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WP183

AGRICULTURAL DEVELOPMENT SYSTEMS EGYPT PROJECT

UNIVERSITY OF CALIFORNIA, DAVIS

REGIONAL LAND AND WATER UTILIZATION IN EGYPT: AN EMPIRICAL ESTIMATION OF OPPORTUNITY COSTS

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Econ.

WORKING PAPER

USAID/EGYPT

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Assistance from the Agricultural Development Systems Project of the University of California, Egyptian Ministry of Agriculture, and USAID, is gratefully acknowledged, but the author is soley responsible for the views expressed in this paper.

Economics
Working Paper Series
No. 183

June, 1983

Agricultural Development Systems:
Egypt Project
University of California
Davis, Ca 95616

I. INTRODUCTION

1.1 Statement of the Problem

Recent indicators show that the agricultural sector in Egypt is moving in a direction where it will increasingly fail to meet future domestic (food) and export (foreign currency) demands. However, in light of the fragmentation of holdings by the private sector, public management and development of natural resources is necessary. In the past two decades conflicting objectives within the public and private sectors, have led to several problems. Examples are urban sprawl, natural and man-made (through brick manufacturing) erosion, avoiding the centrally administered cropping pattern and, above all, the misallocation of scarce land and water resources.

If agriculture is to continue as a stabilizing sector of the economy, the problems of agricultural sector policy and resource allocation require immediate attention.

In the context of development planning and current scarcities, it seems rational to first tackle present resource allocation problems before expanding usage of the existing limited resources.

1.2 Objectives of the Study

The technique employed in this analysis is recursive linear programming because of its combined positive/normative implications. The model was developed to test the effects on land and water resource allocation resulting from the change in pricing policies that allows a gradual trend toward market prices. This is achieved by studying the static (one year) and dynamic (intertemporal) adjustment of land and water use to these changes. Also, the efficiency of (water) utilization in agriculture is examined under the existing price structure.

1.3 Water Resources

Egyptian water supplies are derived from (i) surface water, (ii) ground water, and (iii) other sources such as rain, lakes and desalination plants. The third group is very minor and will not be discussed. The first group is formed mainly of the Nile which delivers a mean annual flow of 84 billion m^3 as measured at Aswan, with a range of 65-120 billion m^3 for this century. After the construction of the High Dam, Lake Nasser was formed and is being used as the system's reservoir.

Ground water sources mainly occur in parts of the Nile valley or in aquifers of the Western Desert. The valley's aquifer is an unconfined one, rechargeable by seepage from the river and irrigated land. The desert aquifers are larger but are not rechargeable, a fact that is causing concern to the local authorities (International Herald Tribune, 1981). Eakin's estimates of ground water reserves were reported in USDA (1976), and the following table was constructed from their figures.

Table 1 Ground Water Resources

Source	Stock (reserve)	Quality (TDS*)	Rechargeable
Nile Valley	27 billion m^3	500 p/m**	Yes
Nile Delta	75 billion m^3	variable (low TDS)	Yes
Western Desert	2340 billion m^3	500 p/m	?(probably not)
Lake Nasser	several hundred million m^3	low TDS	Yes
Other	unknown	?	?

Source: Compiled from data in USDA (1976).

*TDS is total dissolved solids

**p/m is parts per million.

Fao (1973, C) estimates the stock of the Delta's unconfined aquifer to be 500 billion m^3 with 370 billion m^3 passing to the sea annually and about 130 billion m^3 left which could be pumped at rates of 60-170 m^3/hr.

Current usage from all sources exceeds 1 billion m^3 per year. Careful study and assessment of ground water sources is needed before they are exploited, particularly in the Western Desert (nonrechargeable) even though the supply could last for several hundred years.

1.4 Agricultural lands

The total farm area stands at 4,862,000 feddans[1] for 1979; at an average cropping intensity of 1.9, this translates into a cropped area of 11.2 million feddans. A mild climate, a fertile clay soil and water from an elaborate irrigation network make it possible for up to three crops a year to be grown in many areas. The agricultural lands fall into two main categories, the old lands and the new lands. The former is comprised of the Nile Delta and Valley and the latter is the term used for land reclaimed during the last 30 years.

The old lands' area of roughly 6 million feddans is in general of prime quality and productivity, with the majority falling in classes I, II, and III as shown in Table 2.2. A major problem is the inadequate drainage system, exacerbated by the increased availability of irrigation water, without a corresponding increase in drainage capacity. The consequences are increased salinity and water logging, which in turn have caused a deterioration of soil quality.

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[1] A feddan is equal to 1.038 acres or 4200 m^2.

Table 2 Soil Class: Areas and Characteristics (1976)

Land class	TSS (total soluble salts)	EC (electrical conductivity)	% Na (sodium)	pH	Texture	Area feddans	%
I	.2%	4 milliohms/cm	15	8.5	medium	2,101,082	37.241
II	.2-.5%	4-8 " "	15	8.5	fine	2,033,965	36.051
III	1%	8-16 " "	15	9	coarse	1,106,511	19.611
IV	1%	16 " "	15	9	variable	221,002	3.317
V	1.5%	19 " "	19	9	variable	179,386	3.78

Increasing man/land ratios have created the necessary driving force for the land reclamation program, but unfortunately, the reclaimed areas have so far contributed vary little to agricultural production.

The new lands are categorized according to their geographic location: West Delta, Central Delta, East Delta, Middle Egypt, Southern Egypt, Western Desert, East Desert, and Sinai. Emphasis has been on the Delta regions, and it seems that the outlying areas might not undergo large scale development until those areas with closer proximity to the Valley (and population centers) are reclaimed.

