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The potential role of livestock in a nuclear-powered agro-industrial complex in the United Arab Republic

Charles Martin Farmer

To the Graduate Council:

I am submitting herewith a dissertation written by Charles Martin Farmer entitled "The potential role of livestock in a nuclear-powered agro-industrial complex in the United Arab Republic." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Agricultural Economics.

Luther H. Keller, Major Professor

We have read this dissertation and recommend its acceptance:

Thomas J. Whatley, Merton B. Badenhop, Frank O. Leuthold, Hands E. Jensen

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

November 25, 1969

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Frank O Leuthold

Hans E. Jensen

I. J. Whatley

Accepted for the Council:

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Vice Chancellor for
Graduate Studies and Research

THE POTENTIAL ROLE OF LIVESTOCK IN A NUCLEAR-POWERED AGRO-INDUSTRIAL COMPLEX IN THE UNITED ARAB REPUBLIC

A Dissertation
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by
Charles Martin Farmer

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ABSTRACT

The general objective of this study was to evaluate the potential role of livestock in an agricultural-industrial complex in the Middle East, and specifically for a potential site west of Alexandria in the United Arab Republic.

Several analytical models were developed to determine the optimum organization of crop and livestock activities in terms of six alternative goals. These were: (1) maximizing financial returns, (2) maximizing the present value of foreign exchange net credit, (3) maximizing calorie production, (4) maximizing effective protein production, (5) maximizing domestic employment, and (6) minimizing investment capital required for the agricultural complex.

Important sources of published data used in synthesizing livestock production coefficients were the various publications of the state agricultural experiment stations and extension services in the United States, publications of the United States Department of Agriculture and releases prepared by the Food and Agriculture Organization of the United Nations.

Data relating to basic resources and investments in the agro-industrial complex were developed by other members of the Middle East Study Group. Data pertaining to crops were synthesized by members of the agricultural sector of the study team.

The annual income which was provided by various systems selected in each optimization model varied considerably. Relatively high levels of income were provided in the income, foreign exchange, and employment models, while income levels were much lower in the nutrition and investment models. The net return value, excluding water cost, in the income model was $27.8 million, as compared to only $5.6 million in the calorie model.

Employment which would be provided was also considerably higher in the income, foreign exchange, and employment models than in the nutrition and investment models. The man-hours of employment to be provided totaled 11.4 million man-hours in the employment model but only 2.8 million man-hours in the calorie model.

The quantity of calories and protein provided varied to a lesser extent among the models than did other alternative goal characteristics. The maximum quantity of calories, amounting to 1236 billion, was provided in the calorie model. The quantity of calories provided by the income model, on the other hand, was 556 billion. The maximum quantity of protein was provided by the protein model (50 million pounds). This compares with 34 million pounds of protein which were produced in the income model.

Livestock production was included in four of the six optimum systems developed by the various models. Although the greatest contribution of livestock was in terms of income and foreign exchange, contributions to the nutrition and employment goals were quite significant in some models.

In order to evaluate the sensitivity of net returns to the water desalination cost, the cost of water was deducted from the estimated income for each of the various optimization models at cost levels ranging from \$.10 to \$.45 per thousand gallons. Break-even prices for water were also calculated.

Of the 13 sale crops analyzed, only five could break even with water production cost at \$.20 per thousand gallons. Only two crops showed a break-even water price of as much as \$.35 per thousand gallons, which is considered to be the most likely for about 1980.

The break-even water prices for the crop and livestock production systems selected in the six optimization models varied from \$.09 per thousand gallons in the maximum calorie model to \$.47 per thousand gallons in the maximum income model. The calorie model included no livestock in the production system, while the income model included livestock activities at the upper allowable levels.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

TABLE PAGE

CHAPTER I

INTRODUCTION

The development of desert areas of the world depends largely upon the availability of fresh water. The use of nuclear energy for water desalination appears to offer much promise for transformation of the salt water into sweet in large quantities at relatively low costs. Making the deserts bloom, it seems, has indeed been an age-old dream of mankind.

Throughout our civilized history, wherever nature has provided a convenient river, its diversion into the desert has generally proven to be a successful venture. At present there is no shortage of desert area, but the supply of convenient rivers is indeed limited.

There are billions of acres in arid zones of the world. Some insights regarding the inherent possibilities of this previously unutilized resource are provided by Lowe[1], who has stated:

> The desert is man's future land bank. Fortunately, it is a large one, offering eight million square miles of space for human occupation. It is also a wondrously rich bank, which may turn green when man someday taps distilled water for irrigation. Bridging the gap from sea to desert will be greatly facilitated by the geographical nearness of most of the world's deserts to the oceans. When this occurs, it will surely be one of the

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[1] Charles H. Lowe, Jr., Introduction to the Desert (Vol. I of Life Nature Library, ed. A. Starker Leopold. 15 vols.; New York: Times-Life Books, Inc., 1961), p. 7.

greatest transformations made by man in his persistent and successful role in changing the face of the planet.

Until recently, however, making large desert areas productive with desalted sea water has not been technically feasible. Desalting sea water is now possible on a large scale basis and the possibility of additional technological breakthroughs offers promise of even more efficient conversion. The principal question to be answered relates to the economic feasibility of such a venture.

With the world population increasing at a rapid rate, energy plays an important role in alleviating food shortages and promoting general economic development. Abundant low-cost energy could be used to provide fresh water for food production by desalting the seas and also produce many industrial products so important in improving living standards. In fact, developing nations that are deficient in rainfall and critical raw materials could obtain some of the agricultural and industrial benefits now available only in highly developed countries of the world. The basic ingredients required for such benefits are low-cost nuclear energy and a seacoast location with arable land nearby. Nuclear energy must be considered as a fuel source as it is potentially abundant and location is not dependent upon natural resources.

I. PROBLEM SETTING

In the foreword to Volume I of the comprehensive study of The World Food Problem, former President Lyndon B. Johnson stated:

> The world food problem is one of the foremost challenges of mankind today. The dimension of the challenge will define the dimension of our response and the means for that

response. We must join with others in a massive effort to help the less fortunate of the earth to help themselves.[2]

The *World Food Problem* report[3] concludes, in part:

1. The scale, severity, and duration of the world food problem are so great that a massive, long-range, innovative effort unprecedented in human history will be required to master it.

2. Food supply is directly related to agricultural development and, in turn, agricultural development and overall economic development are critically interdependent in the developing countries.

The subject of the world food problem has been treated thoroughly in orations and editorials since World War II. The misery of hunger, the ravages of malnutrition, and the threats of civil strife and political upheaval posed by food shortages have all been vividly portrayed. The need of the United States and other developed nations, agencies, and institutions to help hungry nations has been pointed out repeatedly. The obligation of the more developed nations to aid the less fortunate of the earth has been generally accepted. In many instances, however, citizens of these more developed countries seem to believe they are presently supporting programs which will finally alleviate the problem. The *World Food Problem* report[4] emphasizes, however, that despite the large amount of research directed at the problem and the relatively large expenditures by many nations and other voluntary groups,

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[2]President's Science Advisory Committee, *The World Food Problem*, Vol. I (Washington: Government Printing Office, 1967), p. iii.

[3]*Ibid*., p. 11.

[4]*Ibid*., p. 3.

malnutrition and food shortages are more pronounced in the world today than ever before.

The report concluded that the panel of experts involved in the study were convinced that food shortages and high rates of population growth in the developing countries are not primary problems. Instead, they are manifestations of a more fundamental difficulty, i.e., lagging economic development in the hungry countries.[5] If the world's supply of food is to grow substantially, there needs to be general economic development in the developing nations and not just a change in farming itself. It is not the need for food but the economic demand for it that can induce greater production.[6]

The world's increasingly serious nutritional problem arises from an uneven distribution of food supply among countries, within countries, and among families. Global statistical surveys, based on the total food produced per person, suggest that there is no aggregate shortage in terms of quantity (calories) or quality (protein) at the present time. But in the developing countries, where two-thirds of the world's population live, there is overwhelming clinical evidence of under-nutrition (too few calories) and malnutrition (particularly, lack of protein) among the people, indicating quite clearly that millions of individuals are not receiving the amounts of food suggested by the average figures.[7]

The prevention of malnutrition throughout the world through the provision of adequate diets for a rapidly expanding population is a task of immense proportions. Protein-calorie malnutrition (kwashiorkor),

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[5] *Ibid.*, p. 23. [6] *Ibid.*, p. 59. [7] *Ibid.*, p. 11.

which affects preschool children primarily, is the most widespread nutritional deficiency.[8] Malnutrition causes retardation of physical growth and development and recent evidence strongly suggests that mental development may be impaired also.[9]

Nutrition has a vital role in the health of adults as well as children and substantially influences socio-economic and cultural development. Malnutrition leads to deterioration of physical and mental efficiency, to emotional and personality disturbances, and affects the ability to perform work. The combined effect of these factors on the national economy is obvious. It is a cost that developing countries of the world can hardly afford.

One of the most difficult aspects of the world food problem is the provision of protein supplies adequate to assure good health and to prevent the occurrence of protein malnutrition among children. Man has traditionally balanced his diet of largely plant material with foods of animal origin which contribute essential amino acids, as well as fats, minerals, and vitamins.[10] Provision of adequate quantities of animal products is thus one way to help improve world protein nutrition.

There is no shortage of animal protein in the world as a whole; however, supplies available in the developing countries amount to only

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[8]David L. Call and Vernon R. Young, "Protein Requirements for Nutritional Planning" (Cambridge: Massachusetts Institute of Technology, Department of Nutrition and Food Science, 1969), p. 2 (Mimeographed.)

[9]Ibid.

[10]President's Science Advisory Committee, Vol. I, p. 90.

nine grams per person per day as compared to 44 grams per person per day in the developed countries. Short-term targets of the Food and Agriculture Organization of the United Nations for developing countries are 15 grams and long-term targets are 21 grams of protein per person per day.[11]

World food planners tend to discount the contribution that can be made to the world food supply by land animals, apparently because they believe that increases in animal production can be made only by diverting to animals foodstuffs that otherwise would be eaten by people. Their thesis is that feeding animals is wasteful because the yield in energy from the animal products is less than the energy fed; hence, it would be better to let the people consume the food directly. This concept applies only if the diet of the animal is composed entirely of food eaten by people. Livestock, however, can consume food that cannot be eaten by man. Some examples are residues from food grains, vegetable wastes, oilseed meals, gin wastes, food processing residues, meat scraps, fats, tankage, bone meals, and even certain animal manures. Urea can be utilized in protein synthesis by rumen bacteria and when mixed in feeds in small proportions, can fulfill some of the protein requirements in the diet of ruminants.

The rate of efficiency by which animals convert feed protein to food protein is meaningless except as it relates to diets composed entirely of food which would otherwise be consumed by people. In practice, even in the United States where grains are available in large quantities at relatively low prices, livestock rations include a high

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[11] Ibid.

proportion of forages and by-products not generally consumed by people.[12] In the United States, 71 percent of an average dairy cow's protein intake is derived from forages, 60 percent of that of a beef animal, and 80 to 90 percent of the protein intake of sheep and beef brood stock.[13] The use of rather small quantities of cereal grains as livestock feeds in more developed nations makes it possible to use at low cost, in terms of food that could be consumed by people, large quantities of forages and by-products that might not be otherwise used. An example of food grain consumption in one segment of the livestock industry in the United States will illustrate this point.

The input of protein from cereal grains and oilseed products and the output of milk protein from dairy cattle under commercial conditions are presented in Table 1.[14] Total protein input has been corrected for proteins not considered appropriate for human consumption. About 96 percent of the protein from the grains and oilseed products was returned as milk protein. If urea had been used at the upper recommended levels, the output of milk protein would have exceeded the input of proteins by about 30 percent.

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[12] President's Science Advisory Committee, The World Food Problem, Vol. II (Washington: Government Printing Office, 1967), p. 249.

[13] M. E. Ensminger, Sheep and Wool Science (Danville: The Interstate Printers and Publishers, Inc., 1964), p. 191.

[14] L. A. Moore and others, "Use of Cereals as Supplements to Forages in Modern Livestock Feeding Systems" (Beltsville: Animal Husbandry Division, United States Department of Agriculture, 1967), p. 10.

TABLE 1

PROTEIN INPUTS FROM CEREALS AND OUTPUT OF MILK PROTEIN[a]

Source of Input	Crude Protein in Pounds	
	Input	Output
3,173 pounds of grains and oilseed concentrates per year	392	377

[a]From a survey containing 1,500 cows producing 11,674 pounds of milk containing 3.69 percent butterfat on 46 Wisconsin dairy farms.

Source: L. A. Moore and others, unpublished data, United States Department of Agriculture, Animal Husbandry Division, Beltsville, Maryland, 1967.

It should be evident that in many situations the use of small quantities of food products normally consumed by humans can result in the production of animal products that are more valuable from a nutritional standpoint than the food inputs consumed by the animals.

One of the encouraging stories of livestock development is the rather recent emergence of significant poultry industries in many countries of the world, such as Mexico, Pakistan, Nigeria, Peru, Venezuela and the Middle East nations. Improvement in poultry production is more easily achieved than in any other type of livestock production, as poultry science is more readily transferable to nontemperate areas of the world.[15]

Livestock developed in temperate climates where adequate feed and shelter are generally available are highly demanding in terms of environmental requirements and do not always thrive under the adverse climatic and disease conditions prevalent in many developing countries.[16] It is generally conceded to be easier, for example, to establish a highly productive beef cattle operation in intemperate zones than an equally productive dairy cattle unit due to the fact that adverse environmental, nutritional, and disease factors seem to affect milk production more than beef production.

A review of literature provided a few interesting examples concerning the adaptability of the Holstein-Friesian breed of dairy cattle

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[15] President's Science Advisory Committee, Vol. II, pp. 254-255.

[16] Ibid., p. 284.

to environmental conditions in two developing countries in the Middle East. The Middle East is an area of generally high temperatures, a primary factor adversely affecting milk production.

In a study of the adaptability of Holstein-Friesian cattle in Lebanon, Choueiri and coworkers[17] concluded that this breed can be used in Lebanon for achieving rapid and sound breeding improvements, as these animals proved their suitability as milking cows in the Bekaa valley. The average production over nine lactations was reported to be 12,961 pounds of milk.

In Syria, Holstein-Friesian cattle were first imported from the Netherlands in 1963. In the first lactation the average production for 305 days was approximately 8,400 pounds of milk. The corresponding production for the second lactation was 9,920 pounds. With these preliminary results, this breed of dairy cattle appeared to be a success in the Syrian environment.[18]

In view of the problem of adverse environmental conditions and the rather slow process of improving livestock by selection and crossbreeding, it seems advantageous in the long run to introduce modern breeds of livestock enterprises in developing countries as "production packages," i.e., the improved breed along with nutrition, health, and husbandry practices which provide protection from adverse environmental

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[17] E. Choueiri and others, The Adaptability of Holstein-Friesian Cattle in Lebanon, Technical Series Publication No. 5 (Beirut: Institute of Agricultural Research, 1966), p. 14.

[18] Mohamed Riad El-Ghonemy (comp.), Land Policy in the Near East (Rome: United Nations Publications, 1967), pp. 257-266.

factors. The poultry industries throughout the world have been developed along these lines in the last decade.[19]

In considering the problem of whether animal production should be increased in a given area, one must recognize:

1. That many people do like foods of animal origin.
2. That proteins from animal sources have better quality protein than individual vegetable proteins.
3. That generally the consumption of animal products desired and purchased will increase as the economic level increases.[20]

The latter of these is especially significant when one considers the complementary effect which increases in animal protein would likely have on the productivity of a developing country. As productivity increases and economic growth occurs, a greater demand for animal products would also be expected.

II. OBJECTIVES

The Oak Ridge National Laboratory initiated a study in June, 1967, relating to the technical and economic feasibility of "nuclear-powered agro-industrial complexes." Such an agro-industrial complex was envisioned as consisting of a nuclear reactor station producing electricity and desalted water. The electricity could be used by on-site industry and for pumping water, while the desalted water could be used for agricultural, industrial, and municipal purposes.

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[19] President's Science Advisory Committee, Vol. II, p. 285.

[20] *Ibid.*, p. 331.

The fact that nuclear material was becoming competitive with fossil fuels as an energy source in some areas gave much impetus for the study. Recent developments in agricultural and industrial technology were also important in the decision to initiate the study.

Numerous coastal desert regions around the world were studied as potential areas for location of such a complex. In response to the Baker Senate Resolution 155, an intensive study was authorized and initiated in June, 1968, relating to the problems of the Middle East, one of the sites investigated earlier. The Middle East Study Group, consisting of personnel from several disciplines, was formed to undertake the study.

The general objective of this study was to evaluate the potential role of livestock in an agricultural-industrial complex in the Middle East, and specifically for a potential site west of Alexandria in Egypt. The specific objectives were:

1. To determine relevant livestock enterprises for the complex.

2. To determine input-output relationships and to develop costs and returns budgets for these livestock enterprises.

3. To work with other personnel of the agricultural sector of the Middle East Study Group at Oak Ridge National Laboratory in developing costs and returns budgets for relevant crop enterprises, and to help determine the overall potential financial and economic feasibility of producing agricultural commodities using desalinated water.

4. To determine optimum combinations of crop and livestock production with optimality evaluated using six different goals or

objective functions. These six were: (a) maximizing financial returns, (b) maximizing the present value of foreign exchange net credit, (c) maximizing calorie production, (d) maximizing effective protein production, (e) maximizing domestic employment, and (f) minimizing investment capital required.

III. RESEARCH PROCEDURE

The selection of livestock enterprises which were relevant in this particular setting was the initial basic decision which was necessary in the study. These enterprises were determined by reviewing literature relating to animal science and with the assistance of specialists in the Animal Science Department of the University of Tennessee.

It was generally conceded from the beginning of the study that ruminant animals could play a greater role in such a system than could nonruminants, due to the unique ability of ruminants to convert rather large quantities of roughages to animal products. Poultry enterprises were considered due to the high efficiency of feed utilization. Also important in the poultry consideration was the emphasis being placed on increasing broiler production in all countries of the Middle East.

Another basic requirement of the livestock enterprises was that they be adaptable to an intensive, dry-lot type of management. Range-type livestock activities were excluded from consideration because of the high cost of water, land reclamation, and irrigation system.

Enterprises other than the ones selected for detailed investigation showed varying degrees of promise in this setting but the scarcity of budgetary data, especially under the production and management conditions specified, precluded further consideration of these activities. The five animal enterprises eventually chosen for intensive analysis were beef cattle, dairy cattle, sheep, broilers, and layers.

Once the pertinent enterprises were selected, the next objective was to secure input-output data relating to these enterprises. The most important data problem was the almost complete lack of usable Egyptian data pertaining to these enterprises. Sources of the data used are enumerated in Chapter III. The most important sources of data were the recent crop and livestock budgeting manuals, bulletins, and pamphlets published by various Agricultural Experiment Stations in the United States, as well as various publications of the Agricultural Extension Service. Special attention was given to publications from areas with climatic conditions similar to those of the study site.

Input-output data for various crop activities were synthesized into budget formats. Crop alternatives were specified by other members of the agricultural section of the Middle East Study group following an evaluation of soil maps of the area, the consumptive use of water of various crop possibilities and the expected contribution of each crop to the objectives to be optimized. Of primary importance in establishing necessary assumptions regarding production coefficients, crop inputs, cultural practices, irrigation systems, land reclamation requirements, farm layout and water storage systems were data from the western areas of the United States having similar climatic conditions and a similar intensive, irrigated agriculture.

Optimum combinations of crop and livestock enterprises for each of the six objective functions were determined using linear programming techniques. The relevant goals or objective functions used were determined by the apparent needs of the Egyptian economy.

Some of the overall restrictions in the linear program were the monthly and annual supplies of distilled water available from the desalting plant. The capacity of the water desalination plant was assumed to be 200 million gallons per day. The water plant would be shut down 55 days each year for maintenance and repairs. The total production of desalinated water during the year, with the 55 days of shutdown taken into account, would amount to 190,200 acre-feet. Other restrictions included an upper limit on the quantity of certain field, vegetable, and fruit crops that could be produced as well as an upper limit on the quantity of all classes of livestock that could be produced. The overall acreage of land and the labor and capital availability were not considered to be restrictive resources in the program. Lack of knowledge of the resource situation at the study site precluded any realistic use of detailed resource restrictions.

IV. LITERATURE REVIEW

Although plentiful data are available relating to nuclear theory and desalination technology, no attempt will be made in this thesis to discuss the present state of research in these areas. An effort will be made instead to relate recent research efforts pertaining to agro-industrial complexes.

In the past, as the earth's population has grown, mankind has met the need for more food by bringing more land into production. But now the supply of new, productive agricultural land is almost exhausted, and world population is growing faster than ever before. Yet in most areas of the world the shortage is not one of land itself. The shortage is of fertile, well-drained land with adequate rainfall. Most of the land is too wet or dry, too rocky, too steep, or is characterized by other physical factors which limit its use.

Most world food planners are in agreement that major emphasis must be given to increasing productivity per unit of land if world food needs are to be met in the immediate future. Large-scale desalting, however, may permit much of the presently unused land resource to be used for food production in the future.

In the past two or three years, the encouraging possibilities pertaining to the desalination of sea water with nuclear energy have created enthusiastic attention. Several notable individuals in the United States have proposed a further investigation of the potential of agro-industrial complexes.

Former President Eisenhower[21] has stated: "I am convinced that the time has arrived to put this remarkable new tool (nuclear desalting) into major use." The purpose of the plan envisioned by Eisenhower was not only to bring large arid regions into production and supply useful employment for many refugees but also to hopefully promote peace in the

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[21]Dwight D. Eisenhower, "A Proposal For Our Time," The Reader's Digest, XCIII (June, 1968), 75-79.

troubled Middle East. Eisenhower believes that the proposal, when implemented, might well succeed in bringing stability to a region where many political negotiations have failed. He further stressed that most of those who have studied the water proposal believe that its advantages would be so great that the hostile countries could not afford to withhold their cooperation.

A proposal similar to the one made by Eisenhower was presented by Admiral Strauss[22] in August, 1967. The proposal included a dual-purpose installation producing electricity and desalted water. The impact of such an installation as envisioned by Strauss would be to open up for settlement many hundred square miles which have previously never supported human life, and to absorb the unskilled labor of thousands of displaced persons (refugees).

One of the early proponents of using desalted water for agriculture was Hammond of Oak Ridge National Laboratory. In a paper presented in May, 1967, Hammond[23] concluded that with the improvements in agricultural technology and a reduction in the cost of water, the cost of tapping the waters of the seas may become acceptable. The large amount of desert land available could then be used on a scale that economics dictates.

In June, 1967, the Oak Ridge National Laboratory initiated a study of the technical and economic feasibility of "nuclear-powered

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[22]Lewis L. Strauss, "More War or Real Progress in Mideast," U. S. News and World Report, LXIII (August 7, 1967), 58-60.

