under a regime of world market prices, and (2) were able to respond to the implied allocation of domestic resources.

Cropping Pattern

The cropping patterns in Table 5 highlight the differences in the economic and financial solutions of the model. The financial solution includes government crop and procurement constraints. Had these omitted, cotton would have disappeared from the cropping pattern entirely.

The most interesting results shown in the table, i.e., the low cropping intensity of the economic solution, illustrates again the role of indirect effects. The model is oriented so heavily toward cotton (64 percent of the summer acreage), that 27.1 percent of the winter land is fallow. This result stems in part from the model's use of early planting dates of cotton that allow only a short crop of berseem to be grown during the winter.

According to the logic of the model, if international relative prices determined private decisions, only limited livestock production would be included in the solution. The returns for cotton and rice virtually eliminate summer fodder. Without summer fodder, there can be no livestock. Without livestock, there wold be little need for the short crop of berseem prior to the cotton crop. Instead of incurring the cost of growing berseem for which there was no demand, the land would be left unused for the period of December through February.

TABLE 5

Cropping Pattern - 3 feddan farm
All technologies available

CROP	Maximize Financial Net Revenue Feddans	%	Maximize Economic Net Revenue Feddans	%
Berseem	1.19	39.8	0.64	21.5
Wheat	1.38	45.8	0.68	22.8
Broadbean	0.43	14.4	0.86	28.6
Winter Total	3.00	100.0	2.19	72.9
Rice Transplant	0.25	8.3	0.07	2.5
Rice Broadcast	0.65	21.7	0.83	27.5
Cotton	0.75	25.0	1.92	64.0
Maize	1.20	40.0	0.03	1.0
Fodder Maize	0.0	0.0	0.0	0.0
Tomato	0.15	5.0	0.15	5.0
Summer Total	3.00	100.0	3.00	100.0
Total	6.00	200.0	5.19	172.9

There are obviously a number of arguments that might be raised against the cropping pattern that results from maximizing returns at world market prices. First, large areas in cotton would upset agronomists who are adamant about the need to maintain a rotation that would insure the replenishment of soil conditions after cotton. While the standard rotation that includes cotton every third year is sometimes modified to a two year rotation on especially fertile land, 64 percent of the acreage in cotton implies that <u>all</u> cotton areas would grow cotton twice out of every three years. In a number of the less fertile areas, there are undoubtedly sound agro-economic reasons for not making that the norm.

In the model, the cotton area is achieved at the expense of the maize area that shrinks from 40 percent in the financial solution to only 1 percent in the economic solution. Maize has, at least in the past, been an important rural subsistance staple. It is unlikely that its acreage would be reduced to this extent even if international relative prices were approximated.

The area in wheat is reduced from 1.38 feddans to 0.68 feddans. Both staple food grain crops are thus cut dramatically. While this is an inevitable outcome of permitting comparative advantage to dictate the cropping pattern, it is unlikely that small farmers would undertake such radical moves lightly, at least not in a short period of time. (Both acreage shifts would, of course, undermine the current rhetoric of the government concerning the desirability of achieving cereal self-sufficiency by the end of the decade.)

Lastly, the doubling of cotton acreage, if it were accomplished at the national level and if no staple length adjustments were made, might well have a detrimental effect on its world price due to the strong market position of Egypt in long and extra-long staple cotton production.

The results of the model are typical of linear programming exercises in that optimization of domestic resource use routinely recommends greater crop concentration than what is actually observed. However, the results are significant in that they provide a conclusive demonstration of the nature of comparative advantage in one of Egypt's most important mixed farming areas. Any number of caveats might properly be introduced—including the fact that the results are based on 1977 prices. Nevertheless, the mechanisms by which price distortions have significant effects on efficiency and distribution within and between sectors are clearly revealed. Not only do they reinforce the general rationale for policy reforms, but they demonstrate the role that indirect effects play in distorting the allocation of Egypt's domestic resources.