In the early 60's, some 15 million feddans were surveyed, of which 300,000 feddans potentially fall in classes I and II; 600,000 in class III; and 1,290,000 in class IV (USDA, 1976). An aerial survey of 53 million feddans in the Western Desert (New Valley region) provided the basis for increasing the agricultural area around the Oasis, while in the Lake Nasser area, a further 200,000 feddans could be developed. Even with good management the process of reclamation is long and costly. As a result, there is only about 500,000 feddans currently suitable for some form of agronomic activity.

New lands development has to meet a double burden, one is the extension of the agricultural area, and the other is the replacement of land depleted by urbanization or the practice of successively "shaving" layers of soil from a given feddan for brick making. No official figures about the extent of these problems exist but it is conservatively estimated that between 10 and 25 thousand feddans are lost annually from the stock of old lands. The problem is compounded by the pattern of population dispersion (concentration) which has affected man/land ratios.

The urban population accounts for roughly half the total, with Greater Cairo at over 9 million. This is the result of the short sighted policies of concentrating virtually all businesses, industry and services in the cities. The situation affects agriculture through rural to urban migration which has led to seasonal shortages of agricultural labor. The adverse effects of population growth on agriculture is perhaps best expressed in Table 3.

Table 3 Population and Cropped Area (growth rates)

Year	Population (000's)	Cultivated Area Feddans (000's)	Cultivated Area Per Capita	Cropped Area Feddans (000's)	Cropped Area Per Capita
1887	9,715	4,943	.53	6,725	.69
1907	11,190	5,374	.48	7,595	.67
1917	12,715	5,309	.41	7,729	.60
1927	14,178	5,544	.39	8,522	.61
1937	15,921	5,312	.33	8,302	.53
1947	18,967	5,761	.31	9,133	.48
1960	26,085	5,900	.23	10,200	.39
1966	30,076	6,000	.20	10,400	.34
1970	33,200	6,000	.18	10,900	.33
1975	37,772	6,500	.17	10,800	.29
1981	42,000	6,600	.15	10,900	.25

Source: Ikram (1980), p. 117, and computed for 1981.
Note: This table uses total agricultural area comprised of both old and new lands, whereas Table 2 lists only old lands.

As is seen above, over a 95-year period the cultivated area per capita dropped by more than 71 percent due to a higher rate of growth for the population. The cropped area per capita only dropped by 64 percent over the same period, mainly because of a higher cropping intensity and the expansion of the land base. The dilemma is that currently these two practices do not seem to be adequate to face the challenge. The cropping intensity is already up to the limit in many areas, and land reclamation can only supply marginal lands. The only possible course seems to be a more efficient agricultural system.

II. PATTERNS OF RESOURCE UTILIZATION

2.1 Agricultural Land Use

There is increasing public concern about the pattern of agricultural land use and pressure for a preservation drive. The Nile Delta and Valley lands could be categorized as falling into one of the four categories, urban, perennial, nonperennial, and idle. The problem is that perennial and nonperennial areas are decreasing overtime. The pressures are mainly due to increased urban sprawl and, consequently the growing demand for building materials which in the case of Egypt is mostly red bricks baked from "shaving" agricultural land. In many cases this happens to be prime land (of classes I and II). A farm lot that is situated closer to an urban area thus faces any of three decisions, (a) continue farming practice, (b) sell to urban or industrial developers (zoning is not very effective because population demand for housing is very high), or (c) sell to brick factories. To be able to understand the problem one need only look at the data for land in agricultural production.

Table 4 Agricultural Land in Cultivation (feddans)

Area	1972	1976	1978
North	3,574,217	3,480,561	3,462,727
Center	1,217,665	1,185,110	1,182,016
South	1,043,989	1,009,361	1,009,764
Total	5,835,871	5,675,033	5,654,507

Source: Compiled from Bulletins of Agricultural Economics (1972, 1978, 1979).

The above table shows the symptons of the problem which is also evident in the value of agricultural land in urban-fringe areas. Two important questions arise. First, are the current land markets producing a socially optimal allocation of prime agricultural? Second, are the existing regulations and policies detrimentally affecting the land use patterns? At the farmer's level the market value of land is a function of commodity prices. If farmers receive crop prices below the social value, the imputed value of farm land will be below its social value in agriculture. Given the difficulties of preventing agricultural land transfers into the private sector, socially suboptimal conversion of land out of agriculture will continue as long as the wide discrepancy between the social and private value of land in agriculture remains.

A study of land values would probably answer the first question by showing that the allocation is suboptimal from a national perspective, but this remains to be proven. While the second question is evidently answered by examining the simultaneous decline in cultivated land areas and the passing of legislation (such as the 1973 law) attempting to stop the trend in converting agricultural land to urban use. A third related issue is the ability of

reclaimed lands to offset the loss of old lands not only in numerical terms (feddan for feddan) but also in terms of actual and potential production, especially as urbanization is increasing. The consequences of past land use patterns has been a decline in cultivated areas, loss of capital investment (in the form of irrigation and drainage development on the lands converted to urban uses), foregone production of converted lands, more landless farmers and a relative drop in the supply of several major crops. El-Tobgy (1976) estimates the decline in cultivated areas as varying between 40,000-60,000 feddans annually. Even if the benefits resulting from these practices are taken into account, it is likely that these are highly skewed in favor of a small group and not socially beneficial. The counter arguments are, (a) the higher cost of building and extending services to outlying infertile areas, (b) the higher cost of alternative brick making technology (at least until recently), and (c) the employment generated through the brick making industry.