[23]R. P. Hammond, "Desalted Water for Agriculture" (paper read at the International Conference on Water for Peace, Washington, D. C., May 25, 1967).

industrial and agro-industrial complexes," primarily as a means for industrial, agricultural, and general economic advancement in developing countries.[24] Such a complex might consist of a reactor station producing both electricity and desalted water. The electricity could be consumed in adjacent industrial processes and for pumping water, while the desalted water could be used for municipal, industrial, and agricultural purposes.[25]

The study of nuclear agro-industrial complexes was justified on several grounds. Cited was the dramatic increase in nuclear reactor generating capacity sold to the utility industry in the United States. Also important were recent developments in industrial and agricultural technology which gave further impetus for such a study.

Five coastal desert regions around the world were studied as potential areas for location of such a complex. These were located in India (Kutch), Southeastern Mediterranean (Sinai), Baja California, Peru (Sechura), and Australia. These different locales were studied to test the sensitivity of the assumptions made in relation to actual conditions so that the ranges of applicability of the agro-industrial complex could be estimated.[26]

The overall conclusion of the study was that the use of coastal desert regions for producing a variety of agricultural products by

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[24] United States Atomic Energy Commission, Nuclear Energy Centers; Industrial and Agro-Industrial Complexes, ORNL -4290 (Oak Ridge: Oak Ridge National Laboratory, 1968), p. 1.

[25] Ibid.

[26] Ibid., p. 14.

irrigation with desalted water appeared technically feasible and generally competitive with food produced on existing farms. The anticipated additional cost of water was visualized as being at least partially offset by the opportunity to conduct intensive year-round agriculture.[27]

Though this conclusion seemed to be generally valid at all of the five locales, a more detailed analysis of a specific locale was suggested. This would include using local data on such factors as soils, mineral resources, climatology, and labor availability.

On August 14, 1967, Senator Howard H. Baker, Jr., of Tennessee submitted a resolution pertaining to nuclear desalting to the United States Senate.[28] This proposal called for the construction of nuclear desalting plants in the Middle East. The resolution stated in part:

> Resolved, That it is the sense of the Senate that the prompt design, construction, and operation of nuclear desalting plants will provide large quantities of fresh water to both Arab and Israeli territories and, thereby, will result in:
>
> 1. New jobs for the many refugees,
>
> 2. An enormous increase in the agricultural productivity of existing wastelands,
>
> 3. A broad base for cooperation between the Israeli and Arab Governments, and
>
> 4. A further demonstration of the United States efforts to find peaceful solutions to areas of conflict.

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[27] Ibid., pp. 14-15.

[28] United States Congress, Senate, Committee on Foreign Relations, Construction of Nuclear Desalting Plants in the Middle East, Hearings before Committee, 90th Congress, 1st Session, on S. Res. 155, October 19, 20, and November 17, 1967 (Washington: Government Printing Office, 1967), p. 1.

Resolved, That the President is requested to pursue these objectives, as reflecting the sense of the Senate, within and outside the United Nations and with all nations similarly minded, as being in the highest national interest of the United States.

In response to the Baker Senate Resolution 155, an intensive study was authorized and initiated in June, 1968, relating to the problems of the Middle East. This current so-called Middle East Study at Oak Ridge National Laboratory is attempting to apply the energy center concept to specific areas of Middle East nations as a means of alleviating shortages of water and energy and of creating economic opportunities in the region.

The earliest date for start-up of a production unit is assumed to be 1978 on time schedules for project study, evaporator development, and construction, which is assumed to begin in 1973. Additional production units are assumed to be added at two year intervals based on leveling the construction force and investment schedule. Approximately 200 million gallons of desalted water per day would be produced from each reactor complex, which could be either nuclear or oil-fired, as economics dictates.

Activities considered for the agricultural section of the complex include grains, fruits, vegetables, oil sources, fibers, livestock, poultry, and fish culture. The crops are some of the most important and widely grown in the area and also represent a range of alternatives in terms of water use, sensitivity to water cost and production of high-quality diets.

Power-intensive industrial applications that appear promising include the production of nitrogenous fertilizers from electrolytic hydrogen, electric-furnace phosphorus, pig iron and steel production, aluminum, magnesium, chlorine, caustic soda, and arc-process acetylene. At the present time there appears to be no particular advantage of industry in the complex due to the lack of raw materials in the area.

In addition to the engineers, agriculturists, economists, and social scientists who are serving as full-time members of the study group, there are several consultants, as well as a distinguished panel of advisors who aid in the general direction of the study. Agricultural and engineering personnel from Israel and Egypt are also currently serving as members of the study group.

In any development project, the social consequences must be analyzed. In a recent article, Meier[29] examined some of the social contributions and effects of an agro-industrial complex from the viewpoint of an expert in social planning. Meier pointed out that a complex with a large food-producing component would likely displace local people. Therefore, unless careful preparations are made for the introduction of a complex in advance, it will likely be greeted by bitter resistance, strikes, and even sabotage. In an attempt to avoid these problems, Meier suggested that such an installation should be laid out so as to: (1) disturb the lives of a minimum number of families, (2) settle every prior human claim to the land, and (3) provide a range of options for immigrants, including the freedom of changing their minds at low cost to themselves. Meier further stressed that if some of the

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[29] Richard L. Meier, "The Social Impact of a Nuplex," Bulletin of the Atomic Scientist, XXV (March, 1969), 16-21.

above factors are not considered, the stage will be set for possible political and economic disaster.

The problems of implementation of nuclear energy centers were studied by Ritchey.[30] His primary conclusion was that no amount of technical feasibility would ensure the success of an agro-industrial complex unless the many social problems have been solved. He further stressed that this has been true in the past concerning development projects, is more true today, and can be expected to be increasingly true in the future.

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[30] J. A. Ritchey, Nuclear Energy Centers: The Problems of Implementation, United States Atomic Energy Commission Report, ORNL-4295 (Oak Ridge: Oak Ridge National Laboratory, 1969), p. 16.

CHAPTER II

SETTING: THE UNITED ARAB REPUBLIC

In an attempt to make this study more meaningful, a general description of the United Arab Republic is presented in this chapter. An exhaustive background analysis will not be presented. Only those factors which have direct relevance to this study will be related. The general topics briefly discussed include the history, demography, agriculture, national economy, and prospects for development of the United Arab Republic.

I. HISTORY

Egypt is the oldest nation of the world, with nearly 5,000 years of recorded history. It has alternated between periods of strength and periods of weakness. The last such period began in 1882 when the British occupied the country. Egypt was granted nominal independence in 1922 but did not gain full independence until 1956.[31]

The current regime of President Gamal Abdel Nasser has sought to raise the standard of living, develop the country's military and economic strength, and unify the Arab world under Egyptian leadership.[32]

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[31] United States Department of State, Background Notes: United Arab Republic, Publication No. 8152 (Washington: Government Printing Office, 1967), p. 2.

[32] *Ibid.*, p. 2.

Nasser's leadership and identification with Arab nationalism have acted as a powerful attraction. The union of Egypt and Syria under the name of United Arab Republic was proclaimed in 1958 and dissolved in 1961 due to economic and social incompatibilities. Egypt nevertheless continues to call itself the United Arab Republic and its determination to build a "democratic, socialist, cooperative society" has apparently not weakened.[33]

II. HUMAN FACTORS

Population

The population in the United Arab Republic according to the 1960 Census was 25,984,000.[34] It was estimated to be approximately 32,000,000 in 1969. Of the total population in 1960, about 62 percent was classified as rural, 37 percent urban, and 1 percent nomadic Bedouins.[35]

The population was fairly evenly divided between males and females. An important factor regarding the population in Egypt was that due to relatively high death rates, the average age of the population was quite low by Western standards. The distribution by age groups indicated that about 75 percent of the population was under 30 years of age in 1960. Of the indigenous population, some 92 percent were Muslim

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[33] Ibid., p. 3.

[34] W. B. Fisher, The Middle East: A Physical, Social, and Regional Geography (New York: E. P. Dutton and Company, 1963), p. 265.

[35] Hassan Abdallah, U. A. R. Agriculture, Foreign Relations Department, United Arab Republic Ministry of Agriculture (Cairo: Government Printing Office, 1965), p. 11.

(mostly Sunni), and another 7 percent had kept their historic affiliation with the Coptic Church. Arabic is almost universally spoken. It was estimated that 30 percent of the people are literate.[36]

The population pressure is great in the United Arab Republic, where 99.2 percent of the people live on four percent of the land.[37] The inhabited area consists of the Nile Valley, the Nile Delta, and a few oases.[38] In a few districts near Cairo, densities reach 6,500 people per square mile. The average density for the inhabited areas of the country is approximately 2,370 people per square mile.

As a result of better disease control in recent years, the Egyptian life expectancy has now risen to 53 years. The annual rate of population increase now stands at three percent, which is one of the highest in the world. The imbalance between resources and population is a primary threat to the objectives of the Egyptian government. The population increase was recognized in the National Charter (1962) as the most serious obstacle facing the nation in its drive to raise the standard of living, and the government has introduced a program to reduce the birth rate.[39]

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[36] United States Department of State, op. cit., p. 2.

[37] Fisher, op. cit., p. 269.

[38] United States Department of State, op. cit., p. 2.

[39] Ibid.

Refugees

The Palestinian refugee problem was created by the Arab-Israeli war which broke out in 1948 when the British terminated their mandate responsibilities and approximately one million Arabs left Palestine for various parts of the Arab world.[40] The British had acquired Palestine as their mandate as part of the World War I settlement.

The United Nations Relief and Works Agency of Palestine Refugees in the Near East (UNRWA) was founded in 1950 to provide relief services and to help Arab refugees support themselves. Refugees under the care of UNRWA numbered about 1,340,000 people in the Middle East in April, 1967, with approximately 300,000 located in Egypt. It has been estimated that the June, 1967, conflict created 650,000 new refugees. UNRWA activities include distribution of basic food rations, provision of shelter, operation of health centers, maintenance of hospitals, provision of schools, and a welfare program.[41]

Health

The incidence of human disease in Egypt is extensive and its debilitating effect on human activity is obvious. It is thus a major factor in economic life and a critical aspect in economic development efforts.

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[40] United States Atomic Energy Commission, "Middle East Study Subreport" (Oak Ridge: Oak Ridge National Laboratory, 1968), p. 9. (Mimeographed.)

[41] Ibid., p. 11.

Several factors usually contribute to the high rate of disease in the country, e.g., generally high temperature, widespread overcrowding, and insanitary conditions.[42] At least three specific groups of diseases have been identified:

1. Those originating directly from environmental conditions, being spread primarily by insects,
2. Those originating due to inadequate sanitary facilities with irradication rooted in correcting social, economic, and educational deficiencies, and
3. Those originating due to malnutrition and are thus at least partially affected by general economic productivity.[43]

Nutrition

The occurrence of protein-calorie deficiency disease in Egypt has been recognized for about 35 years.[44] Many studies since that time have documented the public health significance of this disease.

The composition of the Egyptian diet and the United States diet is compared in Table 2. One of the striking differences is the caloric make-up of the diets. Seventy-three percent of the average daily caloric supply in the Egyptian diet was composed of cereal grains compared to only 21 percent in the average daily United States diet. Another major difference was the composition of the average daily protein supply in the diet. Seventy percent of the average total protein intake

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[42] Ibid., p. 12. [43] Ibid., p. 13.

[44] Call and Young, op. cit., p. 14.

TABLE 2

NET PER CAPITA FOOD SUPPLY IN THE UNITED ARAB REPUBLIC AND THE UNITED STATES

	Period			
	U.A.R. 1964-65		U.S. 1963-65	
	N	%	N	%
Calories per day				
Cereals	2130	73	667	21
Meat, eggs and milk	187	6	1089	35
Fruit and vegetables	155	5	174	6
Starches	28	1	96	3
Sugars and sweets	186	6	506	16
Fats and oils	138	5	519	17
Pulses, nuts, and seeds	114	4	75	2
Total	2938	100	3126	100
Protein in grams per day				
Cereals	59.4	70	15.3	16
Animal sources	12.5	15	66.7	71
Other	13.2	15	11.8	13
Total	85.1	100	93.8	100

Source: Food and Agriculture Organization of the United Nations, Production Yearbook, 1967 (Rome: United Nations Publications, 1968), pp. 419-431.

in the Egyptian diet was derived from cereal grains while only 15 percent came from animal sources. The corresponding values in the United States diet were 16 percent and 71 percent, respectively.

III. AGRICULTURE

Climate

The climate of the United Arab Republic can basically be divided into two climatic zones. The first includes the Mediterranean coastal areas, including the delta, and is characterized by a mild winter and a hot summer. The second zone covers the remainder of Egypt south of Cairo. This zone is characterized by warmer winters and hotter summers.[45]

The rainy season in Egypt occurs between October and May, with precipitation being heaviest on the Mediterranean coast and decreasing southwards. At Alexandria, near the study site, the mean annual rainfall is about six to seven inches. This decreases to about one inch annually at Cairo and even less southwards.[46]

Land and Water Resources

The land area of the United Arab Republic is about 386,000 square miles, an area about equal to Texas and New Mexico combined. However, less than three percent of the land area is cultivated. The cultivable land is almost exclusively in the Nile Valley and the Nile Delta.[47]

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[45] Abdallah, op. cit., p. 8. [46] Ibid., p. 10.

[47] United States Department of State, op. cit., p. 2.

An important consideration is the favorable climate for growth of crops and if the water supply is assured multiple cropping is possible. The average rate of approximately 6.4 million cropped acres produce about 10.6 million acres of harvested crops annually, giving a cropping index of about 1.65.[48] An analysis of the historical cropping intensity index indicates that the cropping intensity index has stabilized at about 1.7 since World War II.[49]

The soils of the Nile area are inherently among the most productive in the world. These soils are rich in potash and phosphorus but are deficient in nitrogen. Throughout the remainder of the country the soils are predominantly sand with little or no organic matter. Some of these soils, however, are potentially productive if only water were available.[50]

The water supplies available and presently used by Egypt include direct diversion of the Nile River, rainfall, and ground-water pumping. Of these, the Nile is by far the most important. Rainfall is extremely limited, and the pumping of underground water is still in its infancy.[51]

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[48] Cline J. Warren, Agricultural Development and Expansion in the Nile Basin, United States Department of Agriculture, Economic Research Service, Foreign Agricultural Economic Report No. 48 (Washington: Government Printing Office, 1968), p. 8.

[49] Donald C. Mead, Growth and Structural Change in the Egyptian Economy (Homewood: Richard D. Irwin, Inc., 1967), p. 218.

[50] D. S. Pastir, "Land and Water Resources Development in Egypt" (Oak Ridge: Oak Ridge National Laboratory, 1969), p. 8. (Mimeographed.)

[51] Warren, op. cit., p. 2.

When the High Aswan Dam is completed in 1970, there will be sufficient water to bring approximately 1.3 million new acres into production. With multiple cropping, this is equivalent to 2.1 million new crop acres.[52]

Crop and Livestock Production

Due to its favorable climatic and environmental conditions the United Arab Republic is able to grow a wide variety of field and horticultural crops throughout the year. In 1962, the value of crops accounted for 80 percent of the total agricultural output value while animal production contributed the balance of 20 percent.[53]

The major field crops are cotton, cereals, maize, clover, onions, and sugar cane. Of less importance are beans, groundnuts, sesame, and flax. The area devoted to field crops usually amounts to approximately 10,000,000 acres, which represents about 94 percent of the cropped area.[54]

Cotton is the principal cash crop and the country's major source of foreign exchange. The United Arab Republic is the leading supplier of long and extra long staple cotton in the world.[55]

Wheat is the principal winter crop. Each farmer in the country is required by law to plant at least one-third of his total acreage to wheat each year. The country was a net exporter of wheat in 1946. Although total production has increased since then, at the end of 1965

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[52] *Ibid.*, pp. 11-12.

[53] Abdallah, *op. cit.*, p. 13.

[54] *Ibid.*, p. 28.

[55] *Ibid.*, p. 29.

annual wheat and wheat flour imports exceeded two million metric tons, or about 50 percent of the total national consumption.[56]

The principal oil crops grown in Egypt are groundnuts, sesame, linseed, and castor beans. Most of the oil consumed locally, however, is produced from cottonseed.[57]

Crop production dominates the agriculture of the United Arab Republic with livestock production decidedly in second place. There is, however, a great need as well as potential for improving and expanding livestock production.

Forage production in Egypt is a limiting factor in livestock production. Land limitation precludes a significant expansion of the conventional livestock production system. The country is becoming increasingly dependent on imported meat or slaughter animals to meet its demand for livestock products.

The native cattle of the United Arab Republic have no distinct breeds. In view of their low milk production, which ranges from 1000 to 3000 pounds, the Holstein-Friesian dairy breed has been introduced to upgrade the native cattle.[58]

Poultry raising is essentially of the back-yard type although there are some large-scale farms engaged in commercial production. Imported breeds are now being raised in large numbers on government experimental farms for breeding purposes.[59]

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[56] Ibid., pp. 28-29.

[57] Ibid., pp. 32-35.

[58] Ibid., p. 41.

[59] Ibid., p. 43.

Other animals found on farms throughout the agricultural areas include sheep, goats, donkeys, camels, mules, horses, and a few swine. Few swine are grown since Islamic forbids the raising as well as the consumption of pork.[60]

IV. THE NATIONAL ECONOMY

General Statistics

The gross national product of the United Arab Republic has increased in the past few years at the rate of four to five percent per year. It approached $4.5 billion in 1964 or about $150 per capita. Crops accounted for 30 percent of the total, industry 30 percent, trade and finance 10 percent, and other activities 30 percent. The leading industrial products were textiles, food and tobacco manufactures, chemicals, and fertilizers.[61]

The country currently allocates about 20 percent of its budget for development purposes. The deficit between annual revenues and expenditures is financed by internal borrowing and foreign assistance.[62]

The agricultural development of the country has progressed considerably, with production increasing at an average annual rate of about three percent during the last decade.[63] While this rate of growth has

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[60] United States Department of Agriculture, The Agricultural Economy of the United Arab Republic (Egypt), Economic Research Service, Foreign Agricultural Economic Report No. 21 (Washington: Government Printing Office, 1964), pp. 32-37.

[61] United States Department of State, op. cit., p. 3.

[62] Ibid.

[63] Warren, op. cit., p. 9.

been slightly ahead of the population increase, it has not been made without difficulties, and the country is presently in a tight economic situation. Increased domestic consumption and military disturbances have caused exports to fall far short of projected levels. At the same time, foreign exchange earnings from other sources have decreased.[64]

In spite of the notable expansion in industrial production in recent years, agriculture continues to play a principal role in the economic life of the country. Almost two-thirds of the national wealth and one-third of the national income are derived from this activity.[65] In addition, 62 percent of the population and 53 percent of the active labor force derive their livelihood from agriculture.[66]

Foreign Trade and Prospects for Economic Development

Like all developing countries, Egypt has a great need for imported capital goods. Since these goods must be paid for in foreign currencies, the rate of acquisition is largely dependent on the amount of currency Egypt can earn from exports.

Before the June, 1967, war with Israel, the United Arab Republic had three solid sources of revenue. These were long-staple cotton, revenue from the Suez Canal, and tourism. To a large extent, the prospects for economic development seem to depend on these key sources.

Egypt has long exported long-staple cotton to all parts of the world. Today, it is still the primary source of foreign exchange in

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[64] *Ibid.*, p. 10.

[65] Abdallah, *op. cit.*, p. 12.

[66] *Ibid.*

spite of shifts in the world demand for cotton. In 1965, exports of raw cotton, cotton yarns, and fabric were worth more than $325 million.[67]

The second source of foreign funds was the revenue from the Suez Canal. Each vessel using the Canal had to pay hard, convertible currency in advance. In this manner Egypt accumulated over $200 million in 1966.[68] The loss of this revenue, while the Canal is closed, is an unfavorable aspect in the quest for economic development.

The third and expanding source of foreign exchange has been tourism. For many years people from all over the world have traveled to Egypt to see the monuments of ancient civilization. This has added about $100 million annually to Egypt's receipts of foreign currency.[69]

These sources of foreign exchange, however, have still been inadequate, for Egypt continues to suffer a chronic deficit in her balance of payments. Since the closing of the Suez Canal receipts from exports and tourism have been overshadowed by imports of food and capital goods for the development program.[70]

In order to conserve convertible currency, few Egyptians are permitted to travel outside the country. So tight are the controls on imports that desperately needed replacement parts for foreign-made machinery and equipment are often not available, with a resulting loss in production.[71]

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[67] Albert L. Gray, Jr., "The Egyptian Economy--Prospects for Economic Development," Journal of Geography, LXVI (December, 1967), 513.

[68] Ibid.

[69] Ibid.

[70] Ibid.

[71] Ibid., pp. 513-514.

Although current development projects such as the Aswan High Dam are beginning to increase production, adherence to the optimistic development program (designed to double the national income in ten years) and a growing external debt-repayment burden will likely cause payment problems for a number of years.[72]

Gray[73] analyzed the Egyptian prospects for economic development and cited several favorable and unfavorable factors. The favorable factors enumerated were the well-developed infrastructure, a diversified industrial sector, the Aswan High Dam, and a stable government. The unfavorable factors cited affecting economic development prospects were inadequate natural resources, the population explosion, excessive militarism, and the lack of private initiative. Gray concluded that it will be a long time before the Egyptian people enjoy the fruits of a modern society.

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[72] United States Department of State, op. cit., p. 4.

[73] Gray, op. cit., pp. 510-518.

CHAPTER III

THE DATA AND ANALYTICAL MODELS

A general description of the components of the agricultural complex is presented in this chapter. The major sections included describe the water plant, the land, labor, machinery, and other resources, as well as the crop and livestock production alternatives considered. A justification is made for the coefficients used in the analysis. In the latter part of the chapter the linear programming model used is described, indicating how the assumptions and restrictions were incorporated into the model.

Data relating to the basic resources in the complex were obtained from other members of the Middle East Study Group listed in Table 63, Appendix D. Data pertaining to crop production were compiled by members of the agricultural sector of the team.

The most important published sources of data used in synthesizing livestock production coefficients were the various publications of the state agricultural experiment stations and extension services. Other important sources included United States Department of Agriculture publications, the Food and Agriculture Organization of the United Nations, as well as various unpublished sources.

Also important in the study were consultations with technical scientists at the University of Tennessee. Other contacts included representatives of the United States Department of Agriculture and various personnel representing firms specializing primarily in feed sales and feed processing in the United States.

I. BASIC RESOURCES AND INVESTMENTS

Water Plant[a]

A desalting plant with a capacity of 200 million gallons of water per day was assumed. Generally, the site was considered to be west of Alexandria on the Mediterranean coast near Burg El-Arab in the United Arab Republic. The desalting plant represents a large investment with an assumed life of 30 years. Operation of the complex is assumed to start after a five-year construction period.

The cost of water is the total cost of producing the desalted water. Hence, once constructed, the total water cost is fixed and constant for the 30-year period regardless of the cropping pattern, acreage, or the percentage of capacity utilized. When handled in this manner, the cost of water does not influence the selection of crops but does have a large impact on total production costs and net returns. In the initial analysis no charge is made for the water.