Choice of Technology

Table 6 compares the choice of technology under domestically managed and international prices. As expected, the financial solution shows a greater dependence on mechanical inputs than the economic solution. The result is

TABLE 6

Farm Capital - 3 feddan farm
All technologies available

	Financial Solution			Economic Solution		
		Capital Stock			Capital Stock	
	Quantity	L.E.	%	Quantity	L.E.	%
Tractor	0.0153	37	4.2	0.0117	28	6.8
Thresher	0.0153	3	0.4	0.0117	2	0.6
Winnower	0.0216	3	0.4	0.0189	2	0.7
Pump	0.1819	52	5.8	0.0976	28	6.6
Cattle Cow	0.0892	16	1.9	0.7061	134	31.6
Buffalo Cow	1.8764	459	50.7	0.2668	65	15.4
Saquia	0.0696	10	1.2	0.2463	36	8.7
Norag	0.0	0	0.0	0.0756 #	1	0.3
Other Livestock		322	35.6		124	29.4
Total		906	100.0		425	100.0

immediately evident from the role livestock under the two solutions. In the economic solution, cattle continue to be important because of their ability to supply both dairy products and power for the _saquia_ and the _norag._ In the financial solution, livestock continue to be important, but animals are represented almost entirely by milk buffalo.

In the model, financial and economic prices for livestock and livestock products have been assumed to be equal. Adjustments in the optimal technology package are again produced by indirect effects. For example, the switch to buffalo in the financial solution is because of the greater milk production from the buffalo cow when the change to mechnical power is subsidized. In addition, cattle supply animal power at a lower cost which creates further incentives for the switch to cattle in the economic solution.

The total capital stock in the financial solution is L.E. 906, which is double the L.E. 425 for the economic solution. Virtually the entire difference in the two solutions is a reflection of the difference in livestock ownership on the two farms. Only L.E. 35 of the L.E. 481 difference is accounted for by the greater use of mechanized technology with financial prices. The minimal "part" of a tractor used on such a small farm, 0.153, requires very little capital investment when compared to the investment required to reach the optimal level of livestock production.

The two solutions do have a significant difference in the choice of technology, although it is not as striking as the difference in livestock ownership. The calculations for the percentage of each task performed by animal labor are presented in Table 7. Plowing is completely mechanized for both solutions, which agrees with recent survey findings that the only farmers in Sharkia Governorate who plowed with animals were those who could not reach their fields with a tractor. Threshing is now also highly mechanized according to both the model and the survey results. Harrowing and ridging tasks are performed mostly by tractors in the financial solution and by animals in the economic solution. The experience in Sharkia governorate is that this is highly variable by village, and depends on the availability of tractor services in the area.

TABLE 7

Animal Operations - 3 feddan farm
All technologies available

	Percentage of Task by Animal	
	Financial	Economic
Plowing	0.0%	0.0%
Harrowing	17.6	81.5
Ridging	7.4	98.6
Water Lifting	2.1	82.0
Threshing	0.0	32.0

A major difference between the model results and empirical findings involves water lifting. According to the solution of the model at financial prices, only 2.1 percent of the water lifting is done by animals, whereas farmers in Sharkia use animals for about 90 percent of the water lifting requirements. There are at least two reasons for the differing results. The most obvious is that, unlike the model, farmers undoubtedly treat the long-lived saquia as a sunk cost. A second factor lies in the assumption of complete divisibility, i.e., hire service markets, for all technologies. While this assumption may be appropriate for tractors, it is probably not a good one for mechanical pumps. Unlike pumps, institutions have developed around the saquia that are very efficient in breaking down a durable capital investment into a flow of services.

Introducing the institutional benefits of saquia "groups," e.g., their ability to handle risk and uncertainty, into the model undermines the rationale for low-lift pumps. However, the model's selection of pumps on economic grounds illustrates an interesting aspect of technological choice.

Government price policy has kept diesel fuel prices at extremely low levels compared to the international market. This is encouraging a move to small mobile pumps in Sharkia and a number of local machine dealers are beginning to carry a supply of Indian diesel pumps. However, the distribution of lumpy inputs creates a constraint to the spread of this technology. Ordinarily, the emergence of a hire service market, e.g., pump "groups", that would permit small farmers to take advantage of a productive technology, would be socially desirable. In this case, however, because of the highly subsidized diesel fuels and low interest rates on credit, a flexible institutional response might have negative social profitability!

Estimation of the Rates of Return

The five types of technology considered are (1) a 65 horsepower tractor used for tillage only, (2) the tractor used for tillage and harrowing, (3) the tractor used for tillage, harrowing and ridging, (4) a tractor-powered drum thresher with a hand-powered winnowing machine and (5) a 7 horsepower diesel pumpset. The model is run with and without the technology in order to calculate the internal rate of return. For the tractor, rates of return are calculated separately for its use in tillage, harrowing and ridging. Each rate of return is for that operation alone, without including the benefits for the other tractor operations.