2.2 Irrigation and Drainage

The construction of the Egyptian modern irrigation system dates back to the early 19th Century with the onset of cotton production. With the completion of major irrigation projects such as the Barrages and the Mahmudiya canal, the cultivated area rose from 4.16 million feddans in 1852 to 5.18 million feddans in 1913. The latest addition to the system was the High Dam, completed in 1970. An (estimated) additional 1 million feddans was thus added as a result of the Dam and further irrigation network development. These improvements in water availability and distribution are being somewhat offset by the inadequate development of the drainage system. El-Tobgy (1976) reports that the public irrigation network totals 26,000 kms while the

drainage network extends for only 15,000 kms. The drainage problem is essentially two sided. On one hand, the lack of private investment in field drains prevented full utilization of the public drainage facilities. On the other hand, irrigation practices did not change much from the ancient system of "flooding" and letting the water drain. This was acceptable when only one application per year took place (during the Nile's flood season) but now this happens several times for every crop (with an average of 1.9-2.0 crops per year). Unfortunately, most efforts are directed towards the investment side of the drainage problem with very little being done on the irrigation practices side. It is estimated that with a better drainage system, yields could increase by 20 percent, whereas by focusing on both sides of the problem, yields could increase by up to 100 percent for cotton and maize (Ikram (1980)). A huge program of tile drain installation was started in 1970. Currently, it is still progressing with financial help from the World Bank. At the end of the program, approximately 4.2 million feddans would have been fitted with tile drains (80 percent of total land area). This indicates an increased emphasis on drainage with its share of agricultural investments rising from 8.8 percent in 1968 to 29.2 percent in 1975 (Ministry of Planning). Thus, irrigation and drainage concern us on the following counts: (1) the virtually unlimited availability of water to the farmers without any rationing mechanism, (2) inefficient application of irrigation water [USDA (1976) estimates a possible irrigation efficiency increase of 20 percent]. This could lead to releasing more water to be used for additional new lands, (3) over-irrigation practices and under-drainage problems have led to salinity and water logging which, in turn, caused a decline in crop yields. With a limited area it seems that attention should be focused on extracting more production from the existing areas.

2.3 Problems of Drainage and Irrigation

Presently, water availability does not constitute a limiting constraint for the production pattern. This situation is expected to remain unchanged at least until the year 2000. Many studies have concluded that a change to more water-demanding crops would still leave a water surplus. It is this very fact which underlies all the current irrigation practices. The situation is one where there is no charge for water with a subsequent suboptimal usage pattern. This, in turn, led to water logging which affected yields. At the end of the process comes the drainage problem resulting from an inadequate system. One possible way of correcting this situation is to create a larger monetary surplus to farmers in return for reducing subsidies to irrigation, and instituting some form of user charges, especially as some seasonal, regional shortages in water have been occurring.

2.4 Problems of the New Lands

It is recognized (almost universally) that a faster payoff in the short and medium term is to be expected from improvement investment in the old lands as opposed to New Lands. In other words more gains in overall agricultural productivity would be obtained from the old lands, because marginal returns to capital and labor are much higher. The New Lands promise a long term answer but not without changes. Again, we have irrigation and drainage problems, inadequate infrastructure and services, failure to identify (and properly exploit) the most promising areas, and inefficient public management. The New Lands program should continue, but with a different emphasis, since they are unable to keep up in quantity terms with the depletion of the old lands by urbanization.

III. THE MODEL

The logic behind the optimization technique is inherent in the solutions which are essentially long-run equilibria of the state or region at question. In a normative context we can view the results as the state towards which the economy is tending to move (or should be moved). Recursive programming (RP) augments this procedure in two ways. First, it shows how evolution of economic systems can be tracked, and second, it makes it possible to estimate the short-run response to disequilibrium situations. RP technically belongs to the class of "economic optimization programs" of which LP is an earlier member. Literature on the subject is replete with a multitude of formulations and applications of these techniques. As such, we will confine ourselves to a few applications which are useful to our analyses.

The historical roots of our model start with Leontief's input-output model in the 1920s, then Von Neumann's growth models of the 1930s which was followed by Dantzig's simplex algorithm in 1949. Kuhn and Tucker developed their theorem in 1951 and further advancement of optimization models was due to Dorfman, Samuelson and Solow.

Applications to the theory of the firm were developed by Dorfman, Samuelson and Solow, and Heady and his colleagues in the 1950s and 1960s. Applications using RP are due to Heidhues (1966), Ahn and Sing (1972), and de Haen and Heihues (1973). Models of aggregate production response were initiated by Henderson (1959). This was followed by Day (1963), Schaller and Dean (1965), Sharples and Schaller (1968), Cigno (1971), and Ahn and Singh (1977). These were all models using recursive programming. The third basis of our model is the Interregional and Spatial models which have an extensive literature. We will limit ourselves to models with equilibrium specification,

and those which emphasize disequilibrium in a dynamic context. Examples of the first are Judge (1956) and Plessner and Heady (1965). The second area has RP contributions by Day (1967), Day and Kennedy (1970), Bowden (1966), and several of the already mentioned RP applications. The fourth parent of our model is in the area of Agricultural Development for which the number of optimization models easily exceeds those of all the others. A survey of many of these models is to be found in El-Kheshen (1977), and Day and Sparling (1977). Applications utilizing RP were made by Cigno (1971), Singh (1971), Ahn and Singh (1978), and Thoss (1970).

