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Evaluation of Resource Use and Economic Effects Due to Irrigation Water Availability in Texas

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Texas A&M University

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EVALUATION OF RESOURCE USE AND ECONOMIC EFFECTS
DUE TO IRRIGATION WATER AVAILABILITY IN TEXAS

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ABSTRACT

The State of Texas has been actively developing a State Water Plan which is to become a basic guide for water development in Texas through the year 2020. The availability of water to agriculture in the future and its effect on the Texas economy is of utmost importance to Texans.

Potential agricultural resource requirements are dependent on numerous and diverse factors. Some of these factors are known and measurable such as the water needs of growing plants. Other factors are unknown and remain subject to conjecture. Future agricultural price and production control programs are unknown and can only be hypothesized. These factors and others are important to water requirements of agriculture and must be dealt with by measurement or estimation.

This research was initiated to develop meaningful projections of agricultural water requirements which would be useful in planning for water resource development. Five different models of agricultural resource requirements and production were analyzed. Each model contains: (1) restrictions on production and marketing of products, (2) assumptions relative to resource availability and use, and (3) estimates of output with the specified use of resources. These models illustrate to the water resource planner the potential of Texas agriculture to produce food and fiber as well as the effects of various restrictions on production. These restrictions include some factors which cannot be controlled, such as market limitations. The models include various assumptions concerning water supply for agriculture and the effects of these assumptions are evident in the results of the analysis.

The results of these models present to the water resource planner the effect on Texas agriculture of alternative allocations of water to agriculture. The procedures and computer programs developed can evaluate for the planner an infinite number of alternatives. Comparison of alternative availability of water to agriculture provides a basis for evaluation of the economic benefit from the allocation of water to agriculture.

KEY WORDS: *Water Resources Planning, *Irrigation, Agricultural Water Requirements, Water Supply, *Resource Economics, Optimum Resource Use, Computer Analysis.

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CHAPTER I

INTRODUCTION

Water is crucial to the economic activity of our state and nation. Most production requires huge quantities of water very much as it requires raw materials or fuel. Availability of water to any area may be critical to its economic development.

Approximately 16 million acre-feet of water were used for municipal, industrial, agricultural and mining purposes in Texas in 1965. Eighty percent of this water was used in irrigation. Agricultural commodities worth $675 million were produced on irrigated land. Production of irrigated crops was the primary basis for economic activity in some areas of the state. Water is thus a major determinant of incomes, employment and the general welfare.

In certain areas, water supplies for irrigation and other uses are declining. There is the prospect of shortages of water at existing costs. Agricultural production may be reduced if no new or additional supplies are found for these areas, and economic and social loss might then be realized.

Texas Water Planning

Texas has been concerned with the adequacy of its water supply for many years. State and federal agencies have developed many water development plans for various areas of the State. The Texas Water Commission developed a plan in 1961 for meeting the 1980 water requirements of Texas. Water planning continued with both the Corps of Engineers and the Bureau of Reclamation developing proposals for water development projects extending beyond the scope of the 1980 study.

In August 1964, Governor John Connally directed that Texas develop a comprehensive water plan which would consider the needs of the State. The Texas Water Commission was to develop this State water plan, and the plan was to consider all previous planning by state and federal water agencies. In October 1964, Governor Connally requested the assistance of Texas A&M University to the Texas Water Commission in the evaluation of the future agricultural water requirements. Since that time, the Texas Legislature has changed the name of the Texas Water Commission to the Texas Water Development Board and changed the authority of this agency to be more compatible with water planning.

In May 1966, the Texas Water Development Board issued a preliminary plan entitled, "Water for Texas--A Plan for the Future." Further investigations and planning by this agency resulted in the release of the "Texas Water Plan" in December 1968. This plan is to be a basic guide for considering federal, state and local water development proposals and to set forth general developments required in the future.

Pursuant to the Governor's 1964 request to Texas A&M University for assistance, a special study committee on future water requirements in Texas agriculture was appointed. This report summarizes some of the results of that special study plus some continued research in the Water Resources Institute at Texas A&M University.

Present Texas Agriculture

In order to delineate Texas agriculture, the following four factors were considered: climatic resources, land resources including soils suitable for irrigation, present production from irrigated and nonirrigated land including grazing and forest land, and the importance of agriculture to the total state economy.

Because of the size and diversity of the state and in order to be consistent with available data, the state was divided into 15 broad regions (Land Resource Areas) of similar physical features and climatic environment. These areas are shown in Figure 1.1. The land resource areas were divided into nine major agricultural land use categories: nonirrigated cropland, irrigated cropland, idle cropland, tame pasture and meadow, open range, brushy range, woodland range, forest lands and other lands. The land resource base was also divided into nine major soil types.

Land use for 1964 was determined by adjusting the 1958 Conservation Needs Inventory (CNI) data to reflect changes which have been revealed by recent surveys and inventories (46).[1] The Economic Research Service (ERS) of United States Department of Agriculture reported "normal" acreages of cropland in 1964 which were used to determine total cropland acres (44). A 1964 inventory of irrigation in Texas by the Soil Conservation Service, in cooperation with the Texas Water Commission, was used to revise the CNI estimates of irrigated cropland (14). The Texas Forest Service's recently updated inventory of timberlands was used to revise the CNI timberlands estimates (42). Major uses of agricultural lands by land resource areas for 1964 are summarized in Table 1.1.

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[1]Numbers in parentheses at the end of sentences refer to references given at the end of the publication.