Three different rates of return are calculated for each type of technology. The two having the most immediate policy significance are the financial and economic rates of return when financial prices are used to calculate the elements in the objective function. This formulation most closely resembles what is done in conventional benefit-cost analysis. The third rate of return, to be used as a comparison, is the economic rate of return in the first-best world when international prices are the elements in the objective function. This is the rate of return that is normally calculated

TABLE 8

Rates of Return for Mechanical Technology

Farm Size (Feddans)	Financial Rate of Return Second-Best	Economic Rate of Return Second-Best	Economic Rate of Return First-Best
	TRACTOR - TILLAGE ONLY		
1	101.7	37.7	111.1
3	91.8	47.1	147.1
5	120.3	128.9	109.6
10	377.1	322.0	327.0
	TRACTOR - HARROWING ONLY		
1	23.0	*	*
3	89.9	*	-28.6
5	306.2	18.8	8.8
10	66.7	*	19.5
	TRACTOR - RIDGING ONLY		
1	15.4	*	*
3	72.0	*	*
5	214.0	*	-22.6
10	16.2	*	-10.3
	THRESHER AND WINNOWER		
1	76.7	-6.5	141.6
3	124.0	8.0	186.7
5	244.8	440.3	276.6
10	1089.4	767.4	1080.5
	MOBILE DIESEL PUMP		
1	39.0	*	-28.4
3	38.6	*	-7.8
5	50.5	-12.4	-1.0
10	66.5	*	15.8

* - The internal rate of return is minus infinity because the cash flow contains all negative entries.

as a social rate of return in programming models; but the use of shadow prices in the objective function obviously raises a host of questions about the range of measures that would be required to implement such price reforms.

The three rates of return for each technology are presented in Table 8. Each measure is calculated for four farm sizes. The importance of examining differences in farm size lies in the effect of different resource endownments on technology choice. At the extremes, the one feddan farm can meet its labor demands almost entirely with family labor and the ten feddan farm cannot hire sufficient labor to fulfill demands, driving shadow prices for labor above the market price.

<u>Internal Rates of Return for Tractors</u>: A comparison of the results shown in Table 8 quickly indicates that tractor tillage is both financially and economically profitable, with rates of return above 10 percent, but that tractor harrowing and ridging have high financial rates of return with much lower economic rates of return. The similarity in the all three rates of return for tractor tillage is particularly striking. It is obvious that both the farmer and the economy are benefiting from the the mechanization of tractor tillage, with second-best economic rates of return varying from 37 to 322 percent depending on the degree of labor shortage.

The second-best economic rates of return for tractor harrowing are minus infinity for all but the five feddan farm, despite the fact that financial rates of return are all above 20 percent. The case for tractor ridging is similar with the second-best economic rates of return all being minus infinity while the financial rates of return are above 15 percent.

<u>Internal Rates of Return for Threshers and Winnowers</u>: Table 8 shows that the combination thresher and winnower is financially profitable technology; financial rates of return are above 75 percent for all farm sizes.

The sensitivity of this technology to the wage rate is evident from the fact that second-best economic rates of return are negative for the one feddan farm but increase to 767 percent on the ten feddan farm. This is because the scarcity value of man labor during the wheat threshing season for the non-thresher solution is zero for the one feddan farm and L.E. 18.4 per day for the ten feddan farm. The latter is the highest opportunity cost of labor in any of the many solutions. It is also more than ten times the normal wage rate.

The importance of farm size reflects the fact that mechanization of threshing and winnowing induces large labor savings. Furthermore, these labor saving are realized during late May and early June, a period of peak labor demand. All three measures of rate of return increase dramatically as the size of farm increases.

Internal Rates of Return for Mobile Pumps: Rates of return for mobile pumps demonstrates an interesting difference between pumps and the thresher technology. The rates of return for pumps are little affected by farm size. The introduction of pumps saves only marginally on labor use; in addition, these labor savings are spread across the entire cropping cycle with no concentration in the critical labor-short periods.

The second-best rate of return is always negative for the mobile pump reflecting the fact that the pump consumes heavily subsidized diesel fuel. Therefore, because of no significant labor savings, the economic rate of return is very low despite the high financial rates of return.