The utilization of optimization models in the study of Egyptian problems has only recently been popular. Raphael (1967) reports on the INP's[1] model which he helped develop with the aim of achieving optimal patterns for investment timing. Elaassar et al. (1968) develop a linear program to study the effects of irrigation water supply on agriculture. Sherbiny and Zaki (1974) develop their rather restrictive model without imposing any constraints on inputs. Bazaraa and Bouzaher (1978) use static goal programming in their regional specialization study. Their penalty specification for deviation from goals suffered from inappropriate data. El-Kheshen (1978) analyzed the impact of public investment policy on Egyptian Agriculture. The UNDP in collaboration with IBRD and the Ministry of Irrigation (1979) developed a static linear program to study the efficiency of irrigation, among other objectives. Fischer and Frohberg (1979) built the first dynamic model for Egyptian agriculture, in which they use nonlinear objective functions. Their final results are still not available. Von Braun (1980) and Von Braun and Elshafei (1980) report on the same model, which is a static linear program for

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[1]INP is the Institute of National Planning, Cairo.

1977, and attempt to study the effects of aid on food production. Cuddihy's (1980) study of price management in Egypt used a static linear program that focused on the single farm as the study unit. He uses farm sizes of 3, 10, and 30 (in Sohag) feddans for the different versions. The results confirm that price response by farmers is consistent with prior expectations, even at subsistence level. On the macroeconomic level, Ghali and Taylor (1980) report on the joint IBRD-CU-MIT[1] project for modeling basic needs in Egypt as part of the effort of building a multisectoral model.

Before discussing our model, perhaps it is only fitting to reiterate why we adopted a programming technique, and why the level of aggregation was chosen.

(1) The data base used in the model is at the regional and national levels. This seems a prerequisite for a study concerned with policy action.

(2) Interrelationships at the intraregion and intrasector levels can be incorporated in a regional programming model. This is a clear advantage over econometric models.

(3) Such models are much more adaptable to changes in policy. Thus, if augmented with a recursive formulation they become suited for the study of radical changes in policy, resources, outputs, prices . . . etc.

Further discussion on the use of programming models in agriculture is covered in Rausser et al. (1980) and Candler and Norton (1977).

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[1]International Bank for Reconstruction and Development-Cairo University-Massachussetts Institute for Technology.

In the case of Egypt, even though many reseachers have aggregated the entire agricultural area in one unit, we decided that the maximum acceptable policy level was a Governorate. Thus, we have 19 "groups" in the model (or governorates) which are traditionally pooled as:

I. North	II. Middle	III. South
1. Alexandria	12. Giza	16. Assyut
2. Behera	13. Beni Suef	17. Sohag
3. Gharbiya	14. Fayum	18. Oena
4. Kafr El-Sheikh	15. Minya	19. Aswan
5. Dakahliya		
6. Damietta		
7. Sharkiya		
8. Ismailiya		
9. Suez		
10. Minufiya		
11. Kalyubia		

The regional recursive linear programming model measures several parameters both at the national and regional levels. These are, agricultural net revenue, crop production, demand for inputs, and resource valuations. The formulation of the model makes it possible to assess the two main goals of the exercise. First, net revenue is maximized subject to water supply by region, land productivity by governorate, the availability of purchased and nonpurchased inputs, crop rotations, regional governmental and public policy, behavioral constraints and the current technology. The second objective was to gauge the system's reaction to several proposed changes over time, such as resource policies, and deteriorating land quality because of rising water

tables. For the 30 crops included in the model, production activities are specified by governorate. The data in the model is on an annual basis, thus, we have yield per feddan, price per unit of product, variable and fixed costs, water supply, labor supply, fertilizer input, machinery input, animal input and the various behavioral constraints (flexibility constraints). The matrix of technical coefficients is of size 845 x 1777 and its 9,251 nonzero elements are basically of two types. Transfer (pivot) elements and coefficients for the various resource requirements.

The objective function could be expressed algebraically as follows:

$$\text{Max} \quad Z = \sum^{k+m+n} \sum^{q+r+s} [(P_{iy}Y_{ij}) - C_{ij}]\, X_{ij} \tag{3.1}$$

where

$$C_{ij} = \sum_{y=1}^{b} (m_y L_y + t_y M_y + a_y A_y + V) + d_{ij}\, F_{ij} \tag{3.2}$$

and

Z = agricultural aggregate net revenue from crop production;

P_{ij} = price per unit of output of crop i in governorate j;

Y_{ij} = yield per feddan of crop i in governorate j;

C_{ij} = total cost per feddan in LE for producing one feddan of i in j;

X_{ij} = number of feddans of crop i in j;

m_y = wage rate per man hour in month y for labor L_y hired for growing i in j;

t_y = machine cost per hour in month y for machine time M_y employed in producing i in j;

a_y = cost of feed per draft animal in month y for animals A_y working in producing i in j;

d_{ij} = cost per kilogram of fertilizer F employed in producing i in j;

V = other additional cash outlays;

0 = k, m, n are north, middle, and south, respectively;

= q, r, s are winter, summer, and nili, respectively;

b = 1, ..., 12 is the months of the year.

Regional crop production and net revenue are maximized subject to several constraints:

$$\sum_i X_{ij} \leq X_j \tag{3.3}$$

$$\sum_i X_{ij} \leq \overline{X}_j^w \tag{3.4}$$

$$\sum_i X_{ij} \leq \overline{X}_j^s \tag{3.5}$$

$$\sum_i^{\alpha} \sum_j^{\theta} X_{ij} \leq \overline{X} \tag{3.6}$$

where

$\overline{X}_j$ = the total number of feddans in governorate j;

$\overline{X}_j^w$ = the maximum number of feddans available for winter crop production (including land for permanent crops in the winter months);

$\overline{X}_j^s$ = the maximum number of feddans available for summer and nili crop production (including land for permanent crops in the summer months);

$\overline{X}$ = the total national croped acreage available in all regions.