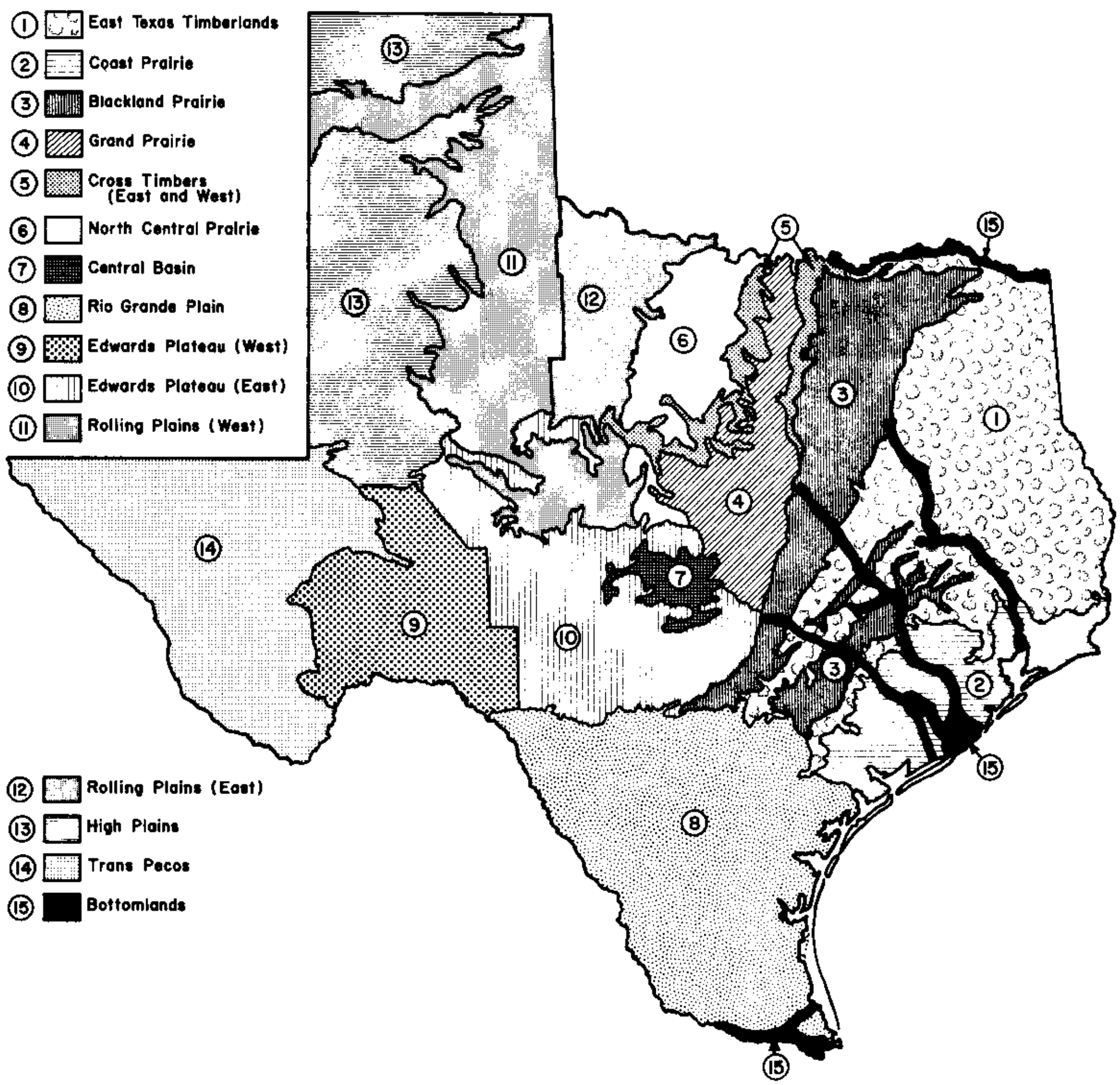

FIGURE 1.1 LAND RESOURCE AREAS OF TEXAS

TABLE 1.1 MAJOR USES OF AGRICULTURAL LANDS BY LAND RESOURCE AREAS, 1964.

Land Resource Areas	Nonirrigated cropland	Irrigated cropland	Idle cropland	Tame pasture & meadow	Open range	Brushy range	Woodland range	Forest land	Other lands	Total
					1,000 Acres					
East Texas Timberlands	2,553.4	21.1	465.5	3,246.8	---	19.2	1,625.4	12,333.3	79.5	20,344.2
Coast Prairie	1,700.4	507.5	433.7	1,215.1	1,399.9	203.8	325.4	492.6	133.8	6,412.2
Blackland Prairies	4,831.4	3.3	668.2	3,418.3	452.2	647.2	1,306.9	1,029.0	35.5	12,392.0
Grand Prairie	1,582.4	0.7	69.8	191.9	3,534.0	2,822.3	1,878.9	575.2	21.7	10,676.9
Cross Timbers (East and West)	864.6	11.6	171.5	208.6	457.2	327.2	506.8	30.6	14.1	2,592.2
North Central Prairies	824.1	9.8	86.8	16.7	1,495.7	2,759.8	494.3	17.6	4.6	5,709.4
Central Basin	98.8	0.2	12.9	---	190.3	988.3	85.9	5.3	0.7	1,382.4
Rio Grande Plain	2,424.0	1,318.9	336.5	57.9	2,643.2	14,571.6	602.8	16.8	39.7	22,011.4
Edwards Plateau (West)	---	15.8	0.5	---	5,620.8	3,287.3	471.0	7.9	3.9	9,407.2
Edwards Plateau (East)	163.9	37.7	37.3	21.0	4,245.1	2,851.3	2,622.5	91.3	20.3	10,090.4
Rolling Plains (East)	1,981.4	75.2	252.0	50.2	1,605.5	3,038.4	83.4	8.2	50.0	7,144.3
Rolling Plains (West)	2,670.5	213.6	369.4	75.2	7,485.2	5,356.2	---	---	34.4	16,204.5
High Plains	4,920.7	5,229.6	578.8	26.5	4,148.1	3,036.6	---	---	82.9	18,023.2
Trans-Pecos	---	379.5	---	---	8,488.2	7,097.5	307.0	40.3	3.4	16,315.9
Bottomlands	439.4	144.5	28.1	551.2	276.7	261.5	45.9	808.0	23.5	2,578.8
TOTALS	25,055.0	7,969.0	3,511.0	9,079.4	42,042.1	47,268.2	10,356.2	15,456.1	548.0	161,285.0

In Texas, data are not available on the production of individual agricultural commodities by land resource areas. Therefore, production for each commodity was obtained by multiplying acres time an estimated yield. Commodity specialists at Texas A&M University developed these estimated yields. The ERS has developed normal total production data for major agricultural commodities for each state. These data were used to normalize the state production data obtained by the yield-acreage calculation.

Data on grazing land production and forest land production were assembled using the best information available and were included in the total agricultural production. Acreage and production of agricultural commodities for 1964 are presented in Table 1.2.

A significant factor in the 1964 production was that, although irrigated cropland was only about 20 percent of the total cropland, the production from irrigation constituted a large portion of the total. Over 63 percent of the cotton production and about 68 percent of the grain sorghum production were from irrigated cropland. All of the citrus and about 65 percent of the vegetable production were from irrigated land.

Texas farmers and ranchers spend about $1.8 billion annually for agricultural production inputs. The value of agricultural production amounted to $2.4 billion. This production was second only to the $3 billion realized from crude oil production. Businesses that process, transport and market agricultural products add an additional $3.9 billion. Thus, in 1964, Texas agriculture contributed about $6.3 billion to the economy of the state.