CONCLUSIONS

Two broad conclusions worthy of restatement emerge from the foregoing analysis. First, the intricacies of Egyptian agriculture are such that indirect effects, i.e., effects other than the immediate results of changes in relative factor prices, play an important role in explaining the demand for mechanical technology in Egypt. It is in this role of shedding light on the way in which various aspects of the farming system interact that the linear programming model comes into its own. Of particular significance in the Egyptian case is the demonstration that a number of apparently unrelated policies: fuel subsidies, livestock concentrate subsidies, cotton and rice taxes, etc., all tend to work in the same direction, namely, the substitution of machine for animal power.[6]

A second important conclusion for policy purposes is that the immediate efficiency gains from rationalizing the current price structure will be relatively small. Regardless of how one describes the impact of long-term disincentives to private investment on growth, government programs have obviously produced a different and more socially profitable allocation of domestic resources than would have been the case had there been no acreage and procurement regulations. Rationalizing the price structure, while it will have profound distributive consequences, will result in only marginal static efficiency gains.

The implication of the foregoing argument is that a great deal Egypt's future agricultural development hinges on the development of technological packages that either (1) make further improvements on an already respectable yield performance, or (2) introduce cash crops whose value-added is greater than the cereal and fodder crops they would replace. Neither of these

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[6] These same conclusions are developed from a more aggregate analysis by Alain de Janvry and K. Subbarao, "Wages, Prices, and Farm Mechanization in Rural Egypt: The Need for an Integrated Policy" Working Paper No. 95, Agricultural Development Systems: Egypt Project, University of California and the Ministry of Agriculture, Davis, 1982.

approaches will be particularly easy to implement, but it is the consensus of many observers that fine-tuning Egyptian agriculture will involve a more sophisticated type of mechanization than that represented by the technologies included in the present model. Examples of the tasks that are required have been cited in the text: more precise placing of seeds and fertilizer, more control over the timing and amount of irrigation, reduction of losses both during and after harvest, and so on. What is perhaps most disappointing at the moment is the limited experimentation on this type of mechanization that has been conducted under Egyptian conditions. It is to be hoped that work currently being undertaken under the auspices of various foreign assistance programs will bear fruit in the not to distant future.

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Appendix A

COEFFICIENTS OF THE MODEL

Crop Activities

Because the seedbed preparation technology was embedded in each activity, it was necessary to enumerate 220 cropping activities to include all of the potential planting dates. The irrigation and threshing technologies were included as individual activities and are discussed below.

Net Revenue:

TABLE 1

Net Revenue for Crops

	Yield	Financial Prices		Economic Prices		Net Revenue	
	(MT)	Output	Input	Output	Input	Financial	Economic
Berseem-4 cuts	24.0	0.0	9.4	0.0	9.4	-9.40	-9.40
Wheat	1.47	59.53	15.83	140.85	25.44	71.68	181.61
Broadbean	0.968	107.94	12.40	168.34	16.67	106.31	160.50
Rice- transplant	2.174	50.00	12.03	205.00	21.35	103.17	430.82
Rice- broadcast	2.174	50.00	12.03	205.00	21.35	103.17	430.82
Cotton	0.895	226.92	25.41	658.80	56.40	194.58	550.13
Maize	1.62	69.80	12.40	138.99	19.90	110.64	215.22
Fodder Maize	16.30	0.0	24.80	0.0	39.80	-24.80	-39.80
Tomato	14.94	49.85	85.26	62.50	118.00	644.56	815.75

The last two columns of the above table correspond to the entries in the objective functions of the model, except for broadbean's net revenue which is the combination of the cropping activity for broadbean and the selling activity. The net revenues for fodder maize and berseem are negative because the crop production is used as an input to the livestock portion of the model, and the activities contribute to the net revenue only through that part of the model. The crops of broadbean, rice, cotton and maize have crop by-products that were valued in the calculation of net revenue, but are not shown above. All other by-products were used as livestock feed and contribute to livestock nutrition, instead of directly to the objective function.