The set of constraints specified by (3.3)-(3.6) relate to the land constraints within which optimization is to take place. The winter and summer acreages were formulated from data on the base period. The water supply is specified through:

$$\sum_{i}^{\alpha} \sum_{j}^{\theta} r_{ijy} x_{ij} \leq \overline{W}_{y}^{\theta} \tag{3.7}$$

where

r_{ijy} = the quantity in cubic meters required to produce crop i in governorate j in month y;

$\overline{W}$ = the total amount of irrigation water available in cubic meters in region θ for month y.

The human labor requirements are estimated through

$$\sum_{i}^{\alpha} \sum_{j}^{\theta} b_{ij} x_{ij} \leq \overline{L}_{j}^{\theta} \tag{3.8}$$

where

$\overline{L}_j$ = the available labor in governorate j expressed in man hours;

b_{ij} = the requirement per feddan of crop i in governorate j of labor.

The final set of constraints on physical inputs is the one which covers fertilizers, machinery and animal input.

$$\sum_{i}^{\alpha} \sum_{j}^{\theta} f_{ij} x_{ij} \leq \overline{F}_{\theta} \tag{3.9}$$

where $\overline{F}_{\theta}$ is the total available supply of nitrogen fertilizer in region θ.

$$\sum_{i}^{\alpha} \sum_{j}^{\theta} \varepsilon_{ij} x_{ij} \leq \overline{M}_{\theta} \tag{3.10}$$

where $\overline{M}_{\theta}$ is the total available machine hours in region θ.

$$\sum_{i}^{\alpha} \sum_{j}^{\theta} \gamma_{ij} x_{ij} \leq \overline{A}_j \tag{3.11}$$

where $\overline{A}_j$ is the available draft animal expressed in animal days for governorate j; and fGG, ε_{ij}, γ_{ij} represent the technical requirement per feddan of nitrogen fertilizer, machine hours and animal days, respectively. The above constraints are in addition to the flexibility constraints

$$\sum_{i} \sum_{j=1}^{N} X_{ij} \leq (1 + \overline{\beta}_{id}) x_{ij(d-1)} \tag{3.12}$$

$$\sum_{i} \sum_{j=1}^{N} X_{ij} \geq (1 - \underline{\beta}_{id}) x_{ij(d-1)} \tag{31.3}$$

where

$\overline{\beta}_{id}$ = the upper flexibility coefficient for crop i in region N or M or S for year d;

$\underline{\beta}_{id}$ = the lower flexibility coefficient for crop i in region N or M or S for year d.

(3.12) and (3.13) are specified separately for each region. This, thus, completes the specification of the model whose estimation, application, and results are presented next.

IV. ESTIMATION RESULTS

The basic model outlined in section III is used in the study and analysis of the agricultural sector with several variations. The applications of the model could be broadly categorized as follows: (a) examination of status quo situations to understand the current relationships and (b) utilization of various scenarios to analyze the effect of alternative policies. El-Kheshen

et al. (1982) reports on the examination of price policy alternatives using the model, while a more comprehensive treatment of all the study results (for the various scenarios) can be found in El-Kheshen et al. (1983, forthcoming). Thus, in our discussion here, we will confine ourselves to only those aspects of the model which are directly related to land and water policy.

4.1 Land Policy

Two model variants were constructed and estimated. One, the "Day Model" is based on the economic status quo parameter values (prices, yields, costs, inputs, . . ., etc.) while the second, "Price Model" was run using a price vector which models the prices of major crops adjusted upwards by adding half the margin between farmgate and international prices. Both models were run for the period 1975-79 recursively.

As mentioned earlier, only those model parameters relevant to our discussion will be examined. So, objective function values (net returns), crop acreage allocations, production estimates, . . ., etc. will not be presented (these are all presented elsewhere, (El-Kheshen et al. (1982, 1983)). We will examine the dual values on land under both model variants. The Day Model estimates these dual values under the cropping pattern observed in 1975-79 (Validation of the model, insofar as it represented reality with a good degree of success, is discussed in the studies reference above). The Price Model estimates the dual values under an alternative higher farm pricing structure for cotton, rice, wheat, and sugar cane.

Table 7, under the Day System, shows the shadow prices for land in each governorate under the observed cropping pattern. The high figures for winter land in 1975 were substantially reduced in subsequent years as a result of the easing of rigid farmgate prices. The high figures for the northern

governorates were due to winter vegetable and winter tomatoes having rather high prices that year (which placed them higher in terms of relative order of net returns as compared to the other crops). The Price System estimates are the result of the higher prices for the four major crops.

Comparison of the figures shows that, on a regional basis, winter land has become a less costly constraint in the North and marginally so in the middle, while it has beocme more costly in the South. This ambiguous result should be viewed in the context that these values are functions of crop prices. So, in other words, it seems that the change in crop prices in the North and Middle has tended to equalize the land opportunity cost. For summer land we find that the reverse situation in which the divergence of 1979 duals compared to 1975 actually increased. This was apparently corrected by the better prices for sugar cane as shown by the effect of such prices on Southern summer land shadow prices.

We notice that Kalyubiya and Giza both have the highest values in comparison with their respective regions (North and South) in the later years, probably due to their proximity to Cairo and the higher valued crops (vegetables) they produce in winter. This result has not changed under Price Systems, although Giza now has zero shadow price which implies that land is not the binding constraint. The same results hold in general for the summer land stock.