A one-month period is used as the accounting interval for determining the supply and utilization of water. It is assumed that the water plant will operate 310 days a year. The plant will not operate

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[a]Details regarding the water plant and system of water conveyance and distribution were developed by engineers on the study team and are presented here for reference purposes.

for 55 days each year, 28 of which can be scheduled in advance during a period when crop requirements are minimal. The remaining 27 days of unscheduled shut-down are prorated over the year. The total production of desalted water during the year, with the 55 days of shutdown taken into account, amounts to 190,200 acre-feet.

Water Conveyance and Distribution

Transporting the desalted water from the desalting plant to the growing crops is complex and expensive. The basic system which has been assumed consists of the following:

1. A buried trunk line with a main pumping station to transport the water to the farming area. An average lift of 275 feet is assumed to be required.
2. A canal running the length of the farming area with pumping stations every one-half mile to deliver water to the sprinkler head at 50 pounds of pressure per square inch.
3. An above-ground water storage reservoir.
4. Buried branch lines which carry the water in each direction from the canal to the irrigated fields.
5. A hand-moved irrigation system which receives water from the branch lines and distributes it to the land.

Investment outlays are considered in two different categories. The first is primarily associated with the amount of water produced and includes trunk lines, pumping stations, canals, and the storage reservoir. Total investment for these facilities was estimated to be $23.8 million (Table 30, Appendix A). The second type of costs depends largely upon the number of acres that is irrigated. This type includes the branch lines and laterals. Investment of this type was estimated to be $295 per acre for the basic acreage and $210 for the extra winter acreage (Table 31, Appendix A).

Land

The detailed characteristics of the land cannot be described accurately until a specific site is selected and soil surveys are completed. For the purpose of this study the land for potential development was assumed to be located along the Mediterranean coast west of Burg El-Arab to the Libyan border. These soils have been classified as Sandy Red Deserts on schematic maps of the area.

The estimated usable land area has been estimated to range from 40 percent to 85 percent, with the average estimated at 65 percent. Judging from available soil maps, the total amount of land available in the area was not considered to be a limiting factor in this study. It was assumed that land could be acquired in any amount consistent with the needs of the assumed desalting plant unit.

Though the area is relatively unsettled, some acquisition costs are likely, either as direct outlays or as compensation to or resettlement of persons in the area. In any event, the acquisition cost should be relatively low. Estimates used for the study were $15 for the basic acreage and $15 for extra winter acreage (Table 31, Appendix A).

Improvements would be required to develop the land. In addition to land clearing and leveling, subsurface drainage systems were assumed to be installed on poorly drained soils, and, access roads built. In selecting usable soils in the area, those which contained large quantities of soluble salts were rejected. A description of soils considered to be usable suggested a low salt content. Hence, no allocation was made for leaching water.

Installation of subsurface drainage facilities was considered to be desirable, although not absolutely necessary. Soils with a hardpan at about 40-60 inches below the surface comprise approximately 40 percent of the usable land area. The cost of drainage facilities per acre was assumed to be $95. Thus, the cost allocation made for drainage facilities was $38 per acre.

In contrast to furrow irrigation systems, the sprinkler irrigation system assumed does not require level land. The degree of leveling depends on the topographic and soil features of the land. The rolling lands of the area under consideration would require minimal development.

The cost of providing farm roads depends on the road type as well as the topographic features in the area. For gravel roads in these areas, an allocation of $15 per acre was made.

<u>Machinery and Equipment</u>

The investment in farm implements will represent another relatively large outlay. Machinery costs constitute one of the major expenditures required in crop production.

The investment and hourly costs for machinery items required by the crops evaluated are summarized in Table 32, Appendix A. These data show operating costs and overhead costs per hour of use, as well as investment costs per hour of use.

Machinery costs which were classified as fixed include depreciation, interest on the investment, housing, and insurance. Depreciation and interest were by far the largest fixed cost items. The straight line method of depreciation was used. Interest on machinery investment was assumed to be 10 percent of the average investment. Housing for machinery was included as a fixed cost even though it was not essential for all implements. Insurance rates were assumed to be one-half of one percent of the average investment.

Machinery costs defined as variable costs in this study include fuel and lubricant expenditures, and repairs. Lubricants included engine oil for tractors and self-propelled machines, and grease. Repair costs were assumed to be a fixed percentage of the purchase price for the entire useful life of the implement.

Crop Storage Facilities

The investment required for storage facilities varied with the type of crop considered. Modern handling equipment for transferring commodities from trucks to storage and from storage to rail cars was included in the investment cost assumptions.

Storage facilities designed to meet controlled temperature conditions for such crops as potatoes, onions, and cantaloupes were assumed to require capital costs of $1.82 per hundredweight stored. Facilities designed for the storage of grain, fiber, and other food products were estimated to require $1.43 in capital outlay per hundredweight stored. Annual storage costs were based on the number of months the commodity was assumed to be stored, with the maximum time being about six months. A linear pattern of removal from storage was assumed.

Labor

The labor requirement for crop and livestock production was handled as a variable cost item in the analysis. The wage rates used were $.25 per hour for the regular labor force and $.20 per hour for seasonal labor.

These wage rates are much higher than those existing at the present time in the United Arab Republic for agricultural workers. The wage rates assumed seem appropriate though, when one considers that wage levels are increasing in Egypt and can be expected to continue to do so as the country continues with the development program. Fringe benefits afforded the workers must also be taken into account. In addition, retraining many of the workers for jobs in the agricultural complex will probably be necessary. At the present time, the Egyptian government also charges taxes on wages paid to agricultural workers. Thus, it seemed appropriate for wage rates used in the analysis to be higher than those currently existing.

Plans call for villages to be constructed to house the labor force necessary for operation of the complex. An assumption was made that the necessary labor would be available at the assumed wage rates. Lack of data and time precluded any analysis of the labor supply in the area.

The seasonal requirement for agricultural labor was recognized but no detailed analysis was made of the effects seasonality might have on the total number of workers required, or the availability of the necessary seasonal labor. This additional labor requirement would be required primarily for harvesting the various crops. The labor could be supplied by family members of the year-round workers, by personnel normally engaged in support operations, or by part-time workers.

The number of man-hours of labor required per crop-acre is presented in Table 57, Appendix C. The man-hours of labor required vary to a considerable extent among crops, especially since some are assumed to be harvested by hand and others by machine.

Markets

In order to calculate coefficients required for the linear programming analysis, assumptions were necessary regarding the destination of crop and livestock commodities. In view of the current and projected food and fiber supply and demand relationships in the United Arab Republic, each crop and livestock commodity was designated as being internally consumed or exported, or some combination of the two.

In view of the large quantities of food stocks currently being imported, much of the basic grain, oil and livestock products was assumed to be sold internally. The crops designated as being primarily grown for export were cotton, grapefruit, winter potatoes, onions, and cantaloupes.

Most of the agricultural products produced in the complex would require processing before being made available for human consumption. Due to the time limitations, no detailed food processing studies were made, although this aspect obviously merits attention.

After preliminary investigation of the possibilities regarding the processing of agricultural products, it was concluded that if meaningful coefficients were to be estimated, careful marketing studies would be required for specified products. The cost of market development, price as a function of season of the year, and the effects of quantity and quality changes are particularly difficult questions when applied to developing nations such as the United Arab Republic where there is, in many cases, no currently existing demand for many products and no developed distribution system.

One of the most important aspects in the economic evaluation of the agricultural complex was the estimation of crop and livestock prices and costs of inputs to be used in production. Reliable data for Egyptian conditions were not available in many cases and estimates were often tied to United States levels with appropriate adjustments.

The primary guide in making these price assumptions was world market prices. In a few instances, data were available regarding the import prices the United Arab Republic has been paying in recent years. Also taken into account in estimating prices was the projected world supply of particular products. The crop prices estimated to be appropriate for this study are presented in Table 3. Costs of inputs used in crop production are shown in Table 35, Appendix A. Assumed prices for livestock and livestock products and input items used in livestock production are shown in the livestock budgets in Appendix B. In most cases, the prices assumed for agricultural products are farm prices, or producer prices.

TABLE 3

CROP YIELDS, PRICES, AND NET RETURNS PER ACRE

Crop	Water Application Level	Market Yield (cwt.)	Price Per Cwt. ($)	Net Returns[a] ($)
Wheat	1	60.00	3.00	110.07
Wheat	2	56.40	3.00	101.92
Wheat	3	49.56	3.00	85.82
Cotton	1	32.00	10.00	188.86
Cotton	2	30.88	10.00	180.41
Cotton	3	28.67	10.00	162.33
Corn	1	90.00	2.20	98.55
Corn	2	83.00	2.20	87.26
Corn	3	73.44	2.20	72.66
Peanuts	1	40.00	7.00	140.84
Peanuts	2	38.00	7.00	130.03
Peanuts	3	35.40	7.00	115.73
Grapefruit	1	500.00	2.00	299.00
Oranges	1	440.00	3.00	365.00
Broad beans	1	34.20	5.00	76.00
Dry beans	1	30.00	7.00	123.06
Spring potatoes	1	432.00	1.50	186.62
Winter potatoes	1	270.00	2.00	168.69
Tomatoes	1	520.00	1.20	231.54
Onions	1	332.00	1.90	211.54
Cantaloupes	1	180.00	4.50	257.33

[a]Excluding water cost.

II. CROP PRODUCTION

The crops considered as having potential for the agro-industrial complex include some of the most important and widely grown in Egypt and also include a range of alternatives for different seasons of the year, efficiency of water use, sensitivity to water cost, and for the production of acceptable and high-quality diets. The number of crops evaluated was restricted somewhat by time limitations and by the availability of the necessary input-output data. The crop alternatives are shown in Table 57, Appendix C.

Water Requirements

The costs of desalting and irrigation equipment form a relatively large part of the investment and operating costs of the complex. Therefore, the crop water requirements and irrigation system layout are critical features of the agricultural complex.

Data were required relating to the total water requirements of the various crops as well as their seasonal variations, for these latter factors determine the size of the reservoir for water storage. Details of the irrigation schedule within the cropping season were also important in determining the amount of labor required for operation of the irrigation equipment.

The total water requirements of the crops were determined by evapotranspiration data from the El-Arish area in the Sinai-Negev desert. The basis for computing total water requirements of the crops was the amount of evapotranspiration, or consumptive use, which is the sum of the water lost by transpiration of the plant and evaporation from the soil and wet foliage from seeding to harvest. The method used to calculate the evapotranspiration was the semiempirical energy balance equation developed by M. E. Jensen. Data supplied by Jensen for some of the crops were for the El-Arish area. Due to the similar climatic conditions existing at the study site west of Alexandria, calculations of evapotranspiration were based on the El-Arish data.

The total rainfall at the Burg El-Arab site was estimated to average 5.27 acre-inches annually. Of this amount, 75 percent was assumed to be utilizable by the field crops and orchards, and 50 percent by the vegetable crops.

The water requirement calculated assumed an irrigation efficiency of 80 percent, i.e., evapotranspiration values were adjusted to allow for 20 percent water loss by deep percolation and sprinkler losses. The total water requirement and the amount to be supplied by desalinated water are given in Table 33, Appendix A.

Most of the crops require a preplant irrigation treatment of two or three acre-inches. The remaining number of irrigations depends upon the total water requirements and length of the growing season.

Ideally, measured values of water application and the resulting crop yield are needed under a wide range of irrigation treatments for each crop at this particular locale. Such data would allow an economic analysis to be made so that the optimum amount of irrigation water to be applied could be determined. Unfortunately, such data are available for only a few crops in areas engaged in an intensive, irrigated agriculture in the United States.

In this study, data were obtained for water-yield relationships at three different water levels for wheat, corn, cotton, and peanuts. The water level associated with a high yield level was reduced by 10 and 20 percent with the resulting downward yield for the four crops.

Crop Yields

Yield estimates were necessary in this study for the economic evaluation of the agricultural complex. In the absence of any reliable theoretical or empirical method for estimating crop yields, another rationale was required.

The primary sources of yield estimates were the crop specialists from the United States Department of Agriculture and from the agricultural colleges and experiment stations. In addition, county agents from seven California counties engaged in irrigated agriculture provided upon request the upper 5, 10, and 25 percent yield values obtained by farmers on a regular basis for each crop grown in each particular county. The yield values finally assumed for this study corresponded approximately to the upper 15 to 20 percent of the yield values furnished by the county agents for the crops grown in their counties.

The assumed crop yields are optimistic when compared with average yields presently obtained, but are considerably below record yields. Although high by present standards, the yield values assumed are for the 1980's in an irrigated, intensively-managed agricultural complex after an initial period of soil development. The estimated yields are shown in Table 3, page 46.

Fertilization Practices

Of all the elements known to be required for plant growth, it is probable that only nitrogen and phosphorus will be required initially in significant amounts. Desert soils are alkaline and inherently rich in potash. They usually contain moderate amounts of phosphorus and minimal amounts of nitrogen.

The amount of each nutrient required for achieving the assumed crop yields was estimated after consulting with crop and soil specialists from arid, irrigated areas of the United States. The assumed fertilization rates are shown in Table 34, Appendix A.

Nitrogenous fertilizer will probably be most effective and efficient when applied in the irrigation water, since the greatest crop response to this element is usually obtained by small and frequent applications during the growing season. Late applications of phosphorus, on the other hand, have little effect on yield and are thus assumed to be applied to the soil at the time of the preplant irrigation.

Crop Production Costs

The direct costs of production for each crop are presented in Table 35, Appendix A. The production costs include the direct inputs and cultural costs associated with each crop activity, with the exception of water cost.

The electrical power cost for pumping water was assumed to be $.28 per acre-inch of water required by each crop. Fertilizer costs per pound were assumed to be $.055 for nitrogen, $.06 for phosphate, and $.07 for potash. Potash was required only in potato production. The storage and marketing cost is composed primarily of the cost of storing the commodities. Marketing costs were assessed only for winter potatoes for export, oranges, grapefruit, cantaloupes, and onions. These fruits and vegetables are designated primarily as export crops. A miscellaneous factor was included to allow for unforeseen expenses and the cost of management of the agricultural complex. Interest on operating capital was assumed to be at a 10 percent annual rate. The interest cost was determined by the production and storage period required for each crop.

III. LIVESTOCK PRODUCTION

An Overview

The livestock enterprises considered were dairy cattle, beef cattle, sheep, broilers, and layers. All are well adapted to intensive production conditions. Specific data relating to the analysis of the livestock enterprises are presented in Appendix B.

The three ruminant animal enterprises would make use of the dry-lot feeding and housing system. The broilers and layers would also be managed under closely confined housing conditions.

All of the livestock activities were considered to be "self-contained," i.e., all replacement animals are to be produced in the complex. With the exception of some purchased feed for the poultry enterprises, all of the feed required for livestock production was assumed to be produced in the complex.

The capital investment required for the establishment of the animal enterprises would represent a relatively large outlay. The total investment requirement includes outlays for buildings, equipment, and the initial procurement of animals.

The investment in buildings and equipment would constitute the major portion of the total investment required. These investment costs were based on the costs of the same type of buildings and equipment in the United States in 1969 plus an additional 15 percent to cover transportation and other costs likely to be incurred in moving the items to the complex site.

The annual fixed costs include depreciation, interest, insurance, and repairs. Depreciation and insurance were by far the largest fixed cost items. The capital recovery method was used in computing depreciation and interest. The capital recovery factor is essentially the sum of the sinking fund payment for repayment of the present value plus interest at an annual rate of 10 percent. Insurance rates were assumed to be one percent of the initial investment. Annual repair rates were assumed to be a fixed percentage of the initial investment, ranging from two to five percent. Higher repair rates were assessed on more mechanized items such as automatic watering equipment.

One of the most crucial assumptions was the estimation of prices for livestock products. An effort was made to establish prices which were realistic in the United Arab Republic. Much difficulty was encountered in searching for meaningful and reliable Egyptian data relating to prices for livestock products. The prices used in the analysis were essentially based on livestock prices in the United States and many foreign countries, as well as import prices paid by the United Arab Republic.

The nutritional requirements and feeding systems for the ruminant animals were necessarily evaluated in a different manner from those for poultry. Ruminant animals have the ability to utilize large quantities of roughages, whereas poultry can make little use of roughages.

The feed requirements of dairy cattle, beef cattle, and sheep were computed in terms of total digestible nutrients, digestible protein, and dry matter. This method for handling feed nutrients was adopted after consultation with animal nutritionists at the University of Tennessee. The nutritional requirements computed are presented in Appendix B.

The analytical model was designed to permit use of by-products of the cropping system as an important source of feed for ruminant animals. However, for broilers, layers, and replacement pullets, rations were predetermined. Least-cost rations were developed which meet the recommended nutritional allowances. Wheat was the primary ingredient in each of the poultry rations, and would be produced in the agricultural complex. The other ingredients in the poultry rations were alfalfa meal, soybean oil meal, fish meal, as well as yellow grease for an additional energy input in the broiler ration. All of these feeds could be and actually may be eventually produced in the complex either by animal processing industries or by field production and processing activities.

The prices assumed for the purchased feeds for poultry were based on current prices in the United States and the United Arab Republic. Where no data on Egyptian prices were available, the United States price plus an additional allowance of 30 percent was assumed.

The feed manufacturing cost assumed in the production costs of the various livestock enterprises was based on a study by Harrington.[74] In estimating the amount of the total feed which would need to be processed, an assumption was necessary regarding a particular roughage to concentrate ratio for each type of livestock.

The allocation of feed additives such as vitamins, minerals, hormones, and other various medicinal ingredients to the animal rations was based on typical amounts of these additives incorporated by commercial feed mills. Costs of specific ingredients were derived from prices reported by feed ingredient manufacturers, wholesalers, and retailers in the United States.

The water allowance for each class of ruminant animals was composed of the amount allocated for consumption plus an equal amount assumed to be required for the water sprinkler system used to control dust. Even with relatively high-cost water, the total cost of water for these purposes is quite small. The water allowance for poultry is that amount assumed for direct consumption plus an additional amount for egg washing and general cleansing purposes.

No credit was taken for manure in the costs and returns budgets. It was generally assumed that the cost of removing the waste product would essentially be equal to the market value for the product. The total annual amount produced would seem to be significant in terms of nutrients furnished and especially organic matter supplied when the

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[74] D. N. Harrington, "Capital Investment Required and Operating Cost for Three Model Animal Feed Manufacturing Plants." (Oak Ridge: Oak Ridge National Laboratory, 1969), pp. 10-12. (Mimeographed.)

scarcity or almost complete lack of organic matter in the desert soils is taken into consideration.

Milk Production

The dairy enterprise was assumed to be a 300-cow unit. It would consist of the milking herd and the production of replacement animals.

Dairy animals have rather simple housing requirements. Protection from storms and drafts or high winds in cold weather would be adequate. Shade would be extremely important in hot weather.

The type of housing assumed for this study was the loose housing system, a system in which the animals would usually be closely confined only at milking time or for medical treatment. This type system would afford lower building costs and require less labor to operate than housing systems in which the animals would be closely confined most of the time. For the United Arab Republic, where mild winter weather prevails, loose housing seemed to be appropriate.

The dry-lot facility was designed for a feeding system using small trucks with automatic feeders. Each lactating cow was allowed approximately 360 square feet in the feeding lot, holding area, loafing area, dry cow area, and maternity pens. A sprinkler system was included for the feedlot to control dust and associated respiratory problems.

The breed assumed for the study was the Holstein-Friesian, with cows averaging about 1200 pounds each. Calves were assumed to average 90 pounds at birth. A yield of 12,200 pounds of milk containing 3.5 percent butterfat was assumed for a 305 day lactation. Of this amount, 12,000 pounds were regarded as saleable with 200 pounds allocated to the young calf.

An annual culling rate of 22 percent, a mortality rate of 3 percent, and an annual replacement rate of 25 percent were assumed. Thus, 75 replacement heifers would need to be added to the 300 cow milking herd each year. Replacement animals are to be produced in the complex and the dairy budget shown in Table 36, Appendix B, includes these costs. The heifers were assumed to be bred at 15.5 months of age and to calve at about 25 months and 1089 pounds.

A 90 percent calf crop was assumed, meaning that 270 calves weighing 90 pounds each would be produced annually. An average mortality rate of five percent would be expected the first week with another five percent assumed from one week of age until placed in the milking herd. The dairy calves not required for replacements would be sold. The number of dairy beef animals fed in the beef enterprise was restricted by the number of surplus calves available from the dairy enterprise. With a 90 percent calf crop and the assumed mortality rates, 177 calves one week of age would be available for feeding from each unit of 300 milk cows.

The facilities for handling replacement heifers were assumed to be similar to the beef feedlot described below and costs were calculated accordingly. These facilities were designed for a 15,000 animal capacity.

Breeding would be by artificial insemination. The cost allocation for breeding included the fixed cost of the necessary cold storage and service equipment plus the ampule cost, with one and one-half services per cow assumed necessary.

Beef Production

The dairy beef enterprise consisted of feedlot facilities designed for a capacity of 15,000 animals. Although larger feedlots are currently being constructed, available data suggested that practically all size economies are realized at this capacity.

The feedyards were designed to allow 200 square feet of surface area per animal. A shade allowance of 30 square feet per animal was made.

A water sprinkler system was considered to be a necessary part of the feedlot equipment in such an arid area where dusty conditions would likely lead to respiratory problems. Large trucks with automatic feeders would distribute the feed directly into the feed bunkers. The grain storage facilities have a capacity of 4000 tons.

The number of calves to be fed in the feedlot was restricted to the number of surplus animals available from the dairy system. It seemed completely unrealistic to assume that a large number of uniform, high-quality calves would be available for purchase within a short time period in Egypt.

The beef enterprise would be essentially a dairy beef enterprise. Recent data suggest, however, that Holstein calves perform quite well in the dry-lot, with average daily gain and efficiency of feed utilization equal or superior to that of the beef breeds.

Since calves would be placed in the beef feedlot at one week of age, a milk replacer feeding system would be required. These facilities would consist essentially of large steel tanks with nipples. Forty pounds of milk replacer were allocated for each calf.

The calves would stay in the feedlot until an average weight of 850 pounds was attained at about 11 months of age. A mortality rate of four percent was assumed over the feeding period.

Sheep Production

The sheep enterprise would consist of the ewe flock, lamb feeding, and ewe replacement production. The accelerated lambing program was assumed for this study.

In the accelerated lambing program the period between lambings is shortened and lamb crops are produced every eight months rather than every 12 months. The productive life of a ewe is normally about six years, extending from 18 months to 7.5 years. Under an accelerated program a ewe can produce nine crops of lambs rather than the usual six. In view of the occasional seasonal breeding difficulties encountered in this system, the Rambouillet breed was assumed for this study. This breed is much more adaptable to off-season mating than other breeds, and also thrives under hot climatic conditions.

The ewe flock would be maintained in a 15,000 animal capacity dry-lot system. An allowance of 30 square feet of surface area per animal was made. As in the beef and dairy enterprises, a water sprinkler system was provided for dust control. Facilities for lambing and creep feeding for the young lambs were provided in the feedlot. Foot baths and dipping vats were also included in an effort to control diseases and parasites.