Crop Technologies:

TABLE 2

Required Tillage Operations

	Tillage	Harrowing	Ridging	No Tillage
Berseem	X	X		X
Wheat	X	X		
Broadbean	X	X		X
Rice	X	X		
Cotton	X	X	X	
Maize	X	X	X	
Fodder Maize	X	X		
Tomato	X	X	X	

Tillage, harrowing and ridging are the three technology choices included within the crop activities. Cotton, for example, requires all three operations and they can be performed with either tractor or animals. To capture all the possible permutations of animal and tractor operations would call for eight different technologies for each crop planting date. In actuality, only four are necessary because of the man and animal labor inputs for each technology. Harrowing and ridging will not be tractorized if the tillage operation is not because the tillage operation is the most labor saving of the technologies. Therefore, the permutations of animal tillage and tractor harrowing or ridging can be eliminated from the activities introduced in the model. Because ridging will not be tractorized when the harrowing is done by animal, the result is only four technolgies need to be introduced for cotton -- all animal operations, tractor plow only, tractor plow and harrow, and all tractor operations.

The crops of berseem and broadbean are permitted to be planted after rice with no tillage. This is a common practice among farmers to save on the time for preparing the land. There is probably a loss in yield from this practice, but because there is no information on the quantity of the loss, it was assumed that there was no yield loss.

Land Coefficients:

Figure A1 depicts the potential cropping patterns included within the model. The planting period for each crop is noted with the letter P in the proper period, and harvest is abbreviated as H. The berseem crop is under constant harvest as a livestock feed, so each cutting of the crop is numbered. The model permits berseem to be grown with any number of cuttings. Thus, the first line of the berseem crop denotes five separate cropping activities, one activity ending at the end of each cutting. The berseem seed crop requires all cuttings to be taken and the last dry cutting in the end of June is threshed and winnowed to extract the seed. The land is occupied until the end of June and this is represented with the T, for threshing, in that period. The threshing of wheat is sometimes done off the farm land, and this is shown in the figure by having the threshing activity after the harvest activity, but freeing the land for the next crop. The tranplanting period for rice is noted with a T in the cropping period for that crop. Fodder maize is actually two separate crops, as shown in the figure. The tomato activity also includes two harvest periods as the plants are cut back and harvested again as a winter crop.