4.2 Water Model

Water resources, as a main factor of production in Egyptian Agriculture, is perhaps receiving less than an appropriate level of analysis and study. The water allocation problem becomes increasingly critical as more and more farmers are experiencing seasonal and/or local shortages. Efficiency

Table 5 International and Local Prices for Major Crops, 1975-79, £E/unit[4]

	1975	1976	1977	1978	1979
Cotton					
International price	84	70	96	73	73
Local price	28	34	36	37	47
Tax percentage	200	106	166.6	97.3	55.3
Rice					
International price	259	154	107	143	135
Local price	40	50	57	65	67
Tax percentage	547	208	87.72	120	101.5
Wheat					
International price	28.2	17.5	14	15.1	12.1
Local price	6.9	6.5	7.0	8.9	8.9
Tax percentage	300	170	100	70	36
Sugar cane					
International price	22.07	16.4	11.17	11.6	10.0
Local price	7.53	8.4	8.03	9.0	10.0
Tax percentage	194	96	40	18	0

Notes:
1. International prices are adjusted for transportation, processing, etc.
2. All prices are in Egyptian pounds per unit of net product (i.e., sugar cane prices, for example, are for the sugar equivalent) based on the appropriate conversion factors.
3. The tax figure is the difference between both prices represented as a percentage of local prices.
4. Units are cotton, kentar; wheat, rice, ardab; sugar cane, tons.

Table 6 New Prices used in Policy Runs, £E/unit[3]

	1975	1976	1977	1978	1979
Cotton					
Price	56	52	66	55	60
Change percentage	100	33	83	49	28
Rice					
Price	113	102	82	104	101
Change percentage	183	105	44	60	51
Wheat					
Price	14.0	12	10.5	12.0	10.5
Change percentage	103	85	58	35	18
Sugar cane					
Price	14.8	12.4	9.6	10.3	10.0
Change percentage	97	48	20	14	0

Notes:
1. All margins were halved except for rice and wheat in 1975, where the new price is based on 33 percent of the difference plus the old price.
2. These prices are only averages for the whole country, but the acutal model price scenario figures vary between governorates.
3. Units are cotton, kentar; wheat, rice, ardab; sugar cane, tons.

Table 7 Day System--Winter Land Shadow Price, £E per feddan

	1975	1976	1977	1978	1979
Alexandria	392.32	52.37	82.0	96.01	154.0
Beheira	392.32	52.37	82.0	96.32	154.0
Gharbiya	392.32	54.07	89.7	124.45	170.8
Kafr El-Sheikh	392.32	52.37	100.86	96.01	180.23
Dakahliya	392.32	52.37	82.0	96.01	154.0
Damietta	394.19	54.04	95.63	103.69	173.75
Sharkiya	396.12	52.37	101.92	96.01	159.5
Ismailiya	392.32	52.37	82.0	108.11	160.62
Suez	394.58	52.37	91.45	96.01	166.96
Minufiya	397.83	56.74	82.0	118.77	163.43
Kalyubiya	392.32	52.37	99.37	141.45	194.32
Giza	90.94	78.99	20.89	57.29	87.72
Beni Suef	90.94	78.99	4.04	50.28	49.69
Fayum	90.94	78.99	14.88	50.28	49.69
Minya	90.94	78.99	4.04	50.28	49.69
Assyut	107.64	72.06	97.9	131.29	174.84
Sohag	102.4	56.26	82.0	115.5	154.0
Qena	102.4	56.26	82.0	115.5	154.0
Aswan	107.85	56.26	82.87	130.2	183.98

Table 8 Day System--Summer Land Shadow Price, £E per feddan

	1975	1976	1977	1978	1979
Alexandria	20.74	33.09	79.32	--	--
Beheira	24.88	29.63	61.22	5.58	6.56
Gharbiya	26.45	35.96	83.09	1.02	13.36
Kafr El-Sheikh	28.83	29.42	39.8	--	--
Dakahliya	22.86	19.19	36.5	19.55	27.25
Damietta	29.35	35.0	48.94	91.68	90.06
Sharkiya	19.07	5.42	24.27	--	--
Ismailiya	28.72	34.0	43.98	--	2.54
Suez	--	--	--	--	--
Minufiya	15.26	12.51	25.23	8.55	42.07
Kalyubiya	25.47	45.41	58.61	17.92	28.09
Giza	22.67	33.43	43.94	25.2	405.00
Beni Suef	16.9	18.88	48.45	34.77	388.49
Fayum	12.75	18.8	59.37	21.47	404.4
Minya	22.34	16.8	66.37	31.31	398.6
Assyut	28.92	24.1	67.32	38.74	313.04
Sohag	12.0	26.58	71.41	34.76	307.09
Qena	16.27	14.07	45.67	28.61	291.19
Aswan	35.67	106.63	66.81	31.3	309.66

Table 9 Price--Winter Land Shadow Price, £E per feddan

	1975	1976	1977	1978	1979
Alexandria	392.32	52.37	82.0	115.5	154.0
Beheira	392.32	52.37	82.0	118.51	154.0
Gharbiya	397.3	54.23	82.0	144.79	163.5
Kafr El-Sheikh	392.32	52.37	87.4	115.5	180.23
Dakahliya	392.32	52.37	82.0	115.5	154.0
Damietta	392.32	52.37	82.0	127.33	173.78
Sharkiya	399.14	52.37	88.46	115.5	162.34
Ismailiya	392.32	52.37	82.0	141.32	161.69
Suez	398.63	38.33	101.15	115.33	167.9
Minufiya	399.3	62.83	91.5	138.26	163.43
Kalyubiya	404.08	61.39	101.0	160.94	194.32
Giza	104.44	7.8	24.58	211.89	--
Beni Suef	104.44	7.8	17.67	204.88	--
Fayum	104.44	7.8	32.69	204.88	--
Minya	104.44	7.8	15.01	208.73	--
Assyut	182.08	80.58	105.43	134.7	175.25
Sohag	157.04	56.26	82.0	115.5	154.0
Qena	157.04	56.26	82.0	115.5	154.0
Aswan	170.14	56.26	82.0	130.19	181.85