TABLE 1.2 ACREAGE AND PRODUCTION OF AGRICULTURAL COMMODITIES, TEXAS 1964

Commodities	Acreage (100's) Nonirrigated	Acreage (100's) Irrigated	Acreage (100's) Total	Production Nonirrigated	Production Irrigated	Production Total	Production Unit
Cotton	38,906.9	23,093.2	62,000.1	845.3	1,449.7	2,295.0	Mil. lb.
Rice	---	4,648.7	4,648.7	---	1,445.0	1,445.0	Mil. lb.
Wheat	19,467.3	8,782.6	28,249.9	26,830.0	32,495.5	59,325.5	Thous. bu.
Peanuts	2,530.5	349.5	2,880.0	172.2	58.2	230.4	Mil. lb.
Other oil crops	1,040.0	510.0	1,550.0	1,540.0	1,360.0	2,900.0	Thous. bu.
Vegetables	1,162.0	1,558.0	2,720.0	8,525.0	16,036.6	24,561.6	Thous. cwt.
Other vegetables	---	2,148.3	2,148.3	---	12,606.7	12,606.7	Thous. cwt.
Sweet potatoes	119.5	30.5	150.0	654.8	465.2	1,120.0	Thous. cwt.
Potatoes	---	181.2	181.2	---	2,620.0	2,620.0	Thous. cwt.
Grapefruit	---	495.8	495.8	---	200.0	200.0	Thous. tons
Other citrus fruits	---	361.4	361.4	---	112.4	112.4	Thous. tons
Other fruits and nuts	540.7	81.2	621.9	46.1	11.7	57.8	Mil. lbs.
Other nonfeed crops	1,600.0	257.0	1,857.0	1,295.7	485.5	1,781.2	Thous. bu.
Barley	2,676.3	862.1	3,538.4	3,838.0	3,312.0	7,150.0	Thous. bu.
Oats	7,823.1	604.8	8,427.9	21,402.0	2,348.0	23,750.0	Thous. bu.
Other small grain	2,893.6	206.4	3,100.0	2,483.7	242.4	2,726.1	Thous. bu.
Small grain - pasture	19,336.1	1,213.9	20,550.0	5,176.6	646.0	5,822.6	Thous. AUM
Corn, grain	10,194.0	835.3	11,029.3	26,345.0	6,655.0	33,000.0	Thous. bu.
Corn, silage	370.7	---	370.7	420.0	---	420.0	Thous. tons
Sorghum, grain	35,523.9	25,476.1	61,000.0	81,278.5	174,921.5	256,200.0	Thous. bu.
Sorghum, silage and forage	4,580.5	3,269.5	7,850.0	992.0	1,693.0	2,685.0	Thous. tons
Alfalfa hay	762.7	937.2	1,699.9	148.0	311.0	459.0	Thous. tons
Other tame hay	10,703.2	496.8	11,200.0	1,414.0	121.0	1,535.0	Thous. tons
Other crop pasture	43,451.1	2,268.9	45,720.0	11,531.6	1,371.7	12,903.3	Thous. AUM
Other feed crops	15,912.1	897.9	16,810.0	1,555.6	175.0	1,730.6	Thous. tons
TOTAL	219,594.2	79,566.3	299,160.5				

CHAPTER II

PROJECTIONS OF FUTURE CROP AND LIVESTOCK PRODUCTION IN TEXAS, 1980, 2000, 2020

To determine resource requirements and specifically water requirements for agriculture in Texas requires: (1) projections of the productive capacity of agriculture with varying combinations of resources and (2) projections of market potentials for agricultural products produced in Texas. Admittedly these two necessary projections are closely related, but with them both, it is possible to determine prospective levels of output in future years and resource requirements appropriate to such output.

Productive Capacity

Projections of productive capacity of Texas Agriculture have been produced by teams of agricultural specialists in terms of the capability of the soils employed in agricultural production and the prospective yields of crops grown in the state.

Availability and Capability of Soils. Based on general soil properties in relation to land use capability classes, Texas A&M University and Soil Conservation Service personnel developed a soil grouping in 1958 for the purpose of compiling crop yield and land use data by land resource areas. These soil groups were designated "A" through "I". A study by the Soil Conservation Service (45) developed the acreage of these soil groups by land resource areas, as given in Table 2.1. In Table 2.2 land use in Texas by soil groups have been "normalized" for 1964 based on this same report and on a consensus of the authors from

TABLE 2.1 SOIL GROUP ACREAGES BY LAND RESOURCE AREAS.[1/]

Land Resource Areas	Total Acreage	Soil Classes A	B	C	D	E	F	G	H	I
	- - - -	- - - -	- - - -	- - - -	1,000 Acres	- - - -	- - - -	- - - -	- - - -	- - - -
East Texas Timberlands	20,344.2	492.6	2,424.3	4,770.7	4,378.9	14.6	1,603.2	763.3	2,456.3	3,440.3
Coast Prairie	6,412.2	652.8	3,031.2	1,480.5	260.6	0.1	325.3	14.9	327.2	319.6
Blackland Prairies	12,392.0	225.5	3,211.8	4,421.8	25.2	204.1	628.6	627.7	2,065.4	981.9
Grand Prairie	10,676.9	244.3	204.2	2,168.2	0.3	1,089.9	22.2	135.1	133.9	6,678.8
Cross Timbers (East and West)	2,592.2	86.3	75.8	914.1	775.3	5.1	21.8	157.8	92.4	463.6
North Central Prairies	5,709.4	302.9	344.7	2,277.9	159.4	495.3	64.3	72.1	186.3	1,806.5
Central Basin	1,382.4	21.2	9.2	308.1	142.1	25.3	---	22.5	1.1	852.9
Rio Grande Plain	22,011.4	185.4	1,594.5	10,030.5	2,468.0	844.4	33.3	42.0	1,826.8	4,986.5
Edwards Plateau (West)	9,407.2	398.7	0.5	70.6	---	75.6	---	236.0	1,002.3	7,623.5
Edwards Plateau (East)	10,090.4	3.5	---	1,801.1	---	430.1	---	125.6	298.7	7,431.4
Rolling Plains (East)	7,144.3	300.4	741.0	2,262.1	533.5	802.4	30.6	20.4	128.3	2,325.6
Rolling Plains (West)	16,204.5	---	293.1	3,505.9	2,176.7	1,487.6	410.7	398.8	29.3	7,902.4
High Plains	18,023.2	0.5	4,325.2	4,594.2	5,395.5	797.4	15.6	267.5	20.9	2,606.4
Trans-Pecos	16,315.9	131.9	33.2	1,829.6	299.3	1,254.1	0.5	0.7	174.4	12,592.2
Bottomlands	2,578.8	453.3	56.4	1.113.9	29.1	---	.8	6.2	650.4	268.7
TOTALS	161,285.0	3,499.3	16,345.1	41,549.2	16,643.9	7,526.0	3,156.9	2,890.6	9,393.7	60,280.3
PERCENT OF TOTAL ACREAGE		2.2	10.1	25.8	10.3	4.7	1.9	1.8	5.8	37.4

[1/] Adapted from The Texas Conservation Needs Committee, U.S.D.A. Soil and Water Conservation Needs Inventory. Soil Conservation Service, U.S.D.A., Temple, Texas. 1962.

TABLE 2.2 LAND USE ACREAGES BY SOIL GROUPS, 1964.[1/]

Soil Group	Nonirrigated cropland	Irrigated cropland	Idle cropland	Tame pasture & meadow	Open range	Brushy range	Woodland range	Forest land	Other lands	Total
	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	1,000 Acres	- - - - - -	- - - - - -	- - - - - -	- - - - - -
A	785.4	429.1	74.8	435.1	402.0	739.8	192.7	428.8	11.6	3,499.3
B	5,482.2	2,374.4	875.0	1,968.5	1,561.5	1,485.1	922.4	1,640.6	35.4	16,345.1
C	11,430.7	3,559.5	1,394.6	2,729.3	6,742.1	11,545.0	1,177.9	2,875.1	95.0	41,549.2
D	4,400.3	1,425.7	522.6	757.2	2,528.2	3,700.9	866.1	2,378.0	64.9	16,643.9
E	1,084.7	109.3	137.2	86.9	3,080.1	2,869.2	136.4	11.0	11.2	7,526.0
F	355.2	6.8	86.9	513.6	290.8	430.4	326.0	1,140.4	6.8	3,156.9
G	507.8	25.1	77.4	429.2	687.5	371.4	294.3	469.9	28.0	2,890.6
H	371.3	17.6	79.1	1,134.6	1,238.3	2,587.0	845.2	3,054.1	66.5	9,393.7
I	637.4	21.5	263.4	1,025.0	25,511.6	23,539.4	5,595.2	3,458.2	228.6	60,280.3
TOTALS	25,055.0	7,969.0	3,511.0	9,079.4	42,042.1	47,268.2	10,356.2	15,456.1	548.0	161,285.0

[1/] Adapted from Soil Conservation Service, U.S.D.A. Present Crop Yields, Acreages, and Land Use for River Basins and Land Resource Areas - Texas. Data developed for United States Study Commission - Texas. August 1960.

studying all available reports on the subject.