The culling rate assumed for the ewes was 20 percent, in addition to an annual mortality rate of five percent. This would give an annual replacement rate of 25 percent. The 3750 replacement ewes required would be bred at 18 months and lamb for the first time at approximately 23 months of age.

The lamb feedlot facilities were designed to handle the 18,329 lambs which would be available annually for feeding. The lambs would be placed in the feedlot at the weaning weight of 40 pounds, or an age of approximately 70 days. They would remain in the dry-lot for approximately five months until an average market weight of 100 pounds was reached. Two lots of lambs would be fed through the dry-lot each year. The lamb feedlot facilities would also be used for replacement ewe production.

The lamb crop was assumed to be 110 percent with a 10 percent mortality rate expected from birth to the weaning weight of 40 pounds. A mortality rate of five percent was assumed for the lambs while they were in the feedlot.

Broiler Production

The broiler enterprise was designed as a 20,000 bird capacity unit with 4.5 broods assumed to be produced each year. The larger broiler units currently being constructed in the United States are of similar size.

The birds would be produced under close confinement. The housing facilities would be of metal construction on a concrete footing and would be insulated overhead and on the sides and end walls. An allowance of one square foot of floor space per bird was made. Fans as well as side vents were provided for ventilation.

The planned feeding system would be essentially a manual type. The feed carrier would be gravity filled from the bulk feed bins and rolled along the track running the length of the building while the operator filled the hanging feeders. A feed conversion rate of 2.25 pounds of feed per pound of gain was assumed. This conversion rate is being regularly achieved in the intensive broiler producing area of Georgia at the present time.

The chicks would be placed in the house at one day of age. They would be marketed at an average weight of 3.5 pounds at approximately 8.0 to 8.5 weeks of age. A mortality rate of four percent was assumed for this feeding period in addition to a condemnation rate of three percent.

The predominant type of broiler produced in the United States is some strain of a White Plymouth Rock - Cornish cross. It is expected that this general breed type would perform well under existing climatic conditions at the Egyptian site.

The broiler ration formulated is presented in Table 56, Appendix B. The primary ingredient is wheat, which would be produced in the agricultural complex. For this study, the remaining feed ingredients were assumed to be purchased.

Day-old chicks were assumed to be available for purchase at a price of \$.07 per straight-run chick. Once the complex was in operation, however, the chicks would probably be produced on-site. Time limitations precluded analysis of breeder flock and hatchery costs in this study.

The litter used for waste absorption was assumed to be wheat straw which would be available as a by-product from the cropping system. The cost allocation for litter was made on the basis of the associated harvesting, transportation and chopping costs.

Egg Production

The layer enterprise was designed as a 20,000 hen flock. This activity included both the layer flock and the production of replacement pullets.

The lay houses would be of metal construction with earth floors. An allowance of 1.3 square feet of floor area per hen was made. The house would be insulated overhead and on the side and end walls. Ventilation would be provided by exhaust fans and side vents. The egg room was located adjacent to the lay house and contained approximately 650 square feet with about 40 percent of this area being refrigerated for temporary egg storage. The egg room equipment included the refrigeration unit, egg washer, and other necessary items. The feed distribution system would be a manual type with the feed being placed from the feed cart into hanging feeders by the operator.

The feed conversion rate over the entire laying period was assumed to be 4.25 pounds of feed per dozen of eggs. Many of the more efficient commercial egg producers in the United States are presently obtaining this conversion rate.

The laying rate assumed was 18 dozen per hen housed or approximately 19.5 dozen per hen based on the average number of hens. The laying period was assumed to be 12 months, after which the hens would be sold. A flock mortality rate of 15 percent was assumed over the laying period. Of the hens surviving the laying period, three percent were regarded as being unsaleable due to poor physical condition.

The breed of hens most popular in the United States in commercial layer flocks is the White Leghorn. It is classified as one of the lighter breeds of laying hens, but one which has superior qualities for intensive egg production. As the breed performs well under warmer climatic conditions, it is anticipated that this breed could be used with good results in the agro-industrial complex.

The houses designed for replacements were quite similar to the lay houses. An allowance of one square foot of floor area per bird was made. The pullets would require about 20 weeks before they would be ready to be placed in the laying flock. Two broods per year could thus be produced with the periods between broods used for house cleaning and disinfection. Each pullet would require 18 pounds of feed prior to the production period. A mortality rate of eight percent was allowed over this period. Replacement pullets would be started throughout the year in an attempt to stabilize egg production. The pullets would be vaccinated three times for diseases. All vaccinating would be completed before the birds were placed in the laying flock. The pullets would be debeaked twice in an attempt to deter cannabilism.

A purchase price of $.35 per day-old pullet was allowed. These chicks will probably eventually be produced in the agricultural complex and probably at a lower cost, but time limitations prevented further analysis in this study.

IV. LINEAR PROGRAMMING MODELS

Alternative Goal Analysis

The final objective in the study was to determine optimum combinations of crop and livestock enterprises. Optimality was to be evaluated using six objective functions.

The alternative goals which were judged to be relevant in the United Arab Republic and used in this analysis were:

1. Maximizing annual income.
2. Maximizing the present value of foreign exchange net credit.
3. Maximizing domestic employment.
4. Maximizing calorie production.
5. Maximizing effective protein production.
6. Minimizing the investment outlay required for the agricultural complex.

Justification for selection of these particular goals to be optimized was presented in Chapter I and II. Only a brief mention of the basic rationale for selection will be given in this section.

Recognizing that the results of any linear programming model are critically dependent upon the underlying assumptions and restrictions, an attempt will be made in this section to relate some of the most crucial ones. Coefficients related to the alternative goal analysis are presented in Appendix C.

Annual income was one of the more obvious goals to be analyzed. The income values were computed by subtracting production and overhead expenses from the gross income.

In view of the critical foreign exchange situation existing in the United Arab Republic, the maximization of the present value of foreign exchange net credit seemed particularly appropriate as a goal. The percentages of gross sales from crop and livestock products which were assumed to be earning foreign exchange were determined after consideration of the current and anticipated export-import situation. Substitution of products produced in the complex for imports, which would result in saving foreign exchange outflow, was considered to be equivalent to exporting products and earning foreign exchange directly.

For the purpose of calculating foreign exchange coefficients, durable buildings and equipment were assumed to have a useful life of 30 years, which is equal to the life of the project. Buildings and equipment used for livestock production were considered to have a useful life of 15 years and thus would need to be replaced once over the 30-year period. Farm machinery and implements were assumed to be replaced twice, based on a 10-year useful life.

The rationale for the selection of the nutrition goals was the existing shortage of food products in Egypt and especially high-quality protein from animal sources. The country is currently importing large quantities of food products which necessitates the outflow of scarce foreign exchange.

The calorie and protein coefficients used in this study are presented in Tables 58 and 59, Appendix C. The values given are for the edible portion of one pound of food as obtained from the retail market or garden. The source of the nutrition data was a United States Department of Agriculture publication.[75]

The protein values used for this study were adjusted to represent effective protein rather than total protein. Nutritionists have developed a number of biological methods of measuring protein quality other than direct measurement of the amino acid pattern. A common measure in the case of man is net protein utilization (NPU).[76] The NPU designation is an index of the digestability of proteins and the biologic values (protein quality) of the amino acid mixture absorbed from the intestine. Egg protein is considered to have an almost ideal pattern of amino acids and digestability, and is referred to as the "reference protein" with an index value of 100. In practice, the quantities of a protein with an NPU value of less than 100 must be larger to meet the daily requirements which are based on reference protein. In other words, it would require two grams of a protein with an NPU value of 50 to meet the daily requirements given in terms of one gram of reference protein. In general, animal products have an NPU

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[75] B. K. Watt and others, Composition of Foods, Agricultural Research Service, United States Department of Agriculture, Handbook No. 8 (Washington: Government Printing Office, 1963), pp. 68-121.

[76] David L. Call and Vernon R. Young, "Protein Requirements for Nutritional Planning" (Cambridge: Massachusetts Institute of Technology, Department of Nutrition and Food Science, 1969), p. 2. (Mimeographed.)

value of approximately 80 to 83, with the exception of egg which is the reference protein, while most food grains have an NPU value of about 52 to 55.

Another goal selected as being relevant for the United Arab Republic was the maximization of domestic employment. This selection was made at least partially in response to the previously mentioned Senate Resolution 155 which listed the provision of new jobs as being one of the major objectives of the proposed nuclear desalting plants in the Middle East.

The final goal to be optimized relates to the minimization of total investment capital required for construction of an agricultural complex, subject to the restriction that all of the desalted water produced be utilized. Outlays for land and land preparation, the irrigation system, the storage reservoir, machinery, buildings, and animals are included in the investment coefficients calculated. This model seems appropriate in view of the rather tight economic situation existing in the United Arab Republic and especially since much of this investment would involve the outflow of foreign exchange if the project were financed by Egypt.

Linear Programming Specifications

An attempt will be made in this section to relate linear programming specifications which have not been explained previously. Of special importance is the description of the techniques for handling the livestock feeding system, the water storage activities, and the land-use activities.

The program was designed to allow for water storage in an above-ground reservoir. A total of 24 water transfer functions were thus required to allow for water to be received from or supplied to storage by any particular month. It was assumed that a water loss of seven percent would result from storage activities. This means that .07 acre-inches of water would be lost to evaporation for each acre-inch stored in the reservoir.

The land resource was considered to be of two different types in the program. The basic farmland, or general purpose land, was assumed to be available for cropping in the summer and winter. Extra winter land, on the other hand, could be selected in the program at a lower cost. The primary difference between the two types was not in land quality, but in the development costs associated with each type. The basic farmland was assumed to require a drainage system for 40 percent of the land area and also a greater initial investment in land clearing and leveling. Since the winter land was used less intensively, a drainage system was considered unnecessary. The total investment costs per acre for each type of land were included in the program on a prorated annual basis.

The investment cost in land included land acquisition and land preparation costs, and that part of the irrigation system associated with acreage. The irrigation system equipment associated primarily with water capacity, such as trunk lines, pumping stations, canals and the water storage reservoir, was regarded as being part of the desalting plant.

The feeding system for ruminant animals was determined by each of the linear programming models. The technique used was to calculate the total annual requirements for each unit of livestock in terms of energy, protein, and dry matter, allowing various concentrates, roughages, residues, and processing by-products produced by the agricultural complex to supply a given amount of each of these nutrients based on their composition. An optimal feeding program was thus selected in terms of the objective function being analyzed.

From the beginning of this study, the animal enterprises were expected to be able to use rather large quantities of roughages, residues, and by-products produced in the complex. Ruminant animals particularly can make use of feeds which might otherwise be unutilized in such a system.

The general types of feed available for ruminant feeding would include grains produced expressly for livestock, processing by-products, dehydrated fruit and vegetable processing residues, and crop residues. The specific feeds available in the analysis were corn, wheat, wheat straw, wheat by-products, citrus pulp, peanut meal, peanut hay, potato meal, tomato pulp, cottonseed meal, corn silage, and alfalfa hay. Some of these feeds would require processing before they were made available for livestock feeding.

Those feeds which would require dehydration include citrus pulp, potato meal and tomato pulp. The costs associated with each of these feeds were based on dehydration costs in the United States.

The cost coefficients used in the program for processing by-products, which included wheat by-products, peanut meal, and cottonseed meal, were based on recent prices for these products in the United States, less the usual cost of advertising, outbound transportation, and other costs which would not be incurred if the products were processed in the agro-industrial complex. It is quite probable that these products would be processed in the complex at a lower cost, but for the purpose of this study, the described method of pricing was used.

Other feeds such as corn, wheat, corn silage, and alfalfa hay were considered to be available for livestock feeding. Such feeds as wheat straw and peanut hay were priced at the computed cost of harvesting, hauling and storing.

The primary overall restriction in the programming models was the monthly and annual amounts of water available from the desalting plant. The annual availability of water was estimated to be 190,200 acre-feet.

Market considerations required a production restraint for several of the crops, especially the high-valued fruit and vegetable crops and all type of livestock products. Cotton was restricted to 173,700 pounds, oranges to 1000 acres, grapefruit to 2000 acres, broad beans to 25,000 acres, spring potatoes for domestic consumption to 7000 acres, winter potatoes for export to 1000 acres, tomatoes to 1000 acres, onions to 6000 acres and cantaloupes to 500 acres. These upper limits were established on the basis of production, marketing, and export considerations.

The quantity of all types of livestock products produced was considered to require production restraints. These upper limits were determined on the basis of projected total consumption of each animal product for 1980 in the United Arab Republic. These consumption projections were based on projected population and per capita income figures.[77] The upper limits were then set at ten percent of this projected national consumption in 1980. This means that the dairy enterprise was restricted to 142 units, beef cattle to 14 units, sheep to 21 units, broilers to 202 units, and layers to 41 units. Due to the requirement that all beef animals fed must come from the dairy enterprise, the effective upper limit on beef cattle production was 1.6756 units.

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[77] B. R. Sen (ed.), Agricultural Commodities-Projections for 1975 and 1985 (Rome: United Nations Publications, 1967), II, 4-220.

CHAPTER IV

SUMMARY OF THE SIX OPTIMIZATION MODELS EVALUATED

This chapter summarizes the alternative production system obtained in each of the six linear programming models. These optimization models were:

1. Maximizing annual income.
2. Maximizing the present value of foreign exchange net credit.
3. Maximizing domestic employment.
4. Maximizing calorie production.
5. Maximizing effective protein production.
6. Minimizing the capital investment required for the agricultural complex development.

Particular topics discussed include the summary of the alternative goal values obtained in the six models, the annual and monthly water distributions, the crop and livestock production systems, the livestock feeding systems, and the contribution made by crops and livestock with respect to each of the alternative goals.

It was assumed that the water desalting plant would operate 310 days per year. The plant would be shut down 55 days each year for maintenance and repairs. Twenty-eight of these days could be scheduled in advance during a period when crop requirements were minimal. The remaining 27 days of unscheduled shutdown were prorated over the year. The total production of desalted water during the year, with the 55 days of shutdown taken into account, amounts to 190,200 acre-feet. Minor water losses in transmission of approximately four percent were assumed. The total annual supply of water available for crop and livestock production thus totals 182,652 acre-feet or 2,191,820 acre-inches.

Use of the land resource was divided into summer and winter seasons. The summer season includes the period from May 1 to November 15, while the winter season includes the period from November 15 to May 1.

I. SUMMARY OF THE OPTIMIZATION MODELS

The values of the alternative goal characteristics obtained in the six optimization models are presented in Table 4. The values given for income, foreign exchange, and investment are in millions of dollars, caloric values in billions, effective protein values in pounds, and employment values in millions of man-hours. The values shown for the income and foreign exchange characteristics are exclusive of water costs. Water costs at varying cost levels are deducted from the income estimate for the various systems in the following chapter.

The income values provided by the various optimization models vary considerably. Similar income values were obtained in the models which maximized income, foreign exchange, and employment, while in the models maximizing nutrition goals and the model minimizing investment estimated income levels were much lower. The calorie and investment models, which included no livestock activities, provided the lowest levels of income. The primary difference in the optimum production

TABLE 4

ANNUAL SUMMARY OF THE ALTERNATIVE GOAL VALUES OBTAINED IN THE SIX OPTIMIZATION MODELS

	Optimization Models					
Characteristic	Income	Foreign Exchange	Employment	Calorie	Protein	Investment
Income[a]	27.8	26.8	24.8	5.6	14.8	7.1
Foreign exchange[a]	209.6	226.9	188.3	52.8	108.4	51.6
Employment[b]	7.8	7.8	11.4	2.8	4.3	3.2
Calories[c]	556.2	545.2	511.4	1,236.3	1,217.4	604.4
Protein[d]	34.0	33.0	34.4	46.7	49.9	27.2
Investment[a]	99.9	106.9	106.4	64.9	85.2	36.4

[a]In millions of dollars.

[b]In millions of man-hours.

[c]In billions.

[d]In millions of pounds.

system estimated for the protein and calorie models was that the protein model included a sizeable dairy enterprise while the calorie model included only crop enterprises. The inclusion of this livestock activity in the protein model resulted in considerably higher levels of income, foreign exchange, and employment than for the calorie model.

The maximum employment model furnished relatively high levels of income and foreign exchange in addition to the highest level of employment. This was due to large labor requirements of the winter vegetable crops, which also provided high income and foreign exchange values. The annual amount of employment furnished was much higher in the employment, income, and foreign exchange models than in the calorie, protein, and investment models. This relationship was not unexpected, in that crops which required a large number of man-hours per acre generally provided high income and foreign exchange values, supplied relatively small quantities of calories and protein, and required a relatively large investment per crop-acre.

The quantity of calories and especially protein provided varied to a lesser extent among the models than did other alternative goal characteristics. The maximum values of calories and protein were obtained in the maximum calorie and protein models, while the other models produced approximately half of the maximum calorie value and over half of the maximum protein level.

Investment capital initially required for the agricultural complex organization was 36.4 million dollars for the minimum investment model, much lower than in any of the other models. Investment required was greatest for the foreign exchange model ($106.9 million). Those models which included livestock activities required considerably higher capital outlays. Investment capital was required for the following items; land acquisition and preparation, irrigation system and water storage reservoir, livestock, machinery and equipment, and buildings used for housing and storage.

II. SUMMARY OF THE MAXIMUM INCOME MODEL

The annual and monthly production and utilization of desalted water for the maximum income model is presented in Table 5. Twenty percent of the total annual production would be stored in the above-ground reservoir. As a result of storage, 31,043 acre-inches of water would be lost to evaporation.

The months with the greatest water requirement were March and April, while January and December had the lowest monthly requirements. The water requirement for April, the peak water-use month, was 190 percent of plant output while the requirement for December, the minimum water-use month, was only 15 percent of the monthly output. The flexibility provided by the water storage reservoir is obvious. The water plant could be closed down for maintenance and repairs during parts of June, September, October, and December, in addition to an average of 2.25 days during each month of the year.

The seasonal land utilization is presented in Table 6. The base farmland included 27,568 acres while an additional 54,002 acres were utilized during the winter months. Of the total land utilized during

TABLE 5

ANNUAL WATER DISTRIBUTION FOR THE MAXIMUM INCOME MODEL IN ACRE-INCHES

Month	Water Plant Output	Water Stored	Water From Storage[a]	Water Requirements
January	202,960	166,379	--	36,581
February	183,320	--	47,689	231,009
March	202,960	--	142,709	345,669
April	196,420	--	177,118	373,538
May	202,960	44,414	--	158,546
June	161,520	--	--	161,520
July	202,960	--	--	202,960
August	202,960	--	3,000	205,960
September	124,869	--	--	124,869
October	134,648	79,215	--	55,433
November	196,420	--	41,900	238,320
December	179,823	153,451	--	26,372
Total	2,191,820	443,459	412,416	2,160,777

[a]Accounts for .07 acre-inches lost to evaporation for each acre-inch stored.

TABLE 6

LAND UTILIZATION BY THE CROP AND LIVESTOCK ENTERPRISES IN THE MAXIMUM INCOME MODEL

Crop or Livestock Activity	Seasonal Land Utilization in Acres	
	Summer Acreage[a]	Winter Acreage[b]
Wheat[c]	--	59,559
Corn feed[d]	14,671	--
Oranges	1,000[e]	1,000[e]
Spring potatoes	--	4,449
Winter potatoes	--	1,000[e]
Tomatoes	1,000[e]	1,000[e]
Onions	--	3,165
Cantaloupes	--	500[e]
Alfalfa hay	9,688	9,688
Eggs (41 units)	69[e]	69[e]
Broilers (202 units)	186[e]	186[e]
Milk (142 units)	781[e]	781[e]
Beef (1.68 units)	173[e]	173[e]
Total	27,568	81,570

[a]May 1 to November 15.

[b]November 15 to May 1.

[c]Water application level 2.

[d]Water application level 1.

[e]Upper limit.

the summer, 25,568 acres, or 93 percent of the total summer acreage, were allocated for livestock and livestock feed production.

Wheat was the primary winter crop, utilizing 73 percent of the winter acreage. Relatively high-valued vegetable crops grown primarily for export, including winter potatoes, tomatoes, onions, and cantaloupes, required 5,665 acres of the winter land.

With the exception of sheep production, all of the livestock enterprises were produced in this model at the upper limit of the market restrictions. The livestock production system included 41 units of layers, 202 units of broilers, 142 units of dairy cattle, and 1.6756 units of beef cattle.

The feeds selected in the model for the dairy and beef cattle enterprises are shown in Table 7. The primary feed ingredients in terms of quantity are wheat straw, corn and cob meal, alfalfa hay, and wheat by-products. The corn and alfalfa hay were grown especially for livestock feeding and were thus treated as intermediate activities.

The broiler and layer enterprises required 67,226 tons of wheat in the ration in addition to the other feed ingredients. The wheat required would be produced in the agricultural complex on 23,839 acres of land with water application at the intermediate level.

The contribution of the crop and livestock components of the agricultural complex to the alternative goals is presented in Table 8. The contribution of all livestock feed activities was included with the livestock component. The greatest contribution of livestock was in terms of income and foreign exchange. Fully 89 percent of the income

TABLE 7

LIVESTOCK FEEDING SYSTEM FOR THE DAIRY AND BEEF ENTERPRISES IN THE MAXIMUM INCOME MODEL

Feed Item	Amount in Tons
Wheat by-products	47,052
Wheat straw	178,678
Corn and cob meal	82,526
Citrus pulp	1,610
Potato meal	9,133
Tomato pulp	330
Alfalfa hay	87,189

TABLE 8

THE CONTRIBUTION OF CROPS AND LIVESTOCK TO THE ALTERNATIVE GOALS IN THE MAXIMUM INCOME MODEL

	Source of Contribution			
	Crops		Livestock	
Characteristic	Amount	Percent	Amount	Percent
Income[a]	2.97	10.7	24.80	89.3
Foreign exchange[a]	31.02	14.8	178.63	85.2
Employment[b]	3.60	45.9	4.25	54.1
Calories[c]	388.30	69.8	167.89	30.2
Protein[d]	14.13	41.5	19.91	58.5
Investment[a]	30.87	30.9	69.06	69.1

[a]In millions of dollars.

[b]In millions of man-hours.

[c]In billions.

[d]In millions of pounds.

and 85 percent of the foreign exchange net credit were derived from livestock activities. Although livestock played a less dominant role in terms of employment, calories, and protein, the major part of the annual employment and the quantity of effective protein produced was supplied by livestock enterprises.

III. SUMMARY OF THE MAXIMUM PRESENT VALUE OF FOREIGN EXCHANGE NET CREDIT MODEL

The annual and monthly distribution of desalted water for the foreign exchange model is presented in Table 9. Of the total annual water output, 27 percent would be stored in the reservoir. This would result in the evaporation of 41,265 acre-inches of water. The months having the greatest water requirements were March and April, with the minimum-use months being January and December. The water requirement in April, the peak month, was 205 percent of plant output, while the December requirement was only 13 percent of the monthly output.

Land utilization by the crop and livestock activities is shown in Table 10. The basic farmland included 25,334 acres with an additional 68,273 acres being utilized during the winter. Of the summer acreage, 92 percent was used for livestock production activities. Wheat was the principal winter crop, accounting for 74,434 acres or 80 percent of the total winter acreage.