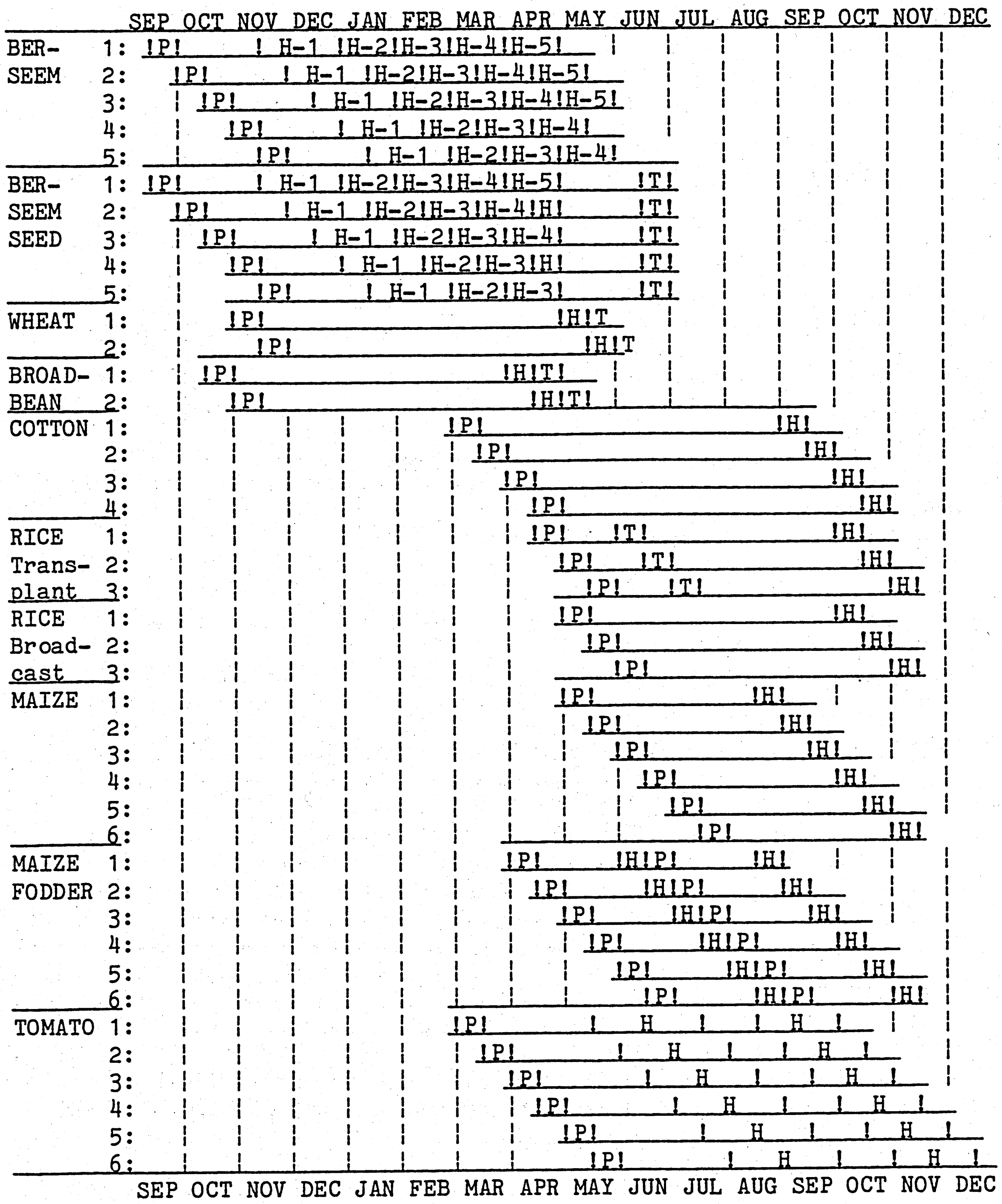

Figure A1: Schedule for Crops

Labor Coefficients:

TABLE 3

Labor Use by Crop

	Animal Seedbed Preparation		Tractor Seedbed Preparation	
	man-days	child-days	man-days	child-days
Berseem	27.5	0.5	25.38	0.0
Berseem Seed	31.5	2.5	29.38	2.0
Wheat	12.5	7.0	9.5	6.5
Broadbean	17.25	17.0	15.13	16.5
Rice- transplant	29.3	29.5	27.55	29.5
Rice- broadcast	18.0	18.5	16.25	18.5
Cotton	35.0	107.75	30.63	107.75
Maize	26.25	20.5	22.75	20.0
Fodder Maize	35.0	15.0	30.75	14.0
Tomato	57.25	41.5	52.13	41.0

(Not including labor for irrigation and threshing)

Table 3 does not include the labor for irrigation and threshing. That labor is captured in separate activities and is dependent on the choice of technology. (See later tables for the labor involved with those activities.) Table 3 shows only the labor use for two extreme technologies used in seedbed preparation, i.e., all animal operations or all tractor operations. Despite showing the widest range in labor use, the range is not that great. There are no large labor savings to be achieved with the tractor utilization for seedbed preparation -- in cotton, for example, there is a eight percent reduction in man labor and a zero percent reduction is child labor.

Power and Water Coefficients:

The power estimates show large differences between animal and tractor power. The power for the seedbed preparation of cotton is either 9.25 days of animal power or 3.5 hours of tractor power. For a small farm, with limited animal power, this could mean a substantial difference in timeliness.

The model's detail in planting dates will capture the impact of the power availability on the planting dates.

TABLE 4

Power Utilization by Crop

	SEEDBED PREPARATION					
	Animal Operations	Tractor plow only		Tractor plow and harrow		Tractor Operations
	animal days	animal days	tractor hours	animal days	tractor hours	tractor hours
Berseem	4.5	0.5	1.0	0.0	1.5	1.5
Berseem seed	4.5	0.5	1.0	0.0	1.5	1.5
Wheat	6.5	0.5	1.0	0.0	1.5	1.5
Broadbean	4.5	0.5	1.0	0.0	1.5	1.5
Rice- transplant	4.5	0.5	1.0			
Rice- broadcast	4.5	0.5	1.0			
Cotton	9.25	1.25	2.0	0.75	2.5	3.5
Maize	7.25	1.25	1.5	0.75	2.0	3.0
Fodder Maize	9.0	1.0	2.0	0.0	3.0	3.0
Tomato	11.25	1.25	3.0	0.75	3.5	4.5

TABLE 5

Water Utilization by Crop

	Saquia days
Berseem	4.30
Berseem seed	5.16
Wheat	3.40
Broadbean	2.88
Rice- transplant	9.15
Rice- broadcast	10.75
Cotton	6.20
Maize	3.68
Fodder Maize	4.48
Tomato	10.60

The water requirments by crop are given in Table 5. The unit of measure in this table is saquia days. Since this is based on an 8 hour day, just multiply the number by 8 to get the number of hours. The amount of time it took a saquia to water the crop was used as the common denominator because farmers could best answer the question about water requirements in terms of saquia time. Many farmers also knew how this time compared to a mechanical pump (usually diesel) and these answers were the basis for a conversion factor from saquia time to pump time. (Farmers could not estimate the number of cubic meters the crops required.)