Soil groups A through D include most of the lands suitable for cultivation. Table 2.1 shows that there are about 75 million acres of soils in these four groups. With a present cropland acreage of approximately 35 million, it is obvious that cropland can be expanded by more than 100 percent if it is needed.

Of the 75 million acres of lands suitable for cultivation, 35 to 40 million acres have been judged to be suitable for irrigation. Present day irrigated acreage is about 7 million, so a five-fold increase in acreage under irrigation is feasible if the products are needed and if water is available.

Soil groups E through I are employed in such extensive uses as grass and tree production. There are approximately 80-90 million acres of land in pastures and forests.

In summary, the total land resource base of suitable quality appears adequate for a very large future expansion of irrigated and nonirrigated agriculture in Texas, even if nonagricultural land uses also expand at a rapid rate.

<u>Crop Yields</u>. Crop yields for the present and future were determined by study of published and unpublished research data of the Texas Agricultural Experiment Station and the Soil Conservation Service, U.S.D.A. Plant and soil science researchers determined trends and probable scientific breakthroughs in the future. Based on these predictions and expected social and economic changes, per acre yield trends of all major crops in the state were estimated by land resource areas for the soil groups shown in Table 2.1.

Figure 2.1 depicts predicted yield trends for selected crops in relation to soil groups. The predictions are based on present-day and predicted normal yields. On the better soils (Groups A to D) under both irrigated and nonirrigated conditions, increases of about 25 to 60 percent over 1964 levels are expected. Although projections of this type must be based on certain assumptions, the indicated levels of increases are reasonable. High yields are possible. The timing of production advances depends on scientific breakthroughs. The yields in this report, while lower than those predicted by some, are judged to be reasonable and appropriate for planning purposes.

Irrigation helps to stabilize yields so it is expected that the relative increase under irriagation will be better than without irrigation. Yields under irrigation will be very much higher than for nonirrigated land in the arid to subhumid western half of the state. Differences in irrigated and nonirrigated yields in the humid part of the state will be considerably less on the average. In humid areas benefit from irrigation may be small for certain crops, depending on the amount and distribution of rainfall.

Yields on soils of lower quality (Groups E to I) are expected to improve but to lesser degree. The tendency will be to return these soils to permanent cover of grass and trees. Some close-growing crops such as feed and food grains and forage will be grown on these soils.

A major change in vegetable yields is probable. Better varieties, more management inputs, mechanical harvesting, and assured markets in the urban complex will be the main factors. In the past, low yields of vegetables often resulted from failure to harvest the crop because no market existed.

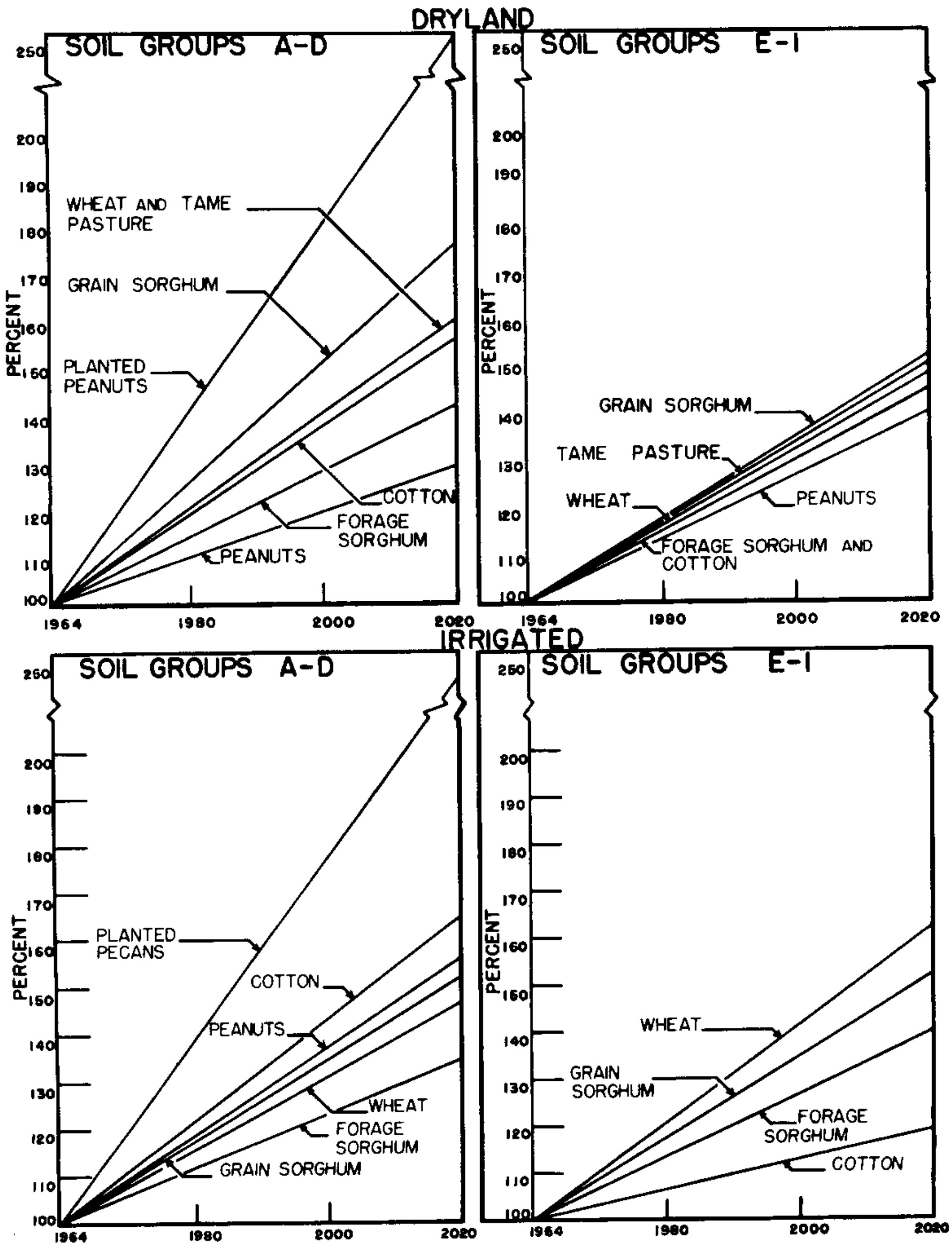

FIGURE 2.1 PREDICTED YIELD TRENDS OF SELECTED CROPS IN RELATION TO SOIL GROUPS

Feed and food grains and forage yields are expected to steadily increase. Improved varieties and more inputs of management will be major factors. The feeds produced will result in more meat per unit of feed since animals and feeding techniques will also improve.

The level of crop yields possible is assumed to be finite, but yields of most crops are likely to increase in the future. Farmers will strive for more precise control of the plant environment--better varieties of crops, improved insect, weed and disease control and improvement in the use of soil moisture.