All livestock activities were included at the upper limit except sheep production, which was not included at any level. Forty-one units of layers, 202 units of broilers, 142 units of dairy cattle, and 1.6756 units of beef cattle were to be produced annually.

TABLE 9

ANNUAL WATER DISTRIBUTION FOR THE MAXIMUM FOREIGN EXCHANGE MODEL IN ACRE-INCHES

Month	Water Plant Output	Water Stored	Water From Storage[a]	Water Requirements
January	202,960	175,950	--	27,010
February	183,320	--	92,496	275,816
March	202,960	--	164,210	367,170
April	196,420	--	205,630	402,050
May	202,960	85,256	--	117,704
June	131,080	--	--	131,080
July	179,707	--	--	179,707
August	179,706	--	--	179,706
September	110,367	--	--	110,367
October	202,960	151,714	--	51,246
November	196,420	--	85,889	282,309
December	202,960	176,570	--	26,390
Total	2,191,820	589,490	548,225	2,150,555

[a]Accounts for .07 acre-inches lost to evaporation for each acre-inch stored.

TABLE 10

LAND UTILIZATION BY THE CROP AND LIVESTOCK ENTERPRISES IN THE MAXIMUM FOREIGN EXCHANGE MODEL

Crop or Livestock Activity	Seasonal Land Utilization in Acres	
	Summer Acreage[a]	Winter Acreage[b]
Wheat[c]	--	41,895
Wheat[d]	--	24,612
Wheat feed[d]	--	7,927
Corn feed[c]	13,161	--
Grapefruit	2,000[e]	2,000[e]
Winter potatoes	--	1,000[e]
Onions	--	6,000[e]
Alfalfa hay	8,964	8,964
Eggs (41 units)	69[e]	69[e]
Broilers (202 units)	186[e]	186[e]
Milk (142 units)	781[e]	781[e]
Beef (1.68 units)	173[e]	173[e]
Total	25,334	93,607

[a]May 1 to November 15.

[b]November 15 to May 1.

[c]Water application level 2.

[d]Water application level 3.

[e]Upper limit.

The feeding system selected for the dairy and beef cattle enterprises is shown in Table 11. Wheat required for the poultry rations would be produced on 23,839 acres of land at the intermediate water application level.

The contribution of livestock to the agricultural complex is presented in Table 12. As in the maximum income model, a large part of the income and foreign exchange net credit was furnished by the animal activities. In fact, nine-tenths of the income and 79 percent of the foreign exchange values were derived from livestock production. In addition, 54 percent of the labor force was employed in the livestock production systems. Livestock also played a significant role in calorie and protein production. Sixty percent of the effective protein and 31 percent of the calories produced were furnished by the animal enterprises.

IV. SUMMARY OF THE MAXIMUM DOMESTIC EMPLOYMENT MODEL

The estimated annual and monthly water use for the model in which domestic employment was maximized is presented in Table 13. Approximately 18 percent of the total annual production of desalted water would be stored temporarily in the reservoir. The evaporation of 26,935 acre-inches of water would result from the storage operation. The months of February, March, and April had the greatest water requirement, while January and December required only minimal amounts.

The optimum enterprise combination for this model is presented in Table 14. Crop and livestock activities required 32,728 acres of basic

TABLE 11

LIVESTOCK FEEDING SYSTEM FOR THE DAIRY AND BEEF ENTERPRISES IN THE MAXIMUM FOREIGN EXCHANGE MODEL

Feed Item	Amount in Tons
Wheat	19,659
Wheat by-products	50,079
Wheat straw	186,572
Corn and cob meal	68,273
Potato meal	680
Alfalfa hay	80,680

TABLE 12

THE CONTRIBUTION OF CROPS AND LIVESTOCK TO THE ALTERNATIVE GOALS IN THE MAXIMUM FOREIGN EXCHANGE MODEL

Characteristic	Source of Contribution			
	Crops		Livestock	
	Amount	Percent	Amount	Percent
Income[a]	2.59	9.7	24.23	90.3
Foreign exchange[a]	48.56	21.4	178.32	78.6
Employment[b]	3.53	45.6	4.22	54.4
Calories[c]	379.07	69.5	166.13	30.5
Protein[d]	13.23	40.0	19.81	60.0
Investment[a]	34.33	32.1	72.61	67.9

[a]In millions of dollars.

[b]In millions of man-hours.

[c]In billions.

[d]In millions of pounds.

TABLE 13

ANNUAL WATER DISTRIBUTION FOR THE MAXIMUM EMPLOYMENT MODEL IN ACRE-INCHES

Month	Water Plant Output	Water Stored	Water From Storage[a]	Water Requirements
January	202,960	168,931	--	34,029
February	183,320	--	81,710	265,030
March	202,960	--	84,329	287,289
April	196,420	--	141,946	338,366
May	202,960	--	--	202,960
June	167,404	--	--	167,404
July	163,004	--	--	163,004
August	183,352	--	--	183,352
September	179,024	--	--	179,024
October	202,960	125,184	--	77,776
November	196,420	--	49,871	246,291
December	111,036	90,676	--	20,360
Total	2,191,820	384,791	357,856	2,164,885

[a]Accounts for .07 acre-inches lost to evaporation for each acre-inch stored.

TABLE 14

LAND UTILIZATION BY THE CROP AND LIVESTOCK ENTERPRISES IN THE MAXIMUM EMPLOYMENT MODEL

Crop or Livestock Activity	Seasonal Land Utilization in Acres	
	Summer Acreage[a]	Winter Acreage[b]
Wheat[c]	--	38,264
Wheat feed[c]	--	9,440
Corn silage	6,024	--
Cotton[c]	16,143	--
Grapefruit	2,000[d]	2,000[d]
Oranges	1,000[d]	1,000[d]
Spring potatoes	--	5,870
Alfalfa hay	5,608	5,608
Winter potatoes	--	1,000[d]
Cantaloupes	--	500[d]
Tomatoes	1,000[d]	1,000[d]
Onions	--	6,000[d]
Broad beans	--	25,000[d]
Eggs (41 units)	69[d]	69[d]
Broilers (202 units)	186[d]	186[d]
Milk (126.86 units)	698	698
Total	32,728	96,635

[a]May 1 to November 15.

[b]November 15 to May 1.

[c]Water application level 3.

[d]Upper limit.

farmland, while an additional 63,907 acres of land were utilized during the winter. Summer land required for livestock production (including forage production) totaled 12,585 acres. The principal winter crop was wheat, utilizing 49 percent of the total winter acreage. Seventy-seven percent of the wheat produced would be utilized by livestock. Other winter crops in the optimum system included the relatively high-valued export crops, including grapefruit, winter potatoes, tomatoes, onions, and cantaloupes. All of these export crops were included at the maximum acreage allowed.

Livestock enterprises included in this model were egg and broiler production at the upper limit, plus milk production at about 90 percent of the upper limit. A total of 41 units of layers, 202 units of broilers, and approximately 127 units of dairy cattle would be produced.

Feeds selected for the dairy enterprise are shown in Table 15. A wide variety of feeds was furnished, including such enterprises as wheat, corn silage, and alfalfa hay produced directly for livestock production. The dairy ration also included considerable quantities of crop by-products such as citrus and tomato pulp, potato meal, and cottonseed meal. The poultry enterprises required 67,226 tons of wheat in the rations. This quantity was to be produced on 27,107 acres of wheat land at the lower water application level.

The relative contribution of crop and livestock to the objective values is shown in Table 16. About three-fourths of the income and foreign exchange values was provided by the livestock associated enterprises. Sixty-nine percent of the total employment and 73 percent of the calories produced would come from crop production.

TABLE 15

LIVESTOCK FEEDING SYSTEM FOR THE DAIRY ENTERPRISE IN THE MAXIMUM EMPLOYMENT MODEL

Feed Item	Amount in Tons
Wheat	23,412
Wheat by-products	26,402
Wheat straw	143,115
Corn silage	150,595
Cottonseed meal	6,942
Citrus pulp	1,610
Potato meal	11,832
Tomato pulp	330
Alfalfa hay	50,473

TABLE 16

THE CONTRIBUTION OF CROPS AND LIVESTOCK TO THE ALTERNATIVE GOALS IN THE MAXIMUM EMPLOYMENT MODEL

	Source of Contribution			
	Crops		Livestock	
Characteristic	Amount	Percent	Amount	Percent
Income[a]	5.36	21.6	19.44	78.4
Foreign exchange[a]	42.56	22.6	145.76	77.4
Employment[b]	7.89	69.4	3.47	30.6
Calories[c]	372.94	72.9	138.44	27.1
Protein[d]	20.46	59.4	13.97	40.6
Investment[a]	45.86	43.1	60.49	56.9

[a]In millions of dollars.

[b]In millions of man-hours.

[c]In billions.

[d]In millions of pounds.

V. SUMMARY OF THE MAXIMUM CALORIE MODEL

The annual and monthly production and utilization of the desalted water for the maximum calorie model is shown in Table 17. The total amount of water to be stored at some time during the year totaled approximately one-third of the total annual production. Evaporation losses would total 48,856 acre-inches of water during the year.

As there were only four crops selected in this model, the monthly water requirements vary quite markedly. The peak water-use month of February required 202 percent of the monthly output while January, October, and December, the minimal water-use months, each required only about one percent of the monthly output.

The seasonal land utilization by crops is presented in Table 18. The only crop grown during the summer was corn. The principal crop of the three winter crops was wheat, which accounted for 79 percent of the total winter acreage. Broad beans and winter potatoes were the other two winter crops grown, both being produced at the upper limit. No livestock enterprises were included in this model.

VI. SUMMARY OF THE MAXIMUM PROTEIN MODEL

The annual and monthly production and utilization of desalted water for the maximum protein model is presented in Table 19. Thirty-two percent of the total annual production of desalted water would be stored in the reservoir. The evaporation loss from water stored in the reservoir would total 49,085 acre-inches. The two months requiring the greatest amount of water were February and March. January and

TABLE 17

ANNUAL WATER DISTRIBUTION FOR THE MAXIMUM CALORIE MODEL IN ACRE-INCHES

Month	Water Plant Output	Water Stored	Water From Storage[a]	Water Requirements
January	202,960	200,760	--	2,200
February	183,320	--	186,707	370,027
March	202,960	--	165,845	368,805
April	196,420	--	127,135	323,555
May	194,401	106,202	--	88,199
June	107,015	--	--	107,015
July	202,960	--	11,069	214,029
August	202,960	--	11,069	214,029
September	118,916	11,902	--	107,014
October	202,960	200,760	--	2,200
November	196,420	--	147,271	343,691
December	180,528	178,328	--	2,200
Total	2,191,820	697,952	649,096	2,142,964

[a]Accounts for .07 acre-inches lost to evaporation for each acre-inch stored.

TABLE 18

LAND UTILIZATION BY THE CROP ENTERPRISES IN THE MAXIMUM CALORIE MODEL

Crop or Livestock Activity	Seasonal Land Utilization in Acres	
	Summer Acreage[a]	Winter Acreage[b]
Wheat[c]	--	97,164
Corn[d]	29,400	--
Winter potatoes	--	1,000[e]
Broad beans	--	25,000[e]
Total	29,400	123,164

[a]May 1 to November 15.

[b]November 15 to May 1.

[c]Water application level 3.

[d]Water application level 2.

[e]Upper limit.

TABLE 19

ANNUAL WATER DISTRIBUTION FOR THE MAXIMUM PROTEIN MODEL IN ACRE-INCHES

Month	Water Plant Output	Water Stored	Water From Storage[a]	Water Requirements
January	202,960	195,917	--	7,043
February	183,320	--	178,290	361,610
March	202,960	--	182,203	385,163
April	196,420	--	143,493	339,913
May	202,960	117,127	--	85,833
June	105,681	--	--	105,681
July	196,674	--	--	196,674
August	196,673	--	--	196,673
September	101,832	--	--	101,832
October	202,960	192,247	--	10,713
November	196,420	--	148,137	344,557
December	202,960	195,917	--	7,043
Total	2,191,820	701,208	652,123	2,142,735

[a]Accounts for .07 acre-inches lost to evaporation for each acre-inch stored.

December, on the other hand, required minimal amounts of water. As in the calorie model, the monthly water requirements vary considerably. Water requirements during March, for instance, were 190 percent of the water plant output, while requirements in December were only three percent of the monthly output.

Table 20 shows the seasonal land utilization by crop and livestock activities. The size of the basic farm was 27,213 acres, with an additional 95,617 acres being cropped during the winter. The principal crops grown were corn during the summer and wheat in the winter. Only 2,215 acres of land during the summer and winter were required by the dairy enterprise, as the feeding system selected was composed primarily of crop residues and by-products.

The only livestock activity included in this model was the dairy enterprise at approximately 77 units, or 54 percent of the upper limit. The feeds selected for the dairy animals are presented in Table 21.

Although the dairy enterprise at approximately 54 percent of the upper limit was the only livestock activity in this model, it accounted for over half of the income and foreign exchange net credit (Table 22). In addition, 37 percent of the labor force was employed by the dairy enterprise. The smallest contribution of livestock was in terms of nutrition, as only four percent of the calories and 10 percent of the protein were supplied by milk.

TABLE 20

LAND UTILIZATION BY THE CROP AND LIVESTOCK ENTERPRISES IN THE MAXIMUM PROTEIN MODEL

Crop or Livestock Activity	Seasonal Land Utilization in Acres	
	Summer Acreage[a]	Winter Acreage[b]
Wheat[c]	--	13,960
Wheat[d]	--	80,655
Corn[c]	24,998	--
Winter potatoes	--	1,000[e]
Broad beans	--	25,000[e]
Alfalfa hay	1,790	1,790
Milk (77 units)	425	425
Total	27,213	122,830

[a]May 1 to November 15.

[b]November 15 to May 1.

[c]Water application level 2.

[d]Water application level 3.

[e]Upper limit.

TABLE 21

LIVESTOCK FEEDING SYSTEM FOR THE DAIRY ENTERPRISE IN THE MAXIMUM PROTEIN MODEL

Feed Item	Amount in Tons
Wheat by-products	66,680
Wheat straw	107,409
Potato meal	680
Alfalfa hay	16,110

TABLE 22

THE CONTRIBUTION OF CROPS AND LIVESTOCK TO THE ALTERNATIVE GOALS IN THE MAXIMUM PROTEIN MODEL

	Source of Contribution			
	Crops		Livestock	
Characteristic	Amount	Percent	Amount	Percent
Income[a]	5.45	36.9	9.31	63.1
Foreign exchange[a]	53.00	48.9	55.37	51.1
Employment[b]	2.67	62.7	1.59	37.3
Calories[c]	1,174.00	96.4	43.35	3.6
Protein[d]	44.75	89.7	5.12	10.3
Investment[a]	62.58	73.4	22.64	26.6

[a]In millions of dollars.

[b]In millions of man-hours.

[c]In billions.

[d]In millions of pounds.

VII. SUMMARY OF THE MINIMUM INVESTMENT MODEL

The annual and monthly water production and utilization for the minimum investment model is shown in Table 23. The monthly water requirements vary considerably as a result of the small number of crops grown. The months with the greatest water requirement were July and August. January, October, and December required no water. Twenty-five percent of the total annual production would be stored in the reservoir.

Only three crops were selected for the cropping system in this model (Table 24). They were cotton at the upper limit, and peanuts during the summer, and wheat in the winter. No additional winter land was included, as all acreage would be the basic farmland. No livestock enterprises were included in this model.

TABLE 23

ANNUAL WATER DISTRIBUTION FOR THE MINIMUM INVESTMENT MODEL IN ACRE-INCHES

Month	Water Plant Output	Water Stored	Water From Storage[a]	Water Requirements
January	106,614	106,614	--	--
February	183,320	36,973	--	146,347
March	202,960	--	16,563	219,523
April	196,420	--	66,528	262,948
May	202,960	29,752	--	173,208
June	196,420	--	67,007	263,427
July	202,960	--	146,585	349,545
August	202,960	--	146,585	349,545
September	196,420	--	67,007	263,427
October	172,384	172,384	--	--
November	125,442	--	--	125,442
December	202,960	202,960	--	--
Total	2,191,820	548,683	510,275	2,153,412

[a]Accounts for .07 acre-inches lost to evaporation for each acre-inch stored.

TABLE 24

LAND UTILIZATION BY THE CROP ENTERPRISES IN THE MINIMUM INVESTMENT MODEL

Crop or Livestock Activity	Seasonal Land Utilization in Acres	
	Summer Acreage[a]	Winter Acreage[b]
Wheat[c]	--	41,814
Cotton[c]	14,475[d]	--
Peanuts[c]	27,339	--
Total	41,814	41,814

[a]May 1 to November 15.

[b]November 15 to May 1.

[c]Water application level 1.

[d]Upper limit.

CHAPTER V

RESOURCE USE AND THE NET FINANCIAL RETURNS IN THE SIX OPTIMIZATION MODELS

This chapter includes a summary of the resources utilized in the six optimization models as well as an evaluation of the net financial returns obtained from each of the models with varying costs of producing desalted water. The resource use summary discusses the water utilization by crops and livestock, labor use, and the capital requirements by crops and livestock in the various models. The utilization of the land resource is not discussed in this chapter, as it was evaluated in Chapter IV.

I. SUMMARY OF THE RESOURCES USED IN THE SIX OPTIMIZATION MODELS

Annual Water Utilization by Crops and Livestock

The most limited resource in the optimization model analysis was the annual supply of desalted water. The annual water utilization by the crop and livestock components of the agricultural complex is presented in Table 25 for each of the optimization models.

The amount of water utilized by the livestock enterprises included that amount consumed directly by the animals, the amount required by the water sprinkler system to control dust in the feedlots, plus the amount required in the production of the intermediate grain and forage crops for livestock consumption. Most of the desalted water required by

TABLE 25

ANNUAL WATER UTILIZATION BY CROPS AND LIVESTOCK IN THE SIX OPTIMIZATION MODELS

Optimization Model	Annual Water Utilization in Millions of Acre-Inches			Percent of Utilization	
	Total	Crops	Livestock[a]	Crops	Livestock
Income	2.16	.82	1.34	38.0	62.0
Foreign exchange	2.15	.83	1.32	38.6	61.4
Employment	2.16	1.07	1.09	49.5	50.5
Calorie	2.14	2.14	--	100.0	--
Protein	2.14	2.03	.11	94.9	5.1
Investment	2.15	2.15	--	100.0	--

[a]Includes water for animal consumption and feedlot dust control plus the water required for grain and forage crop production for livestock consumption.

livestock activities in the various models was for grain and forage crop production.

The total amount of desalted water available annually for crop and livestock production varied among the optimization models due to the varying amounts of water which were stored in the reservoir. Seven percent of the water stored was lost to evaporation.

Livestock and associated activities utilized the major part of the annual supply of desalted water in the income, foreign exchange, and employment models. The small percentage of the total water supply required by the dairy enterprise in the protein model was due to the feeding system being composed primarily of crop residues and by-products.

Initial Investment in Crop and Livestock Enterprises

The capital investment required by the crop and livestock components of the agricultural complex is presented in Table 26. Investment in the crop enterprises included capital outlay for farm machinery, machinery housing, and crop commodity storage. Investment in livestock activities included capital outlays for the necessary buildings and equipment, plus initial outlays for animals in the dairy, sheep, and layer enterprises. The investment in feed production items for livestock included the investment in machinery and machinery housing necessary for producing grain and forage crops and harvesting crop residues, such as straw, plus capital outlays for by-product processing facilities.

A large share of the capital investment in the income, foreign exchange, and employment models was required for livestock production. Sixty-nine percent of the total investment in the maximum income model

TABLE 26

INITIAL INVESTMENT IN CROP AND LIVESTOCK ENTERPRISES IN THE SIX OPTIMIZATION MODELS

Optimization Model	Initial Investment in Millions of Dollars			
	Crops	Livestock Feed Production[a]	Livestock	Total
Income	30.8	20.5	48.6	99.9
Foreign exchange	34.3	24.0	48.6	106.9
Employment	45.9	16.8	43.7	106.4
Calorie	64.9	--	--	64.9
Protein	62.5	2.9	19.8	85.2
Investment	36.4	--	--	36.4

[a]Includes investment in intermediate grain and forage crops grown for livestock feeding plus estimated investment in by-product processing facilities.

was required by the livestock activities. This compared with 68 percent of the total investment required by livestock in the maximum foreign exchange net credit model, and 57 percent in the maximum employment model. The percentage of the total investment in livestock production composed of feed production items ranged from 13 percent in the protein model to 33 percent in the foreign exchange model.

The inclusion of livestock activities resulted in higher initial capital investments required. The largest capital outlays were required in the income, foreign exchange, and employment models, two of which included all livestock enterprises at the upper limit except sheep production, which was not included at any level in any of the models. The smallest capital outlays were required in the investment and calorie models, which included no livestock enterprises and few crop activities.

Crop and Livestock Labor Requirements

Table 27 shows the annual labor requirement in man-years for the crop and livestock components in the six optimization models. The labor requirement for livestock production includes the labor necessary for animal tending plus the labor necessary for livestock feed production.

Over half of the total man-years of labor required in the income and foreign exchange models was utilized in livestock production activities. Approximately 31 percent of the total annual labor was required for livestock production in the employment model, compared with 37 percent in the protein model. No livestock enterprises were included in the calorie and investment models. The total number of man-years of

TABLE 27

ANNUAL LABOR REQUIREMENTS FOR CROP AND LIVESTOCK PRODUCTION IN MAN-YEARS FOR THE SIX OPTIMIZATION MODELS

Optimization Model	Annual Labor Requirements in Man-Years[a]			
	Crops	Livestock Feed Production	Livestock	Total
Income	1565	530	1313	3408
Foreign exchange	1535	522	1313	3370
Employment	3430	330	1178	4938
Calorie	1230	--	--	1230
Protein	1161	161	530	1852
Investment	1400	--	--	1400

[a]One man-year equals 2,300 man-hours.

employment required varied from a low of 1230 in the calorie model to a high of 4938 man-years in the maximum income model.

The annual labor requirements presented do not take into account the seasonality factor. The full-time agricultural labor force might be somewhat less than the number calculated if one assumed that part-time labor was available during peak labor requirement periods such as planting and harvesting.

The seasonal requirement of labor would be especially significant in the calorie and investment models, both of which included no livestock activities and a limited number of crops. In the other models, in which several crop and livestock activities were included, labor requirements would be distributed much more evenly throughout the year.

The additional seasonal labor requirement could be provided by several alternative sources. Labor could be supplied by family members of the full-time agricultural workers. This is probably the most important source of seasonal labor in the United Arab Republic at the present time. Other likely possibilities for supplying the seasonal labor include the personnel normally engaged in agricultural support operations, such as processing and commodity storage, as well as part-time agricultural workers.

II. NET RETURNS IN THE OPTIMIZATION MODELS WITH VARYING COSTS FOR PRODUCING DESALINATED WATER

Of paramount importance in evaluating the economic and financial feasibility of the agricultural complex is the cost of producing desalinated water. The effects of varying water production costs on the financial returns in the optimization models are estimated at water prices ranging from $.10 to $.45 per thousand gallons. Breakeven prices for desalted water were calculated for each of the models.