Livestock Nutrition Coefficients:

TABLE 6

TDN and DP by Crop

	Production per feddan	
	TDN (kg.)	DP (kg.)
Berseem- each cut	708	114.0
Berseem seed by-product	71	11.4
Wheat straw	609	0.5
Broadbean	711	214.0
Maize leaves and tassles	38	6.4
Fodder Maize- each cut	794	81.8
Feed Concentrate (per ton)	716	120.0

The livestock submodel represents an important factor in any of the model runs and interacts with the cropping model through the feed requirements of the animals. The feed is supplied through the on-farm production of berseem, wheat straw, broadbean, maize leaves and fodder maize or through the limited purchase of feed concentrate from the cooperative. The availability of the concentrate is very limited, so the farmer must meet most feed need from his own farm. It is possible to buy feeds from other farmers but this activity was not included because, as mentioned in the main report, forcing the farmer to grow his own feed is the best method of ensuring realistic opportunity cost for the livestock feeds as assumptions are varied.

Indivisble Input Utilization Activities

TABLE 7

Water and Power Utilization Activities

	Cash Cost Fin.	Cost Econ.	Labor man	Use child	Animal labor	Fuel liters
Saquia (per day)	0.22	0.22	1.0	1.0	1.0	
Pump (per hour)	0.03	0.03	0.125			1.63
Tractor (per hour)	0.27	0.52	*	*		7.20
Cattle	0.0	0.0	*	*		
Buffalo	0.0	0.0	*	*		

*-depends on task

Table 7 shows the net revenue entry in both financial and economic terms for use of a saquia, pump or tractor, as well as animal power. It is important to note that the costs for pump and tractor do <u>not</u> include the fuel cost, so the quantity of fuel is listed in the last column. Similarly, the saquia costs do not include any animal power cost. The net revenue entry for animal power is zero because the cost is imputed through the opportunity cost of labor and feed, in addition to the depreciation cost which is an overhead cost.

TABLE 8

Threshing Activities

	Mechanized					Non-mechanized			
	Marginal Cost	Labor days	Tract. hours	Thresh hours	Winnow hours	Marginal Cost	Labor days	Animal days	Norag days
Berseem	0.20	2.98	1.7	1.7	3.0	0.10	10.0	3.0	3.0
Wheat	0.34	4.83	3.1	3.1	5.0	0.13	12.0	4.0	4.0
Broadbean	0.24	2.33	2.4	2.4	3.0	0.10	10.0	3.0	3.0
Rice	0.09	2.33	2.4	-	3.0	0.10	10.0	3.0	3.0

The cost of utilization of machines for threshing activities is presented in Table 8. As in Table 7, the marginal cost only reflects direct costs and not any imputed costs that are handled through other activities. Comparing the labor days for mechanized and non-mechanized activities it is obvious that mechanized threshing cuts labor use drastically, and threshing nearly always occurs during a labor-scarce period -- making the labor savings even more valuable.

Indivisible Input Purchase Activities

TABLE 9

Fixed Cost and Capacity of Lumpy Inputs

	Initial Cost	Life years	Annualized Cost- 10%	Monthly Capacity
Tractor	4950	10	805.59	240 hours
Saquia	300	20	35.24	10 or 15 days*
Pump	575	10	93.58	100 or 150 hours*
Thresher	450	10	73.24	360 hours
Norag	30	20	3.52	36 days
Winnower	300	10	48.82	360 hours
Cattle	-	-	-	50 hours
Buffalo	-	-	-	50 hours

* depends on season (because of canal rotation)

The investment cost of machines and implements is reviewed in Table 9. The table also shows the annualized investment cost, which is calculated from the expected life and an interest rate of 10 per cent, and the monthly capacity that is assumed for each mechanical input and for animal power.

Labor Hire Activities

<u>Net Revenue</u>:

The monthly wage rates were taken from Ministry of Agriculture data and agreed very well with the reports from farmers. The problem with farmers' reports of wage rates is the wide variance that is noticed between different farmers and between villages. If the Ministry of Agriculture data is biased in any way, it is that it understates the change in wage rates between slack season and peak season.