Table 10 Price--Summer Land Shadow Price, £E per feddan

	1975	1976	1977	1978	1979
Alexandria	193.16	151.29	87.76	101.6	47.97
Beheira	192.31	144.2	77.36	139.6	93.27
Gharbiya	193.88	150.72	99.23	139.75	126.64
Kafr El-Sheikh	209.94	145.06	73.66	138.73	87.8
Dakahliya	190.3	133.94	72.12	158.29	121.51
Damietta	211.93	160.03	88.34	231.57	191.58
Sharkiya	198.54	120.18	41.94	121.4	90.53
Ismailiya	210.0	148.75	82.45	122.98	93.07
Suez	159.73	82.7	--	79.48	52.46
Minufiya	182.69	124.67	176.99	155.81	155.35
Kalyubiya	181.07	165.82	265.41	166.14	129.64
Giza	21.39	94.11	50.11	628.3	164.83
Beni Suef	24.82	79.56	58.56	521.76	--
Fayum	5.79	89.82	59.37	508.46	15.9
Minya	22.34	77.48	66.37	518.3	21.83
Assyut	28.92	77.23	76.32	38.74	313.04
Sohag	12.0	81.09	80.41	34.76	307.5
Qena	16.27	67.2	54.67	28.61	291.6
Aswan	57.14	187.68	75.58	31.3	310.07

considerations seem to have been of minor importance in water policy, which is understandable in a country where the Nile's supply has always been abundant. The emerging problem is that the sum of the various demands for Nile water is starting to exceed the river's capacity in some seasons. This has served to highlight the present shortages, and to warrant more investigation of the causes and remedies for the problem. Concern for water analysis should logically focus on three areas: (a) whether it is possible to obtain the same agricultural output with less water, or alternatively, is it possible to increase production using the same amount of water?, (b) directly following from (a) is the question of rationalization of water use so as to lower the pressure on the inadequate drainage system, and (c) whether it is possible to restructure utilization patterns and create a surplus that could be used for meeting the increased demand, or conversely, what is the effect of the increased demand for water[1] on current agricultural production. We have attempted to address these issues in the following two sections.

For the purposes of this investigation, we have used the most recent data available which was for 1979. The model is basically identical in design and structure to the Day and Price system, except that instead of the original 36 water constraints (one for every month for each of the three regions) we now have only three, specified as a total annual constraint for each of three regions. This change was not arbitrary, but was rather dictated by two facts, (i) after several attempts it proved impossible to use a single efficiency factor in all 36 rows because we had situations of one region in one month using up all its supply, while another in the same month only used some proportion of its allocation. Under the monthly specification, this would

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[1]The "new" demand is for water for new communities and land reclamation.

have necessitated an unreasonable number of costly sensitivity runs;

(ii) perhaps more important than (i) is the fact that the technical efficiency information available from the irrigation technicians deals only with overall efficiency estimates, although we are sure that there must be more detailed information it was not available.

Our investigation consists of running the WATER 79 model twice to obtain the following versions:

1. running the model as it is, with the purpose of assessing the effect of changing the monthly specification on water constraints;
2. running the model with the water requirements (technical coefficients, a_{ij}) adjusted to .7 of the original values. This would enable us to examine the effect of increased efficiency in crop water application, suggested by the USDA study.

We will examine the model solutions in both versions.

4.2.1 WATER 79 Model: Base Run

We will restrict our discussion of the water models to those parameters which have direct relevance to the question. This is because we have found the other model parameters such as objective functions, crop row and column shadow prices, inter- and intra-regional dispersion of production, upper and lower bounds, etc., to be acceptable and so will limit our efforts to the water issues.

The base run gives us a first indication of bottlenecks in agricultural water supply. The northern regions used up all their supply of 2.666 x 10 m^3, whereas in Day 79 this was not the case. The difference stems from the varying levels of the upper and lower bounds. The Day model is recursive in these bounds, that is, for 1979 we used the 1978 activity levels as the base

for generating these bounds. For the water model we use a single period estimate, that is the upper and lower bounds are generated using the actual 1978 acreages, which of course led to different values. On the other hand, the Price model, despite the similarities to the Day specification,[1] shows zero slacks for three of the months in 1979. The model's water parameters thus give us only a generalized view of the overall supply and demand, but this could be augmented in two ways: On the supply side, the proportionate monthly figures could be used in the interpretation of results. For example, we know from WATER 79 that there is no slack in the north, and we also know the proportion of monthly water supply to the annual. We also know that by examining the various model solutions we have obtained so far (about 20) that we could identify which months, and which crop mixes are likely to approximate the result depicted in WATER 79. However, as we mentioned at the beginning of this section, this is not our goal, we are only seeking to study the effect of different overall efficiency rates. On the demand side, we know the water consumption rate for the crops on a monthly and annual basis. This information could be used in conjunction with the crop mix and the supply figures to give us an indication of which crop is causing the shortage. Alternatively, we could use the dual values on the flexibility restraints, as an indication of the resource valuation. The figures in Table 11 show that there is a direct relationship between water requirements and the dual values on lower bounds (which are valuations on all resources used in producing that crop).