Net Returns Per Acre From the Crop Enterprises

The net return per acre of each crop activity evaluated as a function of desalted water production cost is presented in Table 28. No consideration was given to values which crop by-products might have in livestock production. In addition, breakeven water prices were calculated. Estimated annual costs of $52 per crop-acre were deducted for the depreciable cost items associated with land preparation including the irrigation system. Net return values were calculated by deducting from gross returns per crop-acre the sum of the total production costs, the annual land cost, and water at alternative costs.

The projected cost for desalted water is currently about $.35 per thousand gallons for the initial agro-industrial complex operation about 1980. Of the 13 crops evaluated for the agricultural complex, only oranges, winter potatoes, tomatoes, onions, and cantaloupes were able to show breakeven water prices of $.20 or higher per thousand gallons. Of these five crops, only tomatoes and winter potatoes could break even with water costing $.35 per thousand gallons.

The breakeven water prices among crops varied considerably. Winter potatoes showed the highest breakeven water price at $.49 per thousand gallons, while corn at the low water application level could break even only if water production costs were approximately $.03 per thousand gallons. The basic grain crops, including wheat and corn, did

TABLE 28

NET RETURN IN DOLLARS PER ACRE FOR THE VARIOUS CROPS WITH VARYING COSTS FOR PRODUCING DESALINATED WATER

Activity	Water Application Level	Water Cost in Dollars Per Thousand Gallons .10	.20	.25	.30	.35[a]	.40	.45	Breakeven Price For Water Per Thousand Gallons
Wheat	1	11.83	-34.24	-57.36	-80.48	-103.43	-126.55	-149.67	$ .13
Wheat	2	9.12	-31.53	-51.93	-72.33	-92.58	-112.98	-133.38	.12
Wheat	3	-1.54	-36.77	-54.45	-72.13	-89.68	-107.36	-125.04	.10
Corn	1	-28.52	-103.32	-140.85	-178.39	-215.65	-253.19	-290.72	.06
Corn	2	-21.02	-99.62	-133.40	-167.19	-200.72	-234.50	-268.28	.05
Corn	3	-39.40	-99.23	-129.26	-159.29	-189.10	-219.13	-249.16	.03
Cotton	1	43.02	-50.48	-97.40	-144.32	-190.89	-237.81	-284.73	.15
Cotton	2	43.95	-40.19	-82.42	-124.65	-166.56	-208.79	-251.02	.15
Cotton	3	35.26	-39.54	-77.07	-114.61	-151.87	-189.41	-226.94	.15
Peanuts	1	-5.00	-98.50	-145.42	-192.34	-238.91	-285.83	-332.75	.10
Peanuts	2	-6.43	-90.57	-132.80	-175.03	-216.95	-259.17	-301.40	.09
Peanuts	3	-11.34	-86.14	-123.67	-161.21	-198.47	-236.01	-273.54	.08
Oranges	1	178.20	43.89	-23.51	-90.91	-157.82	-225.22	-292.62	.23
Grapefruit	1	113.19	-21.12	-88.52	-155.92	-222.83	-290.23	-357.63	.18
Broad beans	1	8.69	-6.57	-14.23	-21.88	-29.48	-37.14	-44.80	.16
Dry beans	1	15.03	-40.80	-68.81	-96.83	-124.64	-152.66	-180.67	.13
Spring potatoes	1	57.05	-20.24	-59.03	-97.82	-136.32	-175.11	-213.89	.17
Winter potatoes	1	92.75	68.91	56.94	44.97	33.09	21.12	9.15	.49
Tomatoes	1	128.16	76.97	51.28	25.59	.08	-25.61	-51.30	.35
Onions	1	101.28	43.23	11.68	-15.03	-43.95	-73.08	-102.21	.27
Cantaloupes	1	127.76	50.47	11.68	-27.11	-65.61	-104.40	-143.18	.26

[a]Considered to be most likely.

not show a positive net return per acre unless water could be produced for less than $.15 per thousand gallons, and in the case of corn, considerably less. Long-staple cotton, currently the leading export crop of the United Arab Republic and the most important source of foreign exchange, showed a breakeven price of about $.15 per thousand gallons.

The higher breakeven prices for water used in vegetable production were due to two important factors. The dominant factor was the much higher gross income to be obtained from the sale of vegetable crops when compared to the field crops. The vegetables produced were assumed to be almost exclusively exported. Another key factor was that all vegetable crops would be grown during the winter season when evapotranspiration rates and the resulting water requirements were much lower. Yet another factor influencing the higher breakeven water prices shown by crops grown during the winter was that the winter crops could utilize the limited rainfall in the area, practically all of which falls during the winter months.

Net Returns from the Crop and Livestock Enterprises in the Optimization Models

The net returns provided by the various optimization models as a function of water desalting costs are presented in Table 29. Breakeven water prices were also calculated for each of the six models. The net returns were calculated by deducting water costs at varying levels from the net returns exclusive of water costs which were provided in the various models.

TABLE 29

NET RETURNS FROM CROP AND LIVESTOCK ENTERPRISES IN THE SIX OPTIMIZATION MODELS WITH VARYING COSTS FOR PRODUCING DESALINATED WATER

Optimization Model	Water Cost in Dollars Per Thousand Gallons							Breakeven Water Price Per Thousand Gallons
	.10	.20	.25	.30	.35[a]	.40	.45	
	Millions of Dollars							
Income	21.8	15.9	12.9	9.9	6.9	4.0	1.0	$ .47
Foreign exchange	20.9	14.9	11.9	9.0	6.0	3.0	--	.45
Employment	18.8	12.9	9.9	6.9	4.0	1.0	-2.0	.42
Calorie	-0.4	-6.3	-9.3	-12.3	-15.2	-18.2	-21.2	.09
Protein	8.8	2.9	-0.1	-3.1	-6.0	-9.0	-12.0	.25
Investment	1.1	-4.8	-7.8	-10.8	-13.7	-16.7	-19.7	.12

[a]Considered to be most likely.

The breakeven water price varies markedly among the models, ranging from a high of $.47 per thousand gallons in the maximum income model to a low of $.09 per thousand gallons in the maximum calorie model. The highest breakeven water prices were obtained in the models which included livestock enterprises at the upper limit, while the lowest values were obtained in the calorie and investment models, neither of which included any livestock activities. The breakeven water price in the protein model was considerably higher than that obtained in the calorie model as a result of the dairy enterprise being included in the protein model at approximately 50 percent of the upper limit. Positive net returns were realized in the income, foreign exchange, and employment models when desalting costs of $.35 per thousand gallons were deducted.

The contribution of livestock activities to the financial objectives was quite significant. The inclusion of livestock enterprises in the models resulted in much higher net returns or much smaller losses, depending on the desalted water production cost assumptions and the particular optimization model. The greatest contribution of livestock was realized in terms of income and foreign exchange, although contributions in terms of nutrition and employment were quite significant in some of the models.

CHAPTER VI

SUMMARY

The vast desert areas of the world have been described as man's future land bank. Although world food planners are in general agreement that increased world food supplies will have to be produced primarily on land now in cultivation, desalting of sea water provides a means of expanding the cultivable land base.

The primary problem confronting many countries of the world today is lagging economic development. Some of the manifestations of this basic problem include food shortages, malnutrition, and high rates of population growth.

In recent years, several people have expressed the view that energy is one of the more limiting resources in developing countries of the world. Man, if provided with abundant low-cost energy, could produce fresh water for food production by desalting the seas, and also produce many industrial products so necessary in improving living standards. Desalting sea water in large quantities is now technically feasible. The critical question to be answered relates to the overall financial and economic feasibility of such a venture.

In previous work the primary attention in the use of desalted sea water for food production has centered on crop production. Large quantities of crop residues and processing by-products would be produced in an agro-industrial complex. Livestock are able to convert large quantities of these low-valued roughages into high-valued animal products. Ruminant animals would be expected to be much more important in utilizing these roughages. Poultry, on the other hand, have much superior feed conversion rates and would likely be easier adapted to such an area of the world.

The general objective of this study was to evaluate the potential role of livestock in an agricultural-industrial complex in the Middle East, and specifically for a potential site west of Alexandria in the United Arab Republic. The specific objectives were:

1. To determine relevant livestock enterprises for the complex.

2. To determine input-output relationships and to develop costs and returns budgets for these livestock enterprises.

3. To work with other personnel of the agricultural sector of the Middle East Study Group at Oak Ridge National Laboratory in developing costs and returns budgets for relevant crop enterprises, and to help determine the overall potential financial and economic feasibility of producing agricultural commodities using desalinated water.

4. To determine optimum combinations of crop and livestock production with optimality evaluated using six different goals. These were: (a) maximizing financial returns, (b) maximizing the present value of foreign exchange net credit, (c) maximizing calorie production, (d) maximizing effective protein production, (e) maximizing domestic employment, and (f) minimizing investment capital required for agricultural complex construction.

I. THE RESEARCH MODEL

The basic resources and investments in the agro-industrial complex include the water desalination plant, the water conveyance and distribution system, land and land development, farm machinery and equipment, and the crop commodity storage facilities.

The crops considered as having potential for the agro-industrial complex include some of the most important and widely grown in Egypt, and also include a range of alternatives for different seasons of the year, efficiency of water use, sensitivity to water costs, and for the production of acceptable and high-quality diets. The crop alternatives include wheat, corn, cotton, peanuts, grapefruit, oranges, potatoes, tomatoes, broad beans, dry beans, onions, cantaloupes, corn silage, and alfalfa hay.

The livestock enterprises considered to have potential for the agro-industrial complex were dairy cattle, beef cattle, sheep, broilers, and layers. All of these activities are well adapted to intensive production conditions. Feed alternatives for livestock include wheat, wheat by-products, wheat straw, corn, corn silage, cottonseed meal, peanut meal, peanut hay, citrus pulp, potato meal, tomato pulp, and alfalfa hay.

The final procedural step in the study involved the determination of optimum combinations of crop and livestock activities with the aid of linear programming. Optimality was evaluated in terms of six alternative goals which seemed to be especially relevant for the Egyptian economy.

The primary fixed resource in the analytical model was the water desalting plant, with a daily capacity of 200 million gallons. The amount of farmland which would be acquired and developed was determined by each optimization model through land purchase activities. An assumption was made that labor would be available in the quantities required in each system at a price of $.25 per hour for the regular labor force and $.20 per hour for seasonal labor. Investment capital necessary for development of the agricultural complex was considered to be a variable resource.

II. SUMMARY OF THE SIX OPTIMIZATION MODELS EVALUATED

In each optimization model, the maximum or minimum value of the particular objective being optimized was obtained in addition to values for the other five alternative goal characteristics.

The annual income which was provided by various systems selected in each optimization model varied considerably. Levels of income provided amounted to $27.8 million in the income model, $26.8 million in the foreign exchange model, and $24.8 million in the employment model. Income levels were much lower in the nutrition and investment models. Only $5.6 million was produced in the calorie model, $14.8 million in the protein model, and $7.1 million in the investment model. The lowest levels of income were provided by the models which selected no livestock enterprises in the optimum systems.

The amount of employment provided was relatively high in the income, foreign exchange, and employment models. Employment amounted to 11.4 million man-hours in the employment model, 7.8 million man-hours in the income model, and 7.8 million man-hours in the foreign exchange model. Employment furnished by the enterprise combinations in the nutrition and investment models was much lower than for the employment, income, and foreign exchange models. A total of 2.8 million man-hours was provided by the calorie model, 4.3 million man-hours by the protein model, and 3.2 million man-hours by the investment model. The number of man-years of labor required varied from 1230 in the calorie model to 4938 in the employment model.

The quantity of calories and protein provided varied to a lesser extent among the models than did other alternative goal characteristics. The maximum quantity of calories was provided in the calorie model, amounting to 1236 billion calories. The quantity of calories provided by the income model, on the other hand, was 556 billion. The maximum quantity of protein was provided by the protein model (50 million pounds), while the quantity of protein provided by the calorie model was only slightly less (47 million pounds). The quantity of protein provided in the income model was 34 million pounds, which is approximately 68 percent of the quantity provided in the protein model.

Investment capital initially required for agricultural complex organization ranged from a low of $36.4 million in the investment model to $106.9 million in the foreign exchange model. Those systems which included livestock activities required considerably higher capital outlays.

An analysis of the monthly water requirements for the optimum systems developed for the various models indicated that the spring months of March and April would have greatest requirements for desalted water, while January and December would be the minimum water-use months. The amount of water stored at some time during the year in the above-ground reservoir would vary from 18 percent to 32 percent of the total annual production of desalted water.

The seasonal utilization of land varied considerably among the optimization models. For the six optimization systems developed, the total amount of land to be used during the summer would range from a minimum of 25,334 acres in the maximum foreign exchange model to a maximum of 41,814 acres in the minimum investment model. The utilization of land during the winter season would vary from no land in the minimum investment model to 123,164 acres in the maximum calorie model. In several of the models, much of the land resource would be used during the summer for livestock feed production. The bulk of the winter land was allocated to wheat. Most of the other winter crops were restricted in terms of acreage produced. The number of crops to be produced ranged from three in the optimum system developed for the investment model to 12 for the employment model. Total land to be used would vary from 41,814 acres in the investment model to 123,164 acres in the calorie model.

With the exception of sheep production, which was not included at any level in any of the models, all livestock activities were included at the upper limit in the optimum systems for the income and foreign exchange models. For the employment model, the broiler and layer activities were included at the upper limit while the dairy enterprise was included at approximately 90 percent of the upper limit. The optimum systems developed for the calorie and investment models included no livestock. The only livestock included in the system which maximized protein production was the dairy enterprise at approximately 55 percent of the upper limit.

The rations selected for the ruminant animals in the income, foreign exchange, employment, and protein models included several feed ingredients. The number of feeds provided ranged from four in the protein model to nine in the employment model. All of the intermediate grain and forage crops were included in at least one of the feeding systems.

The greatest contribution of livestock was in terms of income and foreign exchange. In fact, about 90 percent of the annual income was derived from livestock in these two optimization models.

III. RESOURCE USE AND THE NET FINANCIAL RETURNS IN THE SIX OPTIMIZATION MODELS

The most limited resource in the optimization model analysis was the annual supply of desalted water. The total annual production was assumed to be 190,200 acre-feet. The total amount of desalted water actually available for crop and livestock production varied from model to model as a result of the varying amounts which were assumed to be stored in the above-ground reservoir. Seven percent of the water stored was assumed to be lost to evaporation.

Livestock and related activities utilized the major part of the annual supply of desalted water in the income, foreign exchange, and employment models. Most of the desalted water required by the livestock was necessary for grain and forage crop production for livestock feeding. Although livestock and related activities utilized over half of the desalted water in these three models, they accounted for an even greater share of the income. The sale of livestock and livestock products contributed 89 percent of the income in the income maximizing model, 90 percent in the foreign exchange maximizing model, and 78 percent in the employment maximizing model.

A large share of the capital investment in the agricultural complex would be required for the organization of the livestock activities. Sixty-nine percent of the total investment in the maximum income model was allocated for livestock enterprise organization. This compared with 68 percent of the total investment that would be required by livestock activities in the foreign exchange model, and 57 percent in the employment model. The smallest outlays of capital would be necessary for the optimum system developed for the investment and calorie models, neither of which included any livestock activities.

Livestock and related feed production activities would also require a significant share of the total annual labor requirement. In fact, over half of the total annual manpower would be required by livestock and related enterprises in the optimum systems for the income and foreign exchange models. The total number of man-years of labor that would be required by the crop and livestock activities ranged from a low of 1230 in the calorie model to a high of 4938 man-years in the employment model. Seasonality factors were recognized but not taken into account in the analytical models. The additional seasonal labor required could be provided by family members, by personnel normally engaged in agricultural support operations, or by part-time agricultural laborers.

Of profound importance in attempting to determine the financial and economic feasibility of such an agricultural complex is the cost of producing the desalted water. In order to evaluate the sensitivity of net returns to water production cost, the cost of water was deducted from the income produced in the various models at costs ranging from \$.10 to \$.45 per thousand gallons. In addition, breakeven prices for water were calculated.

If each crop is considered as an independent production activity the relative profitability of an individual crop can be determined at various water prices. Of the 13 sale crops evaluated for the agricultural complex, only two crops could break even with water costing \$.35 per thousand gallons, which is now considered to be the most likely for the target date of 1980. Only five crops showed break-even water prices of \$.20 per thousand gallons. Winter potatoes showed the highest break-even price for water at \$.49 per thousand gallons, while corn at the low water application level showed a break-even price for water of \$.03 per thousand gallons. Crops grown during the winter season had much higher break-even prices for water than crops grown during the summer. This was due to the much lower evapotranspiration rates and resulting water requirements during the winter, plus the fact that winter crops could utilize the limited rainfall, essentially all of which falls during the winter season. In addition, the vegetable crops, which would be grown only during the winter, would have much higher gross incomes per acre than would the basic summer field crops.

The net returns from crop and livestock activities in the various optimization models varied considerably. The break-even prices for water varied from a high of $.47 per thousand gallons in the maximum income model to a low of $.09 per thousand gallons in the maximum calorie model. The highest break-even water prices were obtained in the models which included livestock activities at the upper limit.

The contribution of livestock activities to the financial objectives was extremely significant. The inclusion of livestock enterprises in the models resulted in much higher net returns, or smaller losses, depending on the assumption regarding the cost of the desalted water and the particular optimization model. Although the greatest contribution of livestock was in terms of income and foreign exchange, contributions to the nutrition and employment goals were quite significant in some of the models.

The type of agricultural complex organization and management was not evaluated in this study. Although the system of farm organization and management selected would be at least partially determined by the government of the United Arab Republic, an analysis of alternative management schemes seems to be advisable in on-going studies. The farm management system ultimately adopted will likely be a most important factor in determining the success or failure of this economic development project.

Further research also seems advisable to refine many of the coefficients used in the linear programming analysis. An economic analysis of agricultural processing facilities also seems advisable. On-going studies of the agro-industrial complex concept are planned at Oak Ridge National Laboratory.

The most important limitation of the study was that such an agro-industrial complex is definitely future oriented and planned for an area of the world where data relative to agricultural production possibilities are not generally available. Projected factor and product prices, which are quite crucial in the financial evaluation of such an economic development project, were necessarily made for a period far removed from the present. Input-output data from the United Arab Republic were extremely scarce, and when available their reliability was difficult to ascertain. Needless to say, much judgment was necessary in synthesizing coefficients for the linear programming models.

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APPENDIXES

APPENDIX A

BASIC CROP PRODUCTION DATA

TABLE 30

INVESTMENTS IN WATER CONVEYANCE AND DISTRIBUTION FACILITIES RELATED TO WATER CAPACITY IN THE AGRO-INDUSTRIAL COMPLEX

Item	Investment
Trunk lines	$ 3,300,000
Pumping stations and electrical transmission facilities	4,200,000
Canal	7,000,000
Storage reservoir	9,300,000
Total	$23,800,000

TABLE 31

INVESTMENT IN LAND AND WATER DISTRIBUTION
FACILITIES RELATED TO ACREAGE

Item	Investment Per Acre	
	Basic Acreage	Extra Winter Acreage
Land purchase	$ 15	$ 15
Land clearing, leveling, and smoothing	25	15
Roads	15	15
Drainage system	38	--
Branch lines	229	180
Laterals	66	30
Total	$ 388	$ 255

TABLE 32

INVESTMENT AND HOURLY COSTS OF FARM MACHINERY USED IN CROP PRODUCTION

Machinery Item	Investment Per Hour of Annual Use	Operating Costs Per Hour of Use: Fuel, Oil and Grease	Operating Costs Per Hour of Use: Repairs	Operating Costs Per Hour of Use: Total	Overhead Costs Per Hour of Use: Interest and Depreciation	Overhead Costs Per Hour of Use: Insurance	Overhead Costs Per Hour of Use: Housing	Overhead Costs Per Hour of Use: Total
	Dollars							
Tractor, 20 H.P. wheel	4.64	.44	.35	.79	.67	.01	.05	.73
Plow, 2 disc	3.00	.02	.45	.47	.43	--	.03	.46
Disk harrow, 5 ft. tandem	3.56	.01	.67	.68	.41	.01	.04	.46
Drag harrow, 8 ft. 2 Sect.	.83	--	.16	.16	.11	--	.01	.12
Cultipacker, 8 ft. double	3.00	.01	.11	.12	.44	.01	.03	.48
Grain drill, 8 ft.	9.38	.05	.59	.64	1.08	.03	.10	1.21
Fertilizer distributor, 10 ft.	4.45	.01	.67	.68	.57	.01	.05	.63
Planter, 2 row	5.88	.02	.73	.75	.86	.02	.06	.94
Cultivator, 2 row	3.00	.01	.38	.39	.44	.01	.03	.48
Sprayer, 4 row	1.68	--	.21	.21	.15	--	.01	.16
Duster, 4 row	1.68	--	.21	.21	.15	--	.01	.16
Combine, 7 ft.	15.00	--	.55	.55	2.18	.04	.16	2.38
Truck, 10 ton	24.00	1.00	.60	1.60	4.02	.07	.26	4.35
Potato planter, 2 row	7.69	.02	.85	.87	1.12	.02	.08	1.22
Potato digger, 1 row	5.25	.02	.47	.49	.76	.01	.06	.83
Rotobeater, 1 row	8.06	.01	.80	.81	1.17	.02	.09	1.28

TABLE 32 (continued)

Machinery Item	Investment Per Hour of Annual Use	Operating Costs Per Hour of Use			Overhead Costs Per Hour of Use			
		Fuel, Oil and Grease	Repairs	Total	Interest and Depreciation	Insurance	Housing	Total
	Dollars							
Rake, 8 ft. side delivery	4.80	.02	.36	.38	.70	.01	.05	.76
Haybine, 9 ft. P.T.O.	19.50	.10	2.24	2.34	2.82	.05	.21	3.08
Baler, P.T.O.	14.40	.05	1.08	1.13	2.09	.04	.16	2.29
Silage blower	7.20	.02	.43	.45	1.04	.02	.08	1.14
Bean cutter, 2 row	1.68	.01	.21	.22	.24	.04	.02	.30
Peanut digger-shaker, 2 row	6.00	.06	.60	.66	1.23	.02	.07	1.32
Peanut combine, P.T.O.	27.00	.10	2.36	2.46	4.52	.07	.30	4.89

TABLE 33

IRRIGATION, TOTAL WATER REQUIREMENTS, AND PLANTING AND HARVESTING DATES FOR THE CROPS IN THE AGRO-INDUSTRIAL COMPLEX

Month	Wheat 1	Wheat 2	Wheat 3	Corn 1	Corn 2	Corn 3	Cotton 1	Cotton 2	Cotton 3	Peanut 1	Peanut 2	Peanut 3	Oranges and Grapefruit	Broad Beans	Dry Beans	Spring Potatoes	Winter Potatoes	Tomatoes	Onions	Corn Silage	Cantaloupes	Alfalfa
	Water Requirements Per Crop-Acre in Acre-Inches																					
January													1.81			2.00	2.20				2.00	2.05
February	3.50	3.00	3.34										1.82	1.82		3.79			2.77		4.42	2.05
March	5.25	4.50	3.33										2.85	1.81		3.79			4.17		4.42	4.10
April	5.25	4.50	3.33				3.00	3.00	3.00				3.67			5.68			9.71		6.63	4.10
May				3.00	3.00	3.00	6.30	5.61	4.92	3.00	3.01	3.00	5.19			9.47			2.77		6.63	5.40
June				4.10	3.64	3.17	6.30	5.61	4.92	6.30	5.61	6.15	6.34		4.50	3.79					4.42	7.55
July				8.20	7.28	6.37	6.30	5.61	4.92	9.45	8.41	6.15	6.70		9.80					3.15		7.55
August				8.20	7.28	6.37	6.30	5.61	4.92	9.45	8.41	6.15	6.70		6.30			3.00		6.03		7.55
September				4.10	3.64	3.17	6.30	5.61	4.92	6.30	5.61	6.15	5.62					3.97		7.69		5.40
October													4.74				2.20	5.96		5.02		4.10
November	3.00	3.00	3.00										2.62	2.00			2.20	5.96	2.00			4.10
December													1.50				2.20					2.05
Total Irrigation	17.00	15.00	13.00	27.60	24.84	22.08	34.50	31.05	27.60	34.50	31.05	27.60	49.56	5.63	20.60	28.52	8.80	18.89	21.42	21.89	28.52	56.00
Irrigation Plus Rainfall	20.10	18.10	16.10	27.60	24.84	22.08	34.50	31.05	27.60	34.50	31.05	27.60	53.10	7.88	20.60	29.60	10.60	19.80	23.30	21.89	32.60	59.60
Number of Irrigations	5	5	4	7	7	6	6	6	6	6	6	5	12	3	3	8	4	5	8	6	8	12
Planting Date	Nov. 15	Nov. 15	Nov. 15	May 25	May 25	May 25	Apr. 15	Apr. 15	Apr. 15	May 15	May 15	May 15	—	Nov. 1	June 1	Jan. 1	Oct. 1	Aug. 15	Nov. 1	July 1	Jan. 1	—
Harvesting Date	May 15	May 15	May 15	Oct. 1	Oct. 1	Oct. 1	Oct. 10	Oct. 10	Oct. 10	Oct. 10	Oct. 10	Oct. 10	—	Mar. 1	Aug. 30	June 15	Jan. 15	Dec. 15	May 15	Oct. 30	July 1	—

TABLE 34

FERTILIZER RATES FOR THE VARIOUS CROPS PRODUCED IN THE AGRO-INDUSTRIAL COMPLEX

Crop	Pounds Per Acre	
	Nitrogen	P_2O_5
Wheat	150	60
Corn	250	80
Corn silage	250	80
Dry beans	50	60
Broad beans	50	60
Spring potatoes[a]	200	40
Winter potatoes[a]	200	40
Onions	200	80
Tomatoes	200	150
Cotton	200	40
Oranges	180	30
Grapefruit	180	30
Peanuts	100	20
Cantaloupes	200	200
Alfalfa	10	160

[a]Also requires 45 pounds of K_2O per acre.