TABLE 10

Monthly Wage Rates

	Man LE/day	Child LE/day
January	.70	.30
February	.80	.30
March	.80	.325
April	.85	.45
May	.85	.50
June	1.05	.50
July	.80	.40
August	.80	.325
September	.80	.325
October	.95	.45
November	.85	.40
December	.85	.30

TABLE 11

Upper Bounds on Hire Labor Activities

Size of Farm feddan	Casual Labor per month man-days	child-days	Permanent Labor per year man-yrs.	child-yrs.
1	2.14	5.78	0.03	0.04
3	7.32	19.80	0.11	0.13
5	10.56	28.56	0.22	0.27
10	19.25	52.03	0.52	0.66
25	43.29	117.03	1.26	1.60
50	128.50	347.42	2.20	2.79
100	215.40	582.36	4.07	5.18

As discussed in the main section, bounds were placed on labor hire activities. The problems with this assumptions have been covered.

Exchange Activities

There are two exchange activities reflect the purchase of non-farm sector inputs that are not a form of investment. These two are diesel fuel and feed concentrate (see Table 12). Notice the wide discrepancy in financial and economic price for these two inputs.

TABLE 12

Net Revenue for Exchange Activities

	Price	
	Financial	Economic
Diesel Fuel (liter)	0.025	0.185
Feed Concentrate (ton)	33.0	80.0

Livestock Activities

Net Revenue:

TABLE 13

Net Revenue for Livestock Activities

	Selling Price	
	Financial	Economic
Cattle		
Veal	59.49	59.49
Yearling	189.61	189.61
Culled Cow	170.00	170.00
Buffalo		
Veal	49.90	49.90
Yearling	192.82	192.82
Culled Cow	200.00	200.00

The net revenue coeffecients for livestock selling activities are given in Table 13. The only activities that return revenue for meat are selling calves for veal, selling yearlings for meat and culling cows. The economic price was assumed to be the same as the financial price. There were quality differences between imported meat and domestic meat which made price comparisons difficult. In general, imported meat has been slightly more expensive than domestic meat but it is very nearly the same when quality differences are considered.

Milk Production:

TABLE 14

Milk Production

	Production in kg.		Price in LE per liter	
	Winter	Summer	Winter	Summer
Cattle	523	141	.117	.121
Buffalo	771	288	.129	.131

Revenue is also generated from livestock through milk production, and the assumed prices are given in Table 14. Again, economic prices were assumed to be the same as financial prices. Domestic prices were higher than adjusted international prices for reconstituted milk, but the difficulty in judging quality differences justified the assumptions of setting them to the same price.

Livestock Nutrition Coefficients:

TABLE 15

Nutrition and Labor Requirements

	TDN requirement				DP req.		Labor
	Winter		Summer		Summer		req.
Female Cattle	month	season	month	season	month	season	child-days
Calves for veal	0	0	0	0	0	0	0.0
Weaned calves	14-41	55	0	0	0	0	3.4
Yearlings	50-71	534	34-45	264	3.4-4.2	25	20.4
Heifers	80-88	744	64-72	453	4.2	28	20.4
Raise to Cow	88	756	79	528	4.2	28	20.4
Adult Cow	93	794	58	383	4.2	28	36.75
Male Cattle							
Calves for veal	0	0	0	0	0	0	0.0
Weaned calves	27-40	94	0	0	0	0	5.1
Yearlings	63-79	617	34-45	267	3.4-4.2	25	20.4
Female Buffalo							
Calves for veal	0	0	0	0	0	0	0.0
Weaned calves	27-54	81	0	0	0	0	3.4
Yearlings	63-71	568	34-45	276	3.4-5.6	30	20.4
Heifers	88-96	793	64-79	476	5.6	37	20.4
Raise to Cow	103	882	93	615	5.6	37	20.4
Adult Cow	119	1201	75	401	5.6	37	43.5
Male Buffalo							
Calves for veal	0	0	0	0	0	0	0.0
Weaned calves	27-40	94	0	0	0	0	5.1
Yearlings	63-86	654	34-57	307	3.4-5.6	30	20.4

Table 15 covers the feed and labor requirements of the livestock, which varies for buffalo and cattle, as well as for male and female. These coefficients were entered as necessary constraints on each animal unit.