In the case of rice, we note that the high dual value is primarily due to water usage. Rice is a summer crop, as are Summer Onions or Maize, and we

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[1]The recursive feature.

Table 11 WATER 79--Examples of Water Coefficients and Lower Bound Dual Values for the North, £E per feddan

Crop	Water Coefficient per feddan (annual) --in cubic meters--	Dual Value
Rice	16,100	1497.46
Sugar cane	6,000	836.68
Garlic	4,932	185.24
S. Onions	4,154	211.25
Cotton	3,740	525.59
W. Onions	3,154	339.99
Maize	3,000	254.37
W. Vegetables	2,639	190.41
Long Berseem	2,630	412.45

find that the dual values on Summer land in the North are around 27-29 for the governorates in the rice belt, and since all the other resources are in surplus, we, therefore, conclude that it is indeed the valuation on water usage, as the dual value on North water is .09385 per m^3 which when multiplied by 16100 gives 1510.985, which is the opportunity cost of water used in rice production. If the other cost incurred is added, which is the 27.31356 opportunity cost for Summer land we get an imputed total cost of 1538.2986. The net return associated with rice production in the main rice-producing governorate[1] is 40.83856, which represents the difference between the imputed cost and the dual value on the lower bound.

[1]Dakahliya, this is the model selection under WATER 79.

The base run is thus used as a yardstick against which we can measure changes in model parameters as a result of our investigations.

4.2.2 WATER 79 Model: 30 Percent Increase in Water Use Efficiency

This model shows the effect of a more rationalized usage pattern. This could be achieved either by water price and cost manipulation (which is not applicable to Egypt) or through the extension services helping the farmers to voluntarily use water more efficiently. The means of achieving this end should be the subject of a separate investigation. We are limited here to examining the effects in two ways: (i) examination of the change in dual values on flexibility coefficients, and (ii) determining the change(s) in cropping mix and crop dispersion.

The dual values on upper and lower bounds are presented in Table 12, where they are contrasted with the duals of the base run. The middle and southern regions retain the same dual values for both runs simply because there was no shortage to start with (the base run) and decreasing the water requirements would even create a greater surplus. Their respective dual values remain unchanged and so are not discussed here. In the north though, we notice that the dual values for .7 efficiency level are higher (both lower and upper bounds) than the ones for the base run, with the exception of Cotton, Sugar Cane, and Maize. The decrease in water consumption would lead to less pressure on the lower bounds since a crop is not as costly in its use of the resource. This is what happened in the case of these three crops, but for the rest of the crops which were already at their lower bounds in the base run, we find that under the 70 percent assumption, they are exerting more pressure on the lower bounds. This means that when we force a decrease in water consumption in general (for all crops) we find that some crops become

Table 12 North Acreage Bounds Dual Values

	Base Run		.7 Usage	
	Upper	Lower	Upper	Lower
Cotton		525.59		452.32
Rice		1497.46	a	a
Wheat		444.27		601.43
Peanuts	22.00		105.09	
Lentils		428.85		524.07
Beans		446.85		525.08
Barley		387.74		555.43
Garlic		185.24	13.48	
Sugar cane		836.68		551.3
Flax		338.6		501.86
Sesame		79.27	75.4	
S. Sorghum	n.a.	n.a.	n.a.	n.a.
N. Sorghum	n.a.	n.a.	n.a.	n.a.
S. Maize		254.37	14.03	
W. Onions		339.99		308.13
S. Potatoes	132.41		581.71	
N. Potatoes	420.67		621.8	
W. Tomatoes	a	a		16.47
S. Tomatoes	a	a	449.3	
N. Tomatoes	268.37		469.5	
W. Vegetables		190.41		206.89
S. Vegetables	76.39		525.69	
N. Vegetables	215.19		416.32	
Long Berseem		412.45		429.77
Short Berseem		429.8		571.95
Fruits		3.82	a	a
Oranges		40.02		214.52
Melons	599.45		1048.76	
S. Onions		211.25	165.03	

[a]These crops had acreages between both bounds.

more efficient and others less efficient in their use of water, this is because the relative ordering of crops in terms of net returns to water used has changed. A good example of such changes is rice, as we find that in the base run it had the dual value of 1497.46 corresponding to water consumption of 16100 m^3/feddan. In the 70 percent model the water figure dropped to 11270 and since everything else is held constant,[1] such as net returns and yields, we find that rice's relative position in terms of net returns to water has actually improved and so it no longer remained at its lower bound. These changes thus enable us to conclude that when water consumption drops for all crops, ceteris paribus, then all crops could be classified as follows:

a. Most efficient water users: Rice, Peanuts, Garlic, Seasame, Maize, Summer Potatoes, Nili Potatoes, Summer Tomatoes, Nili Tomatoes, Summer Vegetables, Nili Vegetables, Fruits, Melons, and Summer Onions.

b. Medium efficiency crops: Cotton, Sugar Cane and Winter Onions.

c. Least efficient water users: Wheat, Lentils, Beans, Barley, Flax, Winter Tomatoes, Winter Vegetables, Long Berseem, Short Berseem, and Oranges.

This classification is based on monetary considerations and does not include any evaluation of nonpecuniary returns, which, of course, may change the ordering, nevertheless it should be very useful in formulating actual policy. The model could be expanded to accommodate changes in yield in response to the change in water use, and we will be doing this once we have the relevant information on yield response to water usage.

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[1]This was intentional so as to accentuate the change.

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