TABLE 35

ESTIMATED CROP PRODUCTION COSTS IN DOLLARS PER ACRE

Crop	Water Application Level (Percent)	Production Cost Items: Seed	Fertilizer	Other Chemicals	Machine Operation	Power	Storage and Marketing	Labor	Miscellaneous	Interest[a]	Total
		Dollars									
Wheat	100	9.50	11.85	5.00	5.63	4.76	3.34	2.78	8.24	3.63	54.73
	90	9.50	11.12	5.00	5.50	4.28	3.14	2.74	8.00	3.50	52.78
	80	9.50	9.82	5.00	5.26	3.81	2.76	2.59	7.63	3.29	49.66
Corn	100	7.20	18.55	9.00	9.78	7.73	5.01	7.08	9.43	4.66	78.44
	90	7.20	17.12	9.00	9.37	6.96	4.62	6.76	9.11	5.33	75.47
	80	7.20	15.14	9.00	9.03	6.18	4.09	6.33	8.70	4.99	70.66
Cotton	100	4.00	13.40	33.30	10.73	9.66	--	28.32	12.94	5.62	117.97
	90	4.00	12.93	33.30	10.70	8.69	--	27.78	12.40	5.49	115.29
	80	4.00	12.00	33.30	10.65	7.73	--	26.06	12.37	5.30	111.41
Peanuts	100	32.00	6.70	18.00	17.95	9.66	5.90	6.13	12.63	7.63	116.60
	90	32.00	6.36	18.00	17.47	8.69	5.60	6.06	12.42	7.46	114.06
	80	32.00	5.93	18.00	16.84	7.73	5.22	5.93	12.17	7.27	111.09
Grapefruit	100	3.00[b]	11.70	80.00	26.64	13.88	40.00	95.85	43.66	18.88	333.61
Oranges	100	3.00[b]	11.70	80.00	26.64	13.88	235.00	84.00	71.13	36.77	562.12

TABLE 35 (continued)

Crop	Water Application Level (Percent)	Production Items									
		Seed	Fertilizer	Other Chemicals	Machine Operation	Power	Storage and Marketing	Labor	Miscellaneous	Interest[a]	Total
		Dollars									
Broad Beans	100	11.25	6.35	15.00	13.53	1.58	2.51	5.94	11.42	5.41	72.99
Dry Beans	100	6.00	6.35	15.00	13.09	5.77	2.09	5.70	8.40	4.37	66.77
Winter Potatoes	100	100.00	16.55	70.00	21.29	2.46	36.00	32.42	44.80	6.47	329.99
Spring Potatoes	100	100.00	16.55	70.00	21.29	7.98	60.00	35.30	34.49	27.65	373.26
Tomatoes	100	16.00	20.00	128.60	21.95	5.29	--	106.00	47.96	6.92	352.72
Onions	100	26.00	15.80	50.00	26.28	6.00	87.70	60.45	44.86	13.32	330.41
Corn Silage	100	7.20	18.55	9.00	22.57	6.13	--	5.22	9.87	4.91	83.45
Alfalfa[c]	100	5.00	7.75	8.00	22.80	16.24	3.62	8.33	10.17	1.50	83.41
Cantaloupes	100	7.00	22.19	57.00	26.00	7.98	178.75	65.00	88.59	11.31	463.82

[a]Interest at a rate of 10 percent per year. [b]Tree replacement cost.
[c]Based on reestablishment every three years.

APPENDIX B

BASIC LIVESTOCK PRODUCTION DATA

TABLE 36

ESTIMATED ANNUAL COSTS AND RETURNS FROM A 300 COW DAIRY HERD IN DRYLOT

Item	Unit	Quantity	Price	Amount
Receipts				
Milk (12,000 lbs. per cow)	cwt.	36,000	$ 5.00	$180,000.00
Calves (1 week old)	Head	177	15.00	2,655.00
Cull cows (66 cows @1,200 lbs.)	cwt.	792	15.65	12,394.80
Total				$195,049.80
Expenses				
Variable				
Electricity	Head	300	$ 5.00	$ 1,500.00
Telephone				178.86
Insecticides	Head	300	1.00	300.00
Labor	Hour	15,000	.25	3,750.00
Vet. and medicine	Head	300	5.00	1,500.00
Gas, oil and grease	Head	300	1.65	495.00
Bedding (wheat straw)	Ton	450.5	2.97	1,338.00
Dairy supplies	Head	300	7.50	2,250.00
Artificial insemination	Head	300	3.15	945.00
Replacement cost				3,641.96
Feed manufacturing	Ton	669.15	3.31	2,214.89
Feed additives	Ton	669.15	3.01	2,014.14
Miscellaneous (5% x variable expenses)				1,006.39
Interest (10% for 4 months)				704.47
Total				$ 21,838.71
Fixed				
Capital recovery				$ 16,111.00
Insurance				1,152.00
Repairs				2,880.00
Total				$ 20,143.00
Total Expenses				$ 41,981.71
Other Requirements				
Water	Gallon	4,944,750		
Feed nutrients:				
Total digestible nutrients	000 lbs.	2652.7		
Digestible protein	000 lbs.	301.7		
Dry matter	000 lbs.	4434.4		

TABLE 37

ESTIMATED COSTS OF PRODUCING 75 REPLACEMENT HEIFERS PER YEAR

Item	Unit	Quantity	Price	Amount
Expenses				$
Variable				
Electricity				$ 51.51
Telephone				16.19
Insecticides and nipples				46.12
Labor	Hour	750	$ .25	187.50
Artificial insemination	Head	75	3.15	236.25
Veterinary and medicine				384.38
Gas, oil and grease				138.38
Milk replacer (40 lbs. per calf)	cwt.	30.75	16.00	492.00
Feed manufacturing	Ton	127.7	3.31	422.69
Feed additives	Ton	127.7	2.92	372.88
Miscellaneous (5% x variable expenses)				117.40
Interest (10% for 12.4 months)				254.75
Total				$2,720.05
Fixed				
Capital recovery				$ 735.46
Insurance				58.40
Repairs				128.05
Total				$ 921.91
Total Expenses				$3,641.96
Other requirements				
Water	Gallon	564,750		
Feed nutrients:				
Total digestible nutrients	000 lbs.	466.0		
Digestible protein	000 lbs.	49.9		
Dry matter	000 lbs.	820.9		

TABLE 38

ESTIMATED INITIAL INVESTMENT AND ANNUAL FIXED EXPENSES FOR A 300 COW DAIRY HERD IN DRYLOT

Item	Cost[a]	Life	Capital Recovery[b]	Insurance[c]	Repairs[d]	Total
	(Dollars)	(Years)	- - - - - -	- - - Dollars	- - - - - -	- - - -
Feed yards	10,350	20	1,216	104	207*	1,527
Milking parlor	20,700	20	2,431	207	414*	3,052
Loafing barn	16,675	20	1,959	167	334*	2,460
Feed storage bins	5,851	20	687	58	117*	862
Office	3,048	20	358	30	61*	449
Squeeze chute	632	20	74	6	13*	93
Sprinkler and water system	1,150	15	151	12	34**	197
Bulk tank (3,500 gal.)	28,175	10	4,585	282	845**	5,712
Milking equipment	15,180	10	2,470	152	455**	3,077
Sprayer (200 gal.)	805	15	106	8	24**	138
Tractor and scoop (40 h.p.)	6,785	12	996	68	204**	1,268
Feeding truck	5,750	8	1,078	58	172**	1,308
Total	115,101		16,111	1,152	2,880	20,143

[a]Cost in United States, 1969, plus 15 percent.

[b]Interest at 10 percent.

[c]Initial cost times 1 percent.

[d]Initial cost times 2 percent (*) or initial cost times 3 percent (**).

TABLE 39

NUTRITIONAL ALLOWANCES PER DAIRY COW IN THE MILKING HERD

Function	Days Per Year	Pounds Per Day		
		Dry Matter	Digestible Protein	Total Digestible Nutrients
Maintenance	365	15.48	0.72	8.16
Lactation	305	18.05	1.72	12.19
Reproduction	91	9.92	0.61	6.61
Total average daily requirement		33.00	2.30	19.97
Total annual requirement		12,045.00	839.5	7,289.0

Source: National Academy of Sciences--National Research Council, Nutrient Requirements of Dairy Cattle (Publication 1349. Washington: National Academy of Sciences Printing Office, 1966), pp. 2-4.

TABLE 40

NUTRITIONAL ALLOWANCES PER REPLACEMENT HEIFER FOR THE DAIRY ENTERPRISE

Weight (Pounds)	Daily Gain (Pounds)	Days Required	Dry Matter Daily	Dry Matter Total	Digestible Protein Daily	Digestible Protein Total	Total Digestible Nutrients Daily	Total Digestible Nutrients Total
			Pounds					
100-200	1.24	81	3.8	307.8	.50	40.50	2.9	234.9
200-300	1.45	69	6.8	469.2	.67	46.23	4.5	310.5
300-400	1.54	65	9.3	604.5	.84	54.60	5.7	370.5
400-500	1.51	66	11.7	772.2	.87	57.42	6.9	455.4
500-600	1.43	70	13.8	966.0	.90	63.00	7.9	553.0
600-700	1.37	73	15.5	1,131.5	.92	67.16	8.7	635.1
700-800	1.33	75	17.4	1,305.0	.93	69.75	9.6	720.0
800-900	1.28	78	19.1	1,489.8	.95	74.10	10.1	787.8
900-1000	1.20	83	20.2	1,676.6	.98	81.34	10.7	888.1
1000-1089	.96	93	20.7	2,222.7[a]	1.00	111.30[a]	11.4	1,258.2[a]
Total	--	753	--	10,945.3	--	665.40	--	6,213.5

[a]Includes additional pregnancy allowances.

Source: National Academy of Sciences--National Research Council, Nutrient Requirements of Dairy Cattle (Publication 1349. Washington: National Academy of Sciences Printing Office, 1966), pp. 2-4.

TABLE 41

ESTIMATED COSTS AND RETURNS FROM A 15,000 HEAD DRYLOT BEEF ENTERPRISE

Item	Unit	Quantity	Price	Amount
Receipts				
Beef animals (14,400 @850 lbs.)	cwt.	122,400	$24.00	$2,937,600.00
Expenses				
Variable				
Electricity				$ 5,000.00
Telephone				2,937.60
Insecticides	Head	15,000	$ .40	6,000.00
Labor	Hour	45,000	.25	11,250.00
Vet. and medicine	Head	15,000	1.26	18,900.00
Gas, oil and grease	Head	15,000	.90	13,500.00
Calves	Head	15,000	15.00	225,000.00
Milk replacer (40 lbs. per calf)	cwt.	6,000	16.00	96,000.00
Calf nipples	Head	15,000	.10	1,500.00
Feed manufacturing	Ton	22,028	3.31	72,912.68
Feed additives	Ton	22,028	1.40	30,839.20
Miscellaneous (5% x variable expenses)				24,191.97
Interest (10% for 5.6 months)				23,708.13
Total				$ 531,739.58
Fixed				
Capital recovery				$ 71,405.00
Insurance				5,670.00
Repairs				12,431.00
Total				$ 89,506.00
Total Expenses				$ 621,245.58
Other requirements				
Water	Gallon	81,600,000		
Feed nutrients:				
Total digestible nutrients	000 lbs.	42,418.3		
Digestible protein	000 lbs.	5,461.3		
Dry matter	000 lbs.	56,643.5		

TABLE 42

ESTIMATED INITIAL INVESTMENT AND ANNUAL FIXED EXPENSES FOR A 15,000 HEAD CAPACITY BEEF FEEDLOT

Item	Cost[a]	Life	Capital Recovery[b]	Insurance[c]	Repairs[d]	Total
	(Dollars)	(Years)	- - - - - -	- - - - - -	Dollars - - - - - -	- - - - - -
Feed yards	345,000	20	40,524	3,450	6,900*	50,874
Grain storage bins	90,850	20	10,671	908	1,817*	13,396
Office	6,095	20	716	61	122*	899
Livestock scales (10 ft. x 25 ft.)	2,012	30	213	20	40*	273
Truck scales (10 ft. x 60 ft.)	13,570	30	1,440	136	271*	1,847
Squeeze chutes (2)	1,265	20	149	13	25*	187
Sprayer (200 gal.)	805	15	106	8	24**	138
Pickup truck	2,990	8	560	30	90**	680
Feeding trucks with feeders (2)	20,700	8	3,880	207	621**	4,708
Tractor and scoop (2 - 40 h.p.)	13,570	12	1,992	136	407**	2,535
Sprinkler system	35,650	15	4,687	356	1,079**	6,122
Milk feeder system	34,500	8	6,467	345	1,035**	7,847
Total	567,007		71,405	5,670	12,431	89,506

[a] Cost in United States, 1969, plus 15 percent.

[b] Interest at 10 percent.

[c] Initial cost times 1 percent.

[d] Initial cost times 2 percent (*) or initial cost times 3 percent (**).

TABLE 43

NUTRITIONAL ALLOWANCES PER BEEF ANIMAL IN THE DRYLOT

Weight	Daily Gain	Days Required	Dry Matter		Digestible Protein		Total Digestible Nutrients	
			Daily	Total	Daily	Total	Daily	Total
(Pounds)	(Pounds)		Pounds					
100-200	1.80	56	4.0	224.0	.64	35.84	3.2	179.2
200-300	2.20	45	7.2	324.0	.86	38.70	5.6	252.0
300-400	2.27	44	9.5	418.0	.95	41.80	7.2	316.8
400-500	2.32	43	11.6	498.8	1.08	46.44	8.6	369.8
500-600	2.38	42	13.7	575.4	1.22	51.24	10.2	428.4
600-700	2.35	43	15.4	662.2	1.35	58.05	11.4	490.2
700-800	2.25	44	16.8	739.2	1.45	63.80	12.4	545.6
800-850	2.20	23	17.9	411.7	1.55	35.65	13.2	303.6
Total	--	340	--	3,853.3	--	371.52	--	2,885.6

Source: National Academy of Sciences--National Research Council, Nutrient Requirements of Beef Cattle (Publication 1137. Washington: National Academy of Sciences Printing Office, 1966), p. 2.

TABLE 44

ESTIMATED COSTS AND RETURNS FROM A 15,000 EWE FLOCK IN DRYLOT

Item	Unit	Quantity	Price	Amount
Receipts				
Lambs (17,412 @100 lbs.)	cwt.	17,412	$23.00	$400,476.00
Cull ewes (3,000 @140 lbs.)	cwt.	4,200	7.08	29,736.00
Wool (9 lbs. per ewe)	Lb.	135,000	.55	74,250.00
Total				$504,462.00
Expenses				
Variable-Ewe Flock				
Electricity				$ 900.00
Telephone				309.75
Veterinary and medicine	Head	15,000	$ .75	11,250.00
Gas, oil and grease	Head	15,000	.11	1,650.00
Labor	Hour	45,000	.25	11,250.00
Breeding charge	Head	15,000	1.50	22,500.00
Replacement cost	Head	3,750		27,447.35
Insecticides	Head	15,000	.20	3,000.00
Feed manufacturing	Ton	1742.5	3.31	5,767.68
Feed additives	Ton	1742.5	2.22	3,868.35
Miscellaneous (5% x variable expenses)				4,397.16
Interest (10% for 4 months)				3,078.01
Total				$ 95,418.30
Variable-Lamb Feeding				
Electricity				$ 864.40
Telephone				133.77
Veterinary and medicine	Head	17,412	.40	6,964.80
Gas, oil and grease				903.92
Labor	Hour	8,706	.25	2,176.50
Insecticides				2,593.20
Feed manufacturing	Ton	2013.4	3.31	6,664.35
Feed additives	Ton	2013.4	2.22	4,469.75
Miscellaneous (5% x variable expenses)				1,238.53
Interest (10% for 2.5 months)				540.99
Total				$ 26,550.21

TABLE 44 (continued)

Item	Unit	Quantity	Price	Amount
Fixed-Ewe Flock				
Capital recovery				$ 32,343.00
Insurance				2,651.00
Repairs				5,563.00
Total				$ 40,557.00
Fixed-Lamb Feeding				
Capital recovery				$ 7,831.00
Insurance				611.00
Repairs				1,350.00
Total				$ 9,792.00
Total variable expenses				$121,968.51
Total fixed expenses				$ 50,349.00
Total expenses				$172,317.51
Other requirements				
Water	Gallon	26,775,924		
Feed nutrients:				
Total digestible nutrients	000 lbs.	21,492.4		
Digestible protein	000 lbs.	1,986.8		
Dry matter	000 lbs.	36,260.4		

TABLE 45

ESTIMATED COSTS OF PRODUCING 3,750 REPLACEMENT EWES PER YEAR

Item	Unit	Quantity	Price	Amount
Expenses				
Variable				
Electricity				$ 422.81
Telephone				65.10
Veterinary and medicine				3,843.75
Gas, oil and grease				394.62
Labor	Hour	7,500	$ .25	1,875.00
Breeding charge	Head	3,750	1.50	5,625.00
Insecticides				1,153.12
Feed manufacturing	Ton	675.2	3.31	2,234.91
Feed additives	Ton	675.2	2.22	1,498.94
Miscellaneous (5% x variable expenses)				855.66
Interest (10% for 11 months)				1,647.21
Total				$19,616.12
Fixed				
Capital recovery				$ 6,263.23
Insurance				488.68
Repairs				1,079.32
Total				$ 7,831.23
Total expenses				$27,447.35
Other requirements				
Water	Gallon	5,092,500		
Feed nutrients:				
Total digestible nutrients	000 lbs.	4,475.6		
Digestible protein	000 lbs.	476.4		
Dry matter	000 lbs.	8,102.3		

TABLE 46

ESTIMATED INITIAL INVESTMENT AND ANNUAL FIXED EXPENSES FOR 15,000 EWES IN DRYLOT

Item	Cost[a]	Life	Capital Recovery[b]	Insurance[c]	Repairs[d]	Total
	(Dollars)	(Years)	- - - - - - - -	- - - - Dollars	- - - -	- - - -
Feed yards	57,788	20	6,788	578	1,156*	8,522
Feed storage bins	25,875	20	3,039	259	518*	3,816
Lambing quarters	51,750	20	6,078	518	1,035*	7,631
Lambing pens	34,500	20	4,052	345	690*	5,087
Lamb creep feeders	34,500	20	4,052	345	690*	5,087
Foot baths and dipping vats	5,175	20	608	52	104*	764
Loading chutes	1,265	20	149	13	25*	187
Livestock scales (10 ft. x 25 ft.)	2,012	30	213	20	40*	273
Truck scales (10 ft. x 60 ft.)	13,570	30	1,440	136	271*	1,847
Office	6,095	20	716	61	122*	899
Waterers (500)	5,750	10	936	58	115*	1,109
Sprayer (200 gal.)	805	15	106	8	24**	138
Sprinkler system	6,900	15	907	69	207**	1,183
Feeding truck with feeder	10,350	8	1,940	104	310**	2,354
Tractor and scoop (40 h.p.)	6,785	12	996	68	204**	1,268
Electric hand shearers (30)	1,725	8	323	17	52**	392
Total	264,845		32,343	2,651	5,563	40,557

[a]Cost in United States, 1969, plus 15 percent. [b]Based on interest at 10 percent.
[c]Initial cost times 1 percent.
[d]Initial cost times 2 percent (*) or initial cost times 3 percent (**).

TABLE 47

ESTIMATED INITIAL INVESTMENT AND ANNUAL FIXED EXPENSES FOR LAMBS AND REPLACEMENT EWES IN DRYLOT

Item	Cost[a]	Life	Capital Recovery[b]	Insurance[c]	Repairs[d]	Total
	(Dollars)	(Years)	- - - - - - - - - - - Dollars	- - - - - - - - - - -		
Feed yards	44,400	20	' 5,215	444	888*	6,547
Feed storage bins	29,821	20	3,503	298	596*	4,397
Foot baths and dip vats	5,964	20	701	60	119*	880
Loading chutes	1,265	20	149	13	25*	187
Livestock scales (10 ft. x 25 ft.)	2,012	30	213	20	40*	273
Office	6,095	20	716	61	122*	899
Waterers (576)	6,624	10	1,078	66	132*	1,276
Sprayer (200 gal.)	805	15	106	8	24**	138
Sprinkler system	7,952	15	1,045	80	239**	1,364
Tractor and scoop (40 h.p.)	6,785	12	996	68	204**	1,268
Feeding truck with feeder	10,350	8	1,940	104	310**	2,354
Total	122,073		15,662	1,222	2,699	19,583

[a]Cost in United States, 1969, plus 15 percent.