Market Potentials

Market potentials for agricultural products produced in Texas were projected as Texas' share of United States' food and fiber requirements, 1980-2000-2020 (43). This approach permitted concentration on problems of comparative advantage in the production and marketing of crops and livestock required by the United States and producible in Texas.

Calculation of Texas' shares required consideration of (1) the nature and extent of land resources in the state, (2) water resources including precipitation, surface impoundments and underground water supplies, (3) climatic resources--light, temperature, humidity, etc., (4) labor resources available to agriculture and (5) capital resources as they might be significantly different from those of other areas. To this end an inventory of land used and land capability was accomplished; three different assumptions about water availability in agriculture were made; climatic resources by land resource areas were described; prospects for agricultural labor were investigated; and inquiries were made about capital availability in various areas of the state.

To provide for an adequate base from which to develop projections of Texas' shares of U. S. Food and Fiber requirements 1940-65 data were assembled giving: (1) acreages, yields, and production of crops, and (2) production of livestock and livestock products. Trend lines were fitted to the production data for Texas to provide an indication of direction of change. Texas production was calculated as a percent of U. S. production for each year.

With the physical resource inventories, the analyses of labor and capital resources, and the production data as bases for discussions, the research group consulted with crop and livestock commodity specialists about the competitive positions of Texas agribusinessmen in the production and marketing of import crops. These specialists were asked to review the background information, consider the prospects for economic and technical changes in production and marketing, and then to help develop the estimates of Texas' shares. The effects of three different water supply situations on production were considered. One assumed no further development of Texas water resources. A second assumed the level of development which was deemed likely with the new Texas Water Plan. A third assumed a high level of development, making agricultural water supplies no particular problem in most areas. These varying assumptions about water resource availability led to the development of three sets of projections of product output. The specialists judged that the water is so critical to competitive positions of producers of certain crops, that separate projections of output were necessary for each assumption concerning water availability.

The resulting projections are shown in Tables 2.4 through 2.6. Table 2.3 gives the projections of requirements for farm products in the United States (43).

Table 2.4 gives Texas' shares based on the assumptions of a high level of water resource development. Projections for all crops trend upward, showing the effects that large supplies of water for agriculture could have on competitive positions of agribusinessmen as they produce and market food and fiber crops.

Table 2.5 gives Texas' shares of U. S. requirements based on the assumption of no further water development and declining ground water supplies. Note that Texas' shares drop through time for several crops (wheat, cotton, rice, peanuts, corn, oats, barley and grain sorghums). This decline reflects the generally pessimistic feelings of the specialists relative to the competitive positions of Texas' producers with reduced irrigated acreage. Water appears to be very important to efficient production of any crops grown in the state, especially the important cash crops. Texas' shares of U. S. livestock product requirements were expected to increase moderately except for pork and milk. It was felt that competitive positions with regard to these two products will not improve.

Table 2.6 gives Texas' shares based on the assumptions made about water development according to the preliminary Texas Water Plan of 1966. Shares of U. S. requirements increase for some crops (rice, peanuts, sugar beets, potatoes, vegetables, fruits and nuts), hold steady for

TABLE 2.3 Projected Requirements for Major Farm Products, 1980, 2000, & 2020, United States

Commodity	Unit	Per Capita Utilization	1980[1/] Domestic Require-ments	1980[1/] Net Exports	1980[1/] Total	2000[2/] Domestic Require-ments	2000[2/] Net Exports	2000[2/] Total	2020[3/] Domestic Require-ments	2020[3/] Net Exports	2020[3/] Total
			(mil.)	(mil.)	(mil.)	(mil.)	(mil.)	(mil.)	(mil.)	(mil.)	(mil.)
Livestock Products:[4/]											
Beef and Veal	lbs.	205.93	50,822	-3,170	47,712	68,532	-3,170	65,362	91,225	-3,170	88,055
Lamb and Mutton	lbs.	7.27	1,794	82	1,876	2,420	82	2,502	3,221	82	3,303
Pork	lbs.	98.02	24,192	-86	24,106	32,622	-86	32,536	43,424	-86	43,338
Chickens	lbs.	48.61	11,997	419	12,416	16,177	419	16,596	21,534	419	21,953
Turkeys	lbs.	13.64	3,366	56	3,422	4,539	56	4,595	6,042	56	6,098
Milk	lbs.	570.02	140,681	3,179	143,860	189,704	3,179	192,883	252,520	3,179	255,699
Eggs	no.	307.01	75,769	346	76,115	102,172	346	102,518	136,004	346	136,350
			(thou.)	(thou.)	(thou.)	(thou.)	(thou.)	(thou.)	(thou.)	(thou.)	(thou.)
Crops, Non-feed:											
Wheat	bu.	2.87	707,153	865,005	1,572,158	953,567	865,005	1,818,572	1,269,322	865,005	2,134,327
Cotton	bales	.04	10,366	5,580	15,946	13,978	5,580	19,558	18,606	5,580	24,186
Rice (rough)	cwt.	.13	31,843	49,479	81,322	42,939	49,479	92,418	57,157	49,479	106,636
Flax	bu.	.07	17,629	5,000	22,629	23,772	5,000	28,772	31,643	5,000	36,643
Soybeans	bu.	4.12	1,015,994	349,999	1,365,993	1,370,027	349,999	1,720,026	1,823,684	349,999	2,173,683
Peanuts	lbs.	9.65	2,382,641	50,737	2,433,378	3,212,896	50,737	3,263,633	4,276,782	50,737	4,327,519
Sugar Beets	tons	.26	64,093	-29,713	34,380	86,428	-29,713	56,715	115,047	-29,713	85,334
Potatoes	cwt.	1.46	360,922	2,201	363,123	486,689	2,201	488,890	647,846	2,201	650,047
Sweet Potatoes	cwt.	.07	16,831	2	16,833	22,695	2	22,697	30,210	2	30,212
Vegetables	cwt.	2.36	581,724	1,678	583,402	784,432	1,678	786,110	1,044,181	1,678	1,045,859
Fruits, Citrus	tons	.04	10,366	1,420	11,786	13,978	1,420	15,398	18,606	1,420	20,026
Fruits, Non-citrus	tons	.06	15,053	-3,090	11,963	20,298	-3,090	17,208	27,019	-3,090	23,929
Tree Nuts	lbs.	1.60	395,251	-368	394,883	532,981	-368	532,613	709,466	-368	709,098
			(thou.)	(thou.)	(thou.)	(thou.)	(thou.)	(thou.)	(thou.)	(thou.)	(thou.)
Crops, Feed:[5/]											
Corn for Grain	bu.		229,171	662,420	891,591	309,028	662,420	971,448	411,357	662,420	1,073,777
Oats	bu.		55,528	33,125	88,653	74,880	33,125	108,005	99,675	33,125	132,800
Barley	bu.		7,192	110,425	117,617	9,707	110,425	120,132	12,921	110,425	123,346
Sorghum for Grain	bu.		---	189,263	189,263	---	189,263	189,263	---	189,263	189,263

1/ Population 246.8 million.

2/ Population 332.8 million.

3/ Population 443.0 million.

4/ Live weight requirements.

5/ Includes requirements for human foods and exports; livestock feed requirements are calculated separately from livestock product requirements.

TABLE 2.4 Texas' Share of Projected Requirements for Major Farm Products, United States, with Maximum Water Development in the State, 1980, 2000, & 2020.