[b]Interest at 10 percent.

[c]Initial cost times 1 percent.

[d]Initial cost times 2 percent (*) or initial cost times 3 percent (**).

TABLE 48

NUTRITIONAL ALLOWANCES PER EWE IN THE DRYLOT WITH THE ACCELERATED LAMBING PROGRAM

Function	Days Per Year	Pounds Per Day: Dry Matter	Digestible Protein	Total Digestible Nutrients
Dry and early gestation	197	3.1	0.15	1.7
Late gestation	63	4.1	0.20	2.4
Lactation	105	5.0	0.24	3.1
Total average daily requirement		3.82	0.18	2.22
Total annual requirement		1394.0	67.35	811.6

Source: National Academy of Sciences--National Research Council, Nutrient Requirements of Sheep (Publication 1193. Washington: National Academy of Sciences Printing Office, 1964), pp. 2-3.

TABLE 49

NUTRITIONAL ALLOWANCES PER HEAD FOR LAMBS AND REPLACEMENT EWES

Weight	Daily Gain	Days Required	Dry Matter		Digestible Protein		Total Digestible Nutrients	
			Daily	Total	Daily	Total	Daily	Total
(Pounds)	(Pounds)		-----------	-----------	Pounds	-----------	-----------	-----------
Replacements								
40-60	.30	67	2.20	147.4	.15	10.05	1.50	100.50
60-80	.25	80	2.70	216.0	.16	12.80	1.55	124.00
80-100	.17	118	3.00	354.0	.17	20.06	1.65	194.70
100-120	.10	200	3.20	640.0	.18	36.00	1.70	340.00
120-135	.07	214	3.30	748.2[a]	.20	44.90[a]	1.75	403.90[a]
Total	--	679	--	2,105.6	--	123.81	--	1,163.10
Lambs								
40-60	.35	57	2.2	125.4	.17	9.69	1.40	79.80
60-80	.40	50	2.7	135.0	.19	9.50	1.80	90.00
80-100	.45	44	3.3	145.2	.20	8.80	2.30	101.20
Total	--	151	--	405.6	--	27.99	--	271.00

[a]Includes additional pregnancy allowances.

Source: National Academy of Sciences--National Research Council, Nutrient Requirements of Sheep (Publication 1193. Washington: National Academy of Sciences Printing Office, 1964), pp. 2-3.

TABLE 50

ESTIMATED ANNUAL COSTS AND RETURNS FROM BROILER PRODUCTION
(4.5 BROODS OF 20,000 EACH)

Item	Unit	Quantity	Price	Amount
Receipts				
Broilers (83,808 birds @3.5 lbs.)	Lb.	293,328	$ .195	$57,198.96
Expenses				
Variable				
Electricity	000 birds	90	2.25	$ 202.50
Telephone				57.20
Vaccines and drugs	000 birds	90	20.00	1,800.00
Labor	Hour	2,250	.25	562.50
Insecticides and bulbs	000 birds	90	1.00	90.00
Litter	Ton	45	6.28	282.60
Chicks	Bird	90,000	.07	6,300.00
Fuel	000 birds	90	6.00	540.00
Feed trays and paper	000 birds	90	2.50	225.00
Purchased feed	Ton	129.17		15,650.55
Feed manufacturing	Ton	340.2	3.31	1,126.06
Feed additives	Ton	340.2	3.28	1,115.86
Miscellaneous (5% x variable expenses)				1,397.61
Interest (10% for 1 month)				244.58
Total				$29,594.46
Fixed				
Capital recovery				$ 5,250.00
Insurance				378.00
Repairs				1,039.00
Total				$ 6,667.00
Total expenses				$36,261.46
Other requirements				
Water	Gallon	244,309		
Wheat	Ton	200.72		

TABLE 51

ESTIMATED INITIAL INVESTMENT AND ANNUAL FIXED EXPENSES FOR BROILERS
(20,000 BIRDS STARTED TIMES 4.5 BROODS PER YEAR)

Items	Cost[a]	Life	Capital Recovery[b]	Insurance[c]	Repairs[d]	Total
	(Dollars)	(Years)	- - - - - - - - - -	- - - Dollars	- - - - - - - - - -	- - - - -
House (40 ft. x 500 ft.)	28,750	16	3,675	288	719*	4,682
Hanging feeders	1,233	8	231	12	31*	274
Automatic waterers	1,240	8	232	12	62**	306
Bulk bins	2,300	16	294	23	58*	375
Chick fountain	288	4	91	3	7*	101
Track and carrier (500 ft.)	469	16	60	5	12*	77
Fans (15)	1,121	4	354	11	28*	393
Gas brooders (30)	2,450	16	313	24	122**	459
Total	37,851		5,250	378	1,039	6,667

[a]Cost in United States, 1969, plus 15 percent.

[b]Interest at 10 percent.

[c]Initial cost times 1 percent.

[d]Initial cost times 2.5 percent (*) or initial cost times 5 percent (**).

TABLE 52

ESTIMATED ANNUAL COSTS AND RETURNS FROM A 20,000 HEN FLOCK

Item	Unit	Quantity	Price	Amount
Receipts				
Eggs	Dozen	360,000	$ .38	$136,800.00
Cull hens (16,490 @4 lbs.)	Lb.	65,960	.065	4,287.40
Total				$141,087.40
Expenses				
Variable				
Electricity	000 hens	20	$20.00	$ 400.00
Telephone				87.26
Medication	000 hens	20	20.00	400.00
Lubricants	000 hens	20	4.50	90.00
Labor	Hour	5,000	.25	1,250.00
Replacement pullets	Bird	20,000		20,054.67
Disinfectants	000 hens	20	30.00	600.00
Egg detergent	000 hens	20	15.00	300.00
Litter	Ton	90	6.28	565.20
Purchased feed	Ton	187.42		19,716.88
Egg cases and light bulbs				150.00
Feed manufacturing	Ton	765	3.31	2,532.15
Feed additives	Ton	765	4.98	3,809.70
Miscellaneous (5% x variable expenses)				2,497.79
Interest (10% for 3 months)				1,311.34
Total				$ 53,764.99
Fixed				
Capital recovery				$ 8,380.00
Insurance				583.00
Repairs				1,496.00
Total				$ 10,459.00
Total expenses				$ 64,223.99
Other requirements				
Water	Gallon	684,259		
Wheat	Ton	650.74		

TABLE 53

ESTIMATED COSTS OF PRODUCING 40,000 REPLACEMENT PULLETS PER YEAR

Item	Unit	Quantity	Price	Amount
Expenses				
Variable				
Electricity				$ 225.40
Telephone				53.82
Vaccines				1,739.16
Labor	Hour	2,538	$ .25	634.50
Chicks	Chick	43,479	.35	15,217.65
Fuel				260.87
Litter	Ton	52	6.28	326.56
Feed trays and paper	000 birds	40	2.70	108.00
Purchased feed	Ton	94.13		7,628.58
Insecticides and light bulbs				104.35
Feed manufacturing	Ton	375.66	3.31	1,243.43
Feed additives	Ton	375.66	7.79	2,926.39
Miscellaneous (5% x variable expenses)				1,523.44
Interest (10% for 2.3 months)				613.19
Total				$32,605.34
Fixed				
Capital recovery				$ 5,977.00
Insurance				378.00
Repairs				1,149.00
Total				$ 7,504.00
Total expenses				$40,109.34
Other requirements				
Water	Gallon	269,774		
Wheat	Ton	268.73		

TABLE 54

ESTIMATED INITIAL INVESTMENT AND ANNUAL FIXED EXPENSES FOR A 20,000 HEN LAYING FLOCK

Item	Cost[a]	Life	Capital Recovery[b]	Insurance[c]	Repairs[d]	Total
	(Dollars)	(Years)	- - - - - - - - - - -	- - Dollars - -	- - - - - - - - - -	
Lay house (40 ft. x 650 ft.)	37,375	16	4,777	374	934*	6,085
Egg room	3,220	16	412	32	80*	524
Egg room equipment	3,450	8	647	34	86*	767
Nests (200 metal - 20 hole)	5,175	16	661	52	129*	842
Feeders	2,760	8	517	28	69*	614
Waterers (automatic)	1,610	8	302	16	80**	398
Track and carrier (650 ft.)	690	16	88	7	17*	112
Bulk bins	2,300	8	431	23	58*	512
Fans (20)	1,495	4	472	15	37*	524
Egg baskets	230	4	73	2	6*	81
Total	58,305		8,380	583	1,496	10,459

[a]Cost in United States, 1969, plus 15 percent.

[b]Interest at 10 percent.

[c]Initial cost times 1 percent.

[d]Initial cost times 2.5 percent (*) or initial cost times 5 percent (**).

TABLE 55

ESTIMATED INITIAL INVESTMENT AND ANNUAL FIXED EXPENSES FOR REPLACEMENT PULLETS
(20,000 BIRDS TIMES TWO BROODS PER YEAR)

Item	Cost[a]	Life	Capital Recovery[b]	Insurance[c]	Repairs[d]	Total
	(Dollars)	(Years)	- - - - - - - - - - -	- - Dollars - -	- - - - - - - - - - -	
House (40 ft. x 550 ft.)	31,625	16	4,042	275	791*	5,108
Gas brooders (30)	2,694	16	344	27	135**	506
Fans (16)	1,196	4	377	12	30*	419
Feeders	1,695	8	318	17	42*	377
Bulk feed bins	2,530	8	474	25	63*	562
Waterers (automatic)	1,364	8	256	14	68**	338
Chick fountains (400)	316	4	100	3	8*	111
Debeakers (2)	69	8	13	1	2*	16
Track and carrier	413	16	53	4	10*	67
Total	41,902		5,977	378	1,149	7,504

[a] Cost in United States, 1969, plus 15 percent.

[b] Interest at 10 percent.

[c] Initial cost times 1 percent.

[d] Initial cost times 2.5 percent (*) or initial cost times 5 percent (**).

TABLE 56

POULTRY DIETS FORMULATED FOR LAYERS, BROILERS AND REPLACEMENT PULLETS IN THE AGRO-INDUSTRIAL COMPLEX

	Type of Ration in Percent			
			Replacement Pullet	
Feed Ingredient	Broiler	Layer	0-7 Weeks	8-20 Weeks
Wheat	59.00	67.50	65.00	73.00
Soybean oil meal	27.47	17.00	27.00	16.00
Fish meal	5.00	2.50	2.50	2.50
Alfalfa meal	2.50	5.00	2.50	5.00
Yellow grease	3.00	--	--	--
Ground limestone	1.20	5.75	0.67	1.17
Rock phosphate	1.00	1.50	1.50	1.50
Salt	.40	.50	.50	.50
Manganese sulfate	.02	.02	.02	.02
Coccidiostat	+	--	+	+
Methionine	.10	--	--	--
Vitamin mix	.31	.23	.31	.31
Total	100.00	100.00	100.00	100.00

APPENDIX C

OBJECTIVE FUNCTION VALUES

TABLE 57

OBJECTIVE FUNCTION VALUES PER UNIT OF EACH CROP AND LIVESTOCK ACTIVITY

Activity	Water Application Level	Unit	Objective Function Values Per Unit					
			Employment[a]	Investment	Foreign Exchange	Calories[b]	Protein[c]	Annual Income
Wheat	1	Acre	12.3	$ 92	$ -68	--	--	$ -70
Wheat	2	Acre	12.1	87	-65	--	--	-67
Wheat	3	Acre	11.5	79	-61	--	--	-63
Wheat feed	1	Acre	12.3	92	-68	--	--	-70
Wheat feed	2	Acre	12.1	87	-65	--	--	-67
Wheat feed	3	Acre	11.5	79	-61	--	--	-63
Wheat sell	-	Ton	--	--	279	2,958	106	60
Wheat by-products	-	Ton	2.4	10	-36	-581	-33	-27
Wheat straw harvest	-	Ton	1.3	6	-5	--	--	-3
Corn	1	Acre	32.5	112	-80	14,211	441	99
Corn	2	Acre	31.2	106	-76	13,106	406	87
Corn	3	Acre	29.3	98	-72	11,596	360	73
Corn feed	1	Acre	32.5	112	-80	--	--	-99
Corn feed	2	Acre	31.2	106	-76	--	--	-95
Corn feed	3	Acre	29.3	98	-72	--	--	-89
Corn silage	1	Acre	22.4	147	-127	--	--	-158
Cotton	1	Acre	136.0	86	1,343	2,007	271	189
Cotton	2	Acre	132.0	85	1,294	1,936	261	180
Cotton	3	Acre	124.0	83	1,195	1,799	242	162
Cottonseed meal	-	Ton	1.8	8	-80	-1,660	-568	-63
Peanuts	1	Acre	26.8	114	119	7,472	364	141
Peanuts	2	Acre	26.8	111	110	7,098	346	130
Peanuts	3	Acre	26.0	106	98	6,613	322	116
Peanut meal	-	Ton	1.8	10	-86	-1,611	-182	-66
Peanut hay	-	Ton	3.9	18	-12	--	--	-9

TABLE 57 (continued)

Activity	Water Application Level	Unit	Objective Function Values Per Unit: Employment[a]	Investment	Foreign Exchange	Calories[b]	Protein[c]	Annual Income
Grapefruit	1	Acre	445.0	$2,101	$4,331	4,550	42	$ 299
Oranges	1	Acre	390.0	2,101	199	7,128	112	365
Citrus pulp	-	Ton	3.0	21	-28	--	--	-18
Spring potatoes	1	Acre	169.4	590	-391	12,053	521	187
Winter potatoes	1	Acre	156.0	394	1,649	7,533	325	169
Potato meal	-	Ton	3.6	25	-34	--	--	-25
Tomatoes	1	Acre	523.8	214	423	4,940	181	232
Tomato pulp	-	Ton	5.7	40	-48	--	--	-39
Broad beans	1	Acre	25.6	127	-89	5,229	356	76
Dry beans	1	Acre	24.6	116	-99	4,614	315	123
Onions	1	Acre	283.1	559	2,093	5,212	159	212
Cantaloupes	1	Acre	310.0	535	1,552	1,224	22	257
Alfalfa hay	1	Acre	37.2	176	-184	--	--	-116
Eggs	-	100 Hens	31.3	434	2,569	1,777	310	384
Broilers	-	100 Broilers	2.5	42	198	88	23	23
Milk	-	Cow	52.5	843	2,537	3,540	315	510
Beef	-	Animal	3.0	38	890	551	50	154
Sheep	-	Ewe	4.1	56	126	62	6	22

[a]Man-hours.

[b]In thousands.

[c]In pounds of effective protein.

TABLE 58

CALORIE AND PROTEIN YIELD FROM CROP PRODUCTS

Crop	Water Application Level	Calories Per Pound	Calories Per Acre (Thousands)	Protein Grams Per Pound	Protein NPU[a] Value	Protein Effective Protein Per Acre (Pounds)
Wheat	1	1479	8874	46.3	52	318.3
Wheat	2	1479	8342	46.3	52	299.4
Wheat	3	1479	7330	46.3	52	263.0
Corn	1	1579	14211	40.4	55	440.9
Corn	2	1579	13106	40.4	55	406.5
Corn	3	1579	11596	40.4	55	359.8
Cotton[b]	1	4010[c]	2007	195.0[d]	66	270.7
Cotton[b]	2	4010[c]	1936	195.0[d]	66	261.2
Cotton[b]	3	4010[c]	1799	195.0[d]	66	242.5
Peanuts	1	1868	7472	86.1	48	364.4
Peanuts	2	1868	7098	86.1	48	346.1
Peanuts	3	1868	6613	86.1	48	322.5
Dry beans	1	1538	4614	101.2	47	314.6
Broad beans	1	1538	5229	101.2	47	356.5
Potatoes[e]	1	279	12053	7.7	71	520.7
Potatoes[f]	1	279	7533	7.7	71	325.4
Tomatoes	1	95	4940	4.5	35	180.6
Onions	1	157	5212	6.2	35	158.7
Cantaloupes	1	68	1224	1.6	35	22.2
Oranges	1	162	7128	3.3	35	112.0
Grapefruit	1	91	4550	1.1	35	42.4

[a]Net protein utilization in percentage terms.
[b]Values given for cottonseed flour and oil.
[c]Oil and flour.
[d]Flour value only.
[e]Spring potatoes.
[f]Winter potatoes.

Source: B. K. Watt and others, Composition of Foods, Agricultural Research Service, United States Department of Agriculture, Handbook No. 8 (Washington: Government Printing Office, 1963), pp. 68-121.

TABLE 59

CALORIE AND PROTEIN YIELDS FROM LIVESTOCK PRODUCTS

Product	Calories: Per Pound	Calories: Per Unit (Thousands)	Protein: Grams Per Pound	Protein: Kilograms Per Unit	Protein: NPU[a] Value	Protein: Effective Protein Per Unit (Pounds)
Chicken[b]	270	79,199	40.5	11,880	80	20,952
Egg[c]	658	355,320	52.1	28,134	100	62,024
Beef[d]	1228	8,266,896	62.7	422,096	80	744,442
Lamb[e]	1099	928,086	57.4	48,473	80	85,491
Milk[f]	295	1,062,000	15.9	57,240	75	94,643

[a]Net protein utilization in percentage terms.

[b]Values given for fryers, live weight, over 2.5 pounds, dressing 72 percent of liveweight.

[c]Values for raw, whole, fresh eggs of all sizes with average weight assumed to be 24 ounces per dozen.

[d]Values for raw carcass with bone and fat with dressed weight 55 percent of live weight, USDA grade good, composed of 56 percent lean, 28 percent fat, and 16 percent refuse.

[e]Values given for raw carcass with bone and fat, USDA grade good, composed of 57 percent lean, 25 percent fat, and 18 percent bone, dressing 48.5 percent of live weight.

[f]Assuming 3.5 percent butterfat, fluid, pasteurized and raw.

Source: B. K. Watt and others, Composition of Foods, Agricultural Research Service, United States Department of Agriculture, Handbook No. 8 (Washington: Government Printing Office, 1963), pp. 68-121.

TABLE 60

ESTIMATED PERCENTAGE OF INVESTMENT AND VARIABLE COSTS IN CROP PRODUCTION REQUIRING FOREIGN EXCHANGE

Item	Percent Foreign Exchange
Basic Machinery	10
Specialized Machinery[a]	100
Storage Facilities	5
Seed	0-20
Fertilizer	5
Chemicals	50
Machinery Operations[b]	7
Electrical Power	60

[a]Primarily harvesting equipment.

[b]Includes lubricants and repair parts.

TABLE 61

ESTIMATED PERCENTAGE OF INVESTMENT AND VARIABLE COSTS IN LIVESTOCK PRODUCTION REQUIRING FOREIGN EXCHANGE

Item	Percent Foreign Exchange
Basic machinery and equipment	10
Dairy buildings	10
Poultry houses	8
Furnished offices	25
Egg room	5
Egg room equipment	50
Electric fans	0
Gas brooders	20
Automatic waterers	100
Chick fountains	0
Track and carrier	50
Truck and livestock scales	100
Bulk milk tank	50
Specialized milking equipment	75
Livestock sprayers	50
Electric motors	100
Miscellaneous specialized equipment	100
Initial investment in dairy cows, ewes and laying hens	100
Electric power	60
Telephone	25
Vaccines and medication	0
Natural gas	0
Disinfectants	0
Insecticides	20
Gas, oil, and grease	10
Egg detergent	0
Feed trays and paper	50
Calf nipples	0
Dairy supplies	25
Artificial insemination	35
Broiler and layer chicks	20
Milk replacer	20
Feed additives	7
Feed manufacturing	31

TABLE 62

ESTIMATED INITIAL INVESTMENT REQUIRED
PER UNIT OF LIVESTOCK

Livestock Enterprise	Basis	Unit	Buildings and Equipment	Animals	Total
Sheep	Ewe	15,000	$413,199	$420,000	$833,199
Dairy	Milk Cow	300	117,936	135,000	252,936
Beef	Animal	15,000	567,007	--	567,007
Broilers	Bird	20,000	37,851	--	37,851
Layers	Layer	20,000	79,256	7,609	86,865

APPENDIX D

MEMBERS OF THE MIDDLE EAST

STUDY GROUP

TABLE 63

MEMBERS OF THE MIDDLE EAST STUDY GROUP AT
OAK RIDGE NATIONAL LABORATORY

Name	Specialty	Employer
J. A. Lane	Director	Oak Ridge National Laboratory
C. C. Burwell	Associate Director	Oak Ridge National Laboratory
L. D. Chapman	Economics	Oak Ridge National Laboratory
C. M. Farmer	Ag. Economics	University of Tennessee
J. F. Fried	Economics	Self-employed
V. W. Glass	Editor	Oak Ridge National Laboratory
H. E. Goeller	Engineering	Oak Ridge National Laboratory
J. L. Gregg	Engineering	Oak Ridge National Laboratory
J. M. Holmes	Engineering	Oak Ridge National Laboratory
D. B. Lloyd	Engineering	Oak Ridge National Laboratory
J. C. Moyers	Engineering	Oak Ridge National Laboratory
C. Nader	Political Science	Oak Ridge National Laboratory
D. Pastir	Engineering	U. S. Department of the Interior
G. Stanhill	Meteorology	Government of Israel
P. R. Stout	Agriculture	University of California
T. Tamura	Soil Science	Oak Ridge National Laboratory
R. C. Woodworth	Ag. Economics	Tennessee Valley Authority
W. C. Yee	Engineering	Oak Ridge National Laboratory

VITA

Charles Martin Farmer was born in Pikeville, Tennessee, on November 2, 1942, the son of Mr. and Mrs. Howard Farmer. He attended elementary school in that city and was graduated from Bledsoe County High School in 1960. In June, 1961, he entered Tennessee Technological University. Requirements for a Bachelor of Science degree in Agricultural Economics were completed in March, 1965, and the degree was conferred the following June. He was graduated with Distinction.

In September, 1965, he entered the Graduate School of the University of Tennessee where he was awarded a National Defense Education Act Fellowship in the Agricultural Economics Department. He received his Master of Science degree in Agricultural Economics from the University of Tennessee in December, 1967. In December, 1968, he became a candidate for the Doctor of Philosophy degree in Agricultural Economics and is presently engaged in fulfilling the necessary requirements for this degree. His major area of concentration was in Production Economics and Farm Management, with minors in Economic Theory and General Agricultural Economics. He is a member of Phi Kappa Phi, Gamma Sigma Delta, Delta Tau Alpha, and Alpha Gamma Sigma.

He is married to the former Flora Mae Fields of Pikeville, Tennessee, and they are the parents of a son.