Commodity	Unit	1980 Percentage of U. S. Requirements	1980 Texas Requirements	2000 Percentage of U. S. Requirements	2000 Texas Requirements	2020 Percentage of U. S. Requirements	2020 Texas Requirements
			(millions)		(millions)		(millions)
Livestock Products:1/							
Beef and Veal	lbs.	9.80	4,676	9.90	6,471	10.00	8,805
Lamb and Mutton	lbs.	10.00	188	10.00	250	10.00	330
Pork	lbs.	1.20	289	1.10	358	1.00	433
Chickens	lbs.	6.00	745	6.00	996	6.00	1,317
Turkeys	lbs.	6.00	205	6.50	299	7.00	426
Milk	lbs.	2.30	3,309	2.20	4,243	2.10	5,370
Eggs	no.	4.10	2,875	4.15	4,254	4.20	5,727
			(thousands)		(thousands)		(thousands)
Crops, Non-feed:							
Wheat	bu.	5.00	78,608	6.00	109,114	7.00	149,403
Cotton	bales	30.00	4,784	32.50	6,356	35.00	8,465
Rice (rough)	cwt.	28.00	22,770	30.00	27,725	32.00	34,123
Peanuts	lbs.	12.00	292,005	14.00	456,909	16.00	692,403
Other Oil Crops	bu.	1.00	13,886	1.50	26,232	2.00	44,206
Sugar Beets	tons	3.50	1,203	5.00	2,836	6.50	5,547
Potatoes	cwt.	1.50	5,447	1.75	8,556	2.00	13,001
Sweet Potatoes	cwt.	8.00	1,347	9.00	2,043	10.00	3,021
Vegetables	cwt.	12.00	70,008	13.50	106,124	15.00	156,879
Grapefruit	tons	35.00	981	40.00	1,465	45.00	2,144
Other Citrus2/	tons	5.00	449	7.00	821	9.00	1,374
Fruits, Non-Citrus3/	tons	.25	30	.30	52	.35	84
Tree Nuts4/	lbs.	10.00	39,488	11.00	58,587	12.00	85,092
			(thousands)		(thousands)		(thousands)
Crops, Feed:5/							
Corn for Grain	bu.	1.00	8,916	1.50	14,572	2.00	21,475
Oats	bu.	2.00	1,773	2.50	2,700	3.00	3,984
Barley	bu.	1.50	1,764	1.75	1,932	2.00	2,467
Sorghum for Grain	bu.	45.00	85,168	47.50	89,900	50.00	94,631

1/ Live weight requirements.

2/ Oranges and other citrus fruits produced in Texas.

3/ Only peaches and pears considered for Texas.

4/ Only pecans considered for Texas.

5/ Includes Texas' share of U. S. requirements for human foods and exports.

TABLE 2.5 Texas' Shares of Projected Requirements for Major Farm Products, United States, With No Further Water Development in the State, 1980, 2000, & 2020.

Commodity	Unit	1980 Percentage of U. S. Requirements	1980 Texas Requirements	2000 Percentage of U. S. Requirements	2000 Texas Requirements	2020 Percentage of U. S. Requirements	2020 Texas Requirements
			(millions)		(millions)		(millions)
Livestock Products:1/							
Beef and Veal	lbs.	9.80	4,676	9.90	6,471	10.00	8,805
Lamb and Mutton	lbs.	10.00	188	10.00	250	10.00	330
Pork	lbs.	1.20	289	1.10	358	1.00	433
Chickens	lbs.	6.00	745	6.00	996	6.00	1,317
Turkeys	lbs.	6.00	205	6.50	299	7.00	426
Milk	lbs.	2.30	3,309	2.20	4,243	2.10	5,370
Eggs	no.	4.10	2,875	4.15	4,254	4.20	5,727
			(thousands)		(thousands)		(thousands)
Crops, Non-Feed:							
Wheat	bu.	3.80	59,742	3.70	67,287	3.60	76,836
Cotton	bales	25.00	3,986	22.50	4,401	20.00	4,837
Rice (rough)	cwt.	24.00	19,517	23.00	21,256	22.00	23,460
Peanuts	lbs.	10.00	243,338	9.00	293,727	8.00	346,201
Other Oil Crops	bu.	---	---	---	---	---	---
Sugar Beets	tons	---	---	---	---	---	---
Potatoes	cwt.	1.00	3,631	1.00	4,889	1.00	6,500
Sweet Potatoes	cwt.	7.00	1,178	7.00	1,589	7.00	2,115
Vegetables	cwt.	10.00	58,340	10.00	78,611	10.00	104,586
Grapefruit	tons	25.00	701	25.00	916	25.00	1,191
Other Citrus2/	tons	3.00	269	3.00	352	3.00	458
Fruits, Non-Citrus3/	tons	.22	26	.22	38	.22	53
Tree Nuts4/	lbs.	9.00	35,539	9.00	47,935	9.00	63,819
			(thousands)		(thousands)		(thousands)
Crops, Feed5/							
Corn for Grain	bu.	.50	4,458	.45	4,371	.40	4,295
Oats	bu.	1.75	1,551	1.60	1,728	1.50	1,992
Barley	bu.	1.10	1,294	1.00	1,201	.90	1,110
Sorghum for Grain	bu.	40.00	75,705	35.00	66,242	30.00	56,779

1/ Live weight requirements.

2/ Oranges and other citrus fruits produced in Texas.

3/ Only peaches and pears considered in Texas.

4/ Only pecans considered for Texas.

5/ Includes Texas' share of U. S. requirements for human foods and export.

TABLE 2.6 TEXAS' SHARES OF PROJECTED REQUIREMENTS FOR MAJOR FARM PRODUCTS, UNITED STATES, WITH WATER DEVELOPMENT ACCORDING TO PRELIMINARY TEXAS WATER PLAN, 1980, 2000, & 2020.

Commodity	Unit	1980 Percentage of U. S. Requirements	1980 Texas Requirements	2000 Percentage of U. S. Requirements	2000 Texas Requirements	2020 Percentage of U. S. Requirements	2020 Texas Requirements
			(millions)		(millions)		(millions)
Livestock Products:1/							
Beef and Veal	lbs.	9.80	4,676	9.90	6,471	10.00	8,805
Lamb and Mutton	lbs.	10.00	188	10.00	250	10.00	330
Pork	lbs.	1.20	289	1.10	358	1.00	433
Chickens	lbs.	6.00	745	6.00	996	6.00	1,317
Turkeys	lbs.	6.00	205	6.50	299	7.00	426
Milk	lbs.	2.30	3,309	2.20	4,243	2.10	5,370
Eggs	no.	4.10	2,875	4.15	4,254	4.20	5,727
			(thousands)		(thousands)		(thousands)
Crops, Non-Feed:							
Wheat	bu.	4.00	62,886	3.90	70,924	3.80	81,104
Cotton	bales	29.00	4,624	29.00	5,672	29.00	7,009
Rice (rough)	cwt.	25.00	20,330	25.50	23,567	26.00	27,725
Peanuts	lbs.	11.00	267,672	11.75	383,477	12.50	540,940
Other Oil Crops	bu.	.23	3,194	.23	4,022	.23	5,084
Sugar Beets	tons	3.00	1,031	3.80	2,155	4.70	4,011
Potatoes	cwt.	1.00	3,631	1.15	5,622	1.30	8,451
Sweet Potatoes	cwt.	7.00	1,178	7.60	1,725	8.20	2,477
Vegetables	cwt.	10.00	58,340	11.00	86,472	12.00	125,503
Grapefruit	tons	30.00	841	35.00	1,282	40.00	1,906
Other Citrus2/	tons	3.00	269	4.00	469	5.00	763
Fruits, Non-Citrus3/	tons	.22	26	.25	43	.28	68
Tree Nuts4/	lbs.	9.50	37,514	10.40	55,392	11.40	80,837
			(thousands)		(thousands)		(thousands)
Crops, Feed:5/							
Corn for Grain	bu.	.60	5,350	.55	5,343	.50	5,369
Oats	bu.	1.90	1,684	1.90	2,052	1.90	2,523
Barley	bu.	1.10	1,294	1.05	1,261	1.00	1,233
Sorghum for Grain	bu.	40.00	75,705	40.00	75,705	40.00	75,705

1/ Live weight requirements.

2/ Oranges and other citrus fruits produced in Texas.

3/ Only peaches and pears considered for Texas.

4/ Only pecans considered for Texas.

5/ Includes Texas' share of U. S. requirements for human foods and export.

others (cotton, oil crops and oats), and decline for still others (wheat, corn and barley). It was not anticipated that water supply development in the state would significantly affect irrigation in the High Plains, where a problem of declining ground water supplies exists. Importation of water into that area was problematic, so no new supplies were assumed for the purpose of the projections. Acreage of irrigated wheat would probably decline in the High Plains in favor of cotton and grain sorghum as water supplies are reduced. The latter two crops ordinarily produce higher net returns. With careful use of ground water, cotton and grain sorghum production on irrigated land may continue for many years. The increased water supplies of the state were assumed to come from new surface storage and to affect agriculture in the central, south and southwest regions. Irrigation of rice, peanuts, beets, vegetables and fruits would probably be expanded, causing Texas' shares of these crops to be increased in the future. Estimates of Texas' shares of U. S. livestock requirements were constant for all levels of water development. The specialists did not view the changed assumption about water supply as very important to the production of livestock products. It was believed that beef cattle feeding would increase in the future, but this would involve only a diversion of feed grains from traditional cash markets to local feeding enterprises.

The projections of Table 2.6 are probably most useful to researchers, water planners and other interested persons. They are realistic in-so-far as likely water developments are concerned and are therefore more practical guides as to future food and fiber production in Texas.

CHAPTER III

TEXAS AGRICULTURAL LAND AND WATER REQUIREMENTS

Future agricultural water use in Texas depend on numerous and diverse factors. Some of these factors are known and measurable. The water needs of growing plants, for example, are generally well known. Other factors are as yet unknown and some may remain a subject of conjecture. The extent and locations of surface water supplies in future years have not yet been determined, but relevant information about these supplies will be forthcoming. Agricultural price and production control programs for future years are unknown and can only be hypothesized. But all these factors are important to water requirements of agriculture and must be dealt with by measurement, estimation or assumption.

Projections of Land and Water Use

To develop meaningful projections of land and water use which could be helpful in planning for water resources development, five models of agricultural production in Texas were synthesized. Each of these models contains (1) assumptions relative to resource availability, (2) restrictions on production and marketing of products, and (3) estimates of production with projected yields and employment of resources as specified for each model. It was judged that these models would illustrate to the water resource planner the potential of Texas agriculture to produce food and fiber and the effects of resource limitations and production restrictions on total output. Resource limitations include the assumptions within each model about the water supply available to agriculture. Production restrictions include estimates of market shares, which are a function of competitiveness in the product markets.

Projections of land and water use and of production of crops for the periods 1980, 2000 and 2020 are available for each of the first four models (2). However, projections for only the year 2000 are included in this report due to the voluminous data for each projection.

Present Uses of Agricultural Lands. As a starting point in the development of the projections of agricultural production, existing quantities and uses of agricultural lands in Texas were determined and reviewed. The land use data were presented earlier, in Table 1.1, and estimates of crop production for major agricultural commodities in 1964 were shown in Table 1.2. The data in these tables provide a basis from which projections may be made and permit comparisons of future land use and productivity with that of the present.

Restrictions in the First Four Models. For the purpose of the projections, some realistic controls on resource use and productive output were necessary.

The restriction of the 1964 cropping pattern was imposed on land use and agricultural production among the land resource areas of the state. The food and fiber requirements established for Texas were distributed among the 15 land resource areas in proportions relative to 1964 production records. Transfer of these production requirements among land resource areas was not permitted in the models of this study. Within each land resource area, land use and agricultural production was generally based on the 1964 cropping pattern, but each model allowed specified deviations from this rigid restriction.

Changes in the Agricultural Land Base. Reductions over time in lands available to agriculture were imposed on land use inputs of each model. These reductions were designed to account for the anticipated expansion of urban areas and further development of transportation right-of-ways, airports, public outdoor recreation facilities and new public service areas. Final distribution of these reductions in land available to agriculture was proportionate among soil groups in each land use effected. In 1964, there were 161 million acres available for food, fiber and timber production. By 2020, total calculated acreages available declines to 149 million acres.

Model A

The first model which is referred to as Model A, illustrated the maximum physical capacity of agriculture in Texas. No economic or institutional restrictions were placed on production or marketing of products; land resources were employed according to their use-capacities; no limitations were placed on capital or labor resources; and no limitations were placed on water available to agriculture.

This model has not been important to later analyses and therefore its output is not repeated here. Reference to it may be found in an earlier report (2).

Model B

This model was designed to illustrate resource use and product output with water available to all irrigable acres at costs which in the future are the same proportion of production costs as those in agriculture today. The proportions of productive factors in agricultural enterprises are assumed to be unchanging over time and factor cost-product price relationships are held constant. Restrictions on output are introduced in the form of Texas' shares of future national food and fiber requirements. The model is designed to be more realistic than Model A, but still assumes availability of water to all irrigable acres in the state.

The cost of water used in agriculture varies widely over the state and depends on the sources, methods of procurement, and transport requirements. Some farmers pump water from beneath their lands. In these cases, costs are the pumping costs for this resource. Others buy water from authorities and other agencies, then transport it to points of use and apply it. Water costs for them are the delivery prices established by the relevant agency. Costs in all situations vary widely and are difficult to ascertain. It was necessary to rely on personnel of the Agricultural Extension Service, the Agricultural Experiment Station, the water districts, and others for estimates of water costs.

Based on the cost estimates, decisions were made about the economics of irrigated crop production by land resource areas. Farm management specialists, irrigation engineers, agronomists and others studied irrigation in each land resource area and developed judgments about the practicality of irrigation of each crop produced. According to their decisions, lands were allocated to crop production with and without irrigation, and product output was calculated. Normalized yield estimates were used for these calculations.

The restrictions on crop output were introduced in recognition of the very real market limitations for most crops produced in Texas. The restrictions are based on the projections of food and fiber requirements for Texas which are in Table 2.4.

In order to calculate projected livestock products requirements for Texas, the requirements were converted to corn equivalent feed units (43). This was accomplished by multiplying the pounds of requirement for each class of product by a predicted feed conversion efficiency factor which was expressed in corn equivalent feed units. The total corn equivalent feed units for all livestock products was then adjusted downward by subtracting the feed units provided by high protein and by-product feeds. Future requirement projections for each feed crop were based on 1964 feed crop proportions. These projections were then converted back to actual units of measure and combined with human food crop requirements. The future total food, feed and fiber requirements as projected for the year 2000 are shown in Table 3.1.

The land needed to produce future food and feed crops in Texas was determined by: (1) calculation of production requirements, (2) the judgments about irrigation made by the agronomists and engineers, (3) the normalized yields obtained by adjustment of yield estimates, and (4) the lands still available after the requirements of urban and industrial uses had been satisfied.

Water was assumed available wherever there were irrigable soils. However, irrigation was not permitted when such use was determined to be non-economic. Future uses of agricultural lands in Texas under the assumptions of Model B are given in Table 3.2. Irrigated cropland

TABLE 3.1 PROJECTED REQUIREMENTS FOR MAJOR FARM PRODUCTS, 2000, TEXAS (MODEL B)

Commodity	Units	2000
Cotton	Mil. lbs.	3,187.0
Rice	Mil. lbs.	2,772.5
Wheat	Thous. bu.	109,114.0
Peanuts	Mil. lbs.	456.9
Other Oil Crops	Thous. bu.	26,232.0
Vegetables	Thous. cwt.	70,137.0
Other Vegetables	Thous. cwt.	35,987.0
Sweet Potatoes	Thous. cwt.	2,043.0
Potatoes	Thous. cwt.	8,556.0
Grapefruit	Thous. tons	1,465.0
Other Citrus Fruit	Thous. tons	821.0
Other Fruits and Nuts	Mil. lbs.	162.6
Other Nonfeed Crops	Thous. bu.	4,147.0
Barley	Thous. bu.	10,862.0
Oats	Thous. bu.	32,352.0
Other Small Grain	Thous. bu.	3,932.0
Small Grain for Pasture	Thous. AUM	7,229.0
Corn, Grain	Thous. bu.	55,763.0
Corn, Silage	Thous. tons	524.0
Sorghum, Grain	Thous. bu.	409,675.0
Sorghum, Silage and Forage	Thous. tons	3,352.0
Alfalfa Hay	Thous. tons	547.0
Other Tame Hay	Thous. tons	2,010.0
Other Crop Pasture	Thous. AUM	16,105.0
Other Feed Crops	Thous. tons	2,159.0

TABLE 3.2 MAJOR USES OF AGRICULTURAL LAND BY LAND RESOURCE AREAS, 2000
(MODEL B)

Land Resource Areas	Nonirrigated cropland	Irrigated cropland	Idle cropland	Tame pasture & meadow	Open range	Brushy range	Woodland range	Forest land	Other lands	Total
	- - -	- - -	- - -	- - -	1,000 Acres	- - -	- - -	- - -	- - -	- - -
East Texas Timberlands	2,183.2	356.6	22.5	2,688.9	---	19.2	1,625.4	12,333.3	79.5	19,308.6
Coast Prairie	1,462.9	699.3	---	402.2	1,235.7	191.2	302.1	464.6	133.8	4,891.8
Blackland Prairies	3,815.4	542.8	40.7	2,886.1	446.4	641.8	1,277.9	1,021.2	35.4	10,707.7
Grand Prairie	1,326.0	134.7	84.0	128.6	3,393.8	2,699.7	1,774.2	550.2	21.7	10,112.9
Cross Timbers (East and West)	678.4	136.7	86.7	191.2	450.7	319.6	494.6	7.0	14.0	2,378.9
North Central Prairies	524.9	122.5	284.6	8.4	1,475.7	2,710.2	488.3	17.4	4.6	5,636.6
Central Basin	97.7	.9	7.2	---	186.5	968.2	84.1	5.2	.7	1,350.5
Rio Grande Plain	918.2	3,062.1	182.8	28.4	2,518.8	13,642.3	584.3	16.3	39.7	20,992.9
Edwards Plateau (West)	---	17.5	.5	---	5,571.4	3,257.2	466.9	7.8	3.9	9,325.2
Edwards Plateau (East)	131.1	32.5	69.4	14.5	4,244.7	2,851.1	2,622.3	91.3	20.3	10,077.2
Rolling Plains (West)	864.3	794.4	1,397.2	64.6	7,475.9	5,350.2	---	---	34.4	15,981.0
Rolling Plains (East)	530.8	578.1	1,106.7	35.7	1,602.7	3,034.2	83.1	8.2	50.1	7,029.6
High Plains	.0	7,277.6	3,017.7	26.5	4,148.2	3,036.6	---	---	82.9	17,589.5
Trans-Pecos	---	443.3	.3	---	8,361.6	6,999.7	303.9	38.6	3.4	16,150.8
Bottomlands	170.7	279.7	45.6	498.8	276.5	261.5	45.9	808.0	23.5	2,410.2
TOTALS	12,703.6	14,478.7	6,345.9	6,973.9	41,388.6	45,982.7	10,153.0	15,369.1	547.9	153,943.4

TABLE 3.3 ACREAGE AND PRODUCTION OF AGRICULTURAL COMMODITIES, TEXAS 2000
(MODEL B)

Commodity	Acreage (100's) Nonirrigated	Acreage (100's) Irrigated	Acreage (100's) Total	Production Nonirrigated	Production Irrigated	Production Total	Production Unit
Cotton	1,263.6	35,791.1	37,054.7	51.8	3,126.2	3,178.0	Mil. lbs.
Rice	---	5,371.6	5,371.6	---	2,772.5	2,772.5	Mil. lbs.
Wheat	2,687.5	19,608.7	22,296.2	6,950.5	102,163.5	109,114.0	Thous. bu.
Peanuts	1,008.2	1,624.3	2,632.5	73.9	383.0	456.9	Mil. lbs.
Other Oil Crops	7,837.7	3,585.8	11,423.5	13,777.0	12,454.9	26,231.9	Thous. bu.
Vegetables	34.3	3,732.7	3,767.0	357.7	69,779.0	70,136.7	Thous. cwt.
Other Vegetables	---	3,652.2	3,652.2	---	35,986.9	35,986.9	Thous. cwt.
Sweet Potatoes	167.7	43.6	211.3	1,183.7	859.3	2,043.0	Thous. cwt.
Potatoes	---	401.8	401.8	---	8,556.1	8,556.1	Thous. cwt.
Grapefruit	---	2,724.5	2,724.5	---	1,465.0	1,465.0	Thous. tons
Other Citrus Fruit	---	1,758.3	1,758.3	---	821.0	821.0	Thous. tons
Other Fruits and Nuts	102.7	873.5	976.2	13.8	148.8	162.6	Mil. lbs.
Other Nonfeed Crops	2,659.3	382.4	3,041.7	3,016.5	1,130.5	4,147.0	Thous. bu.
Barley	2,363.8	1,417.8	3,781.6	4,177.5	6,684.5	10,862.0	Thous. bu.
Oats	7,958.0	901.2	8,859.2	27,822.7	4,529.2	32,351.9	Thous. bu.
Other Small Grain	2,245.9	846.7	3,092.6	2,704.8	1,227.2	3,932.0	Thous. bu.
Small Grain for Pasture	17,756.4	2,105.0	19,861.4	5,598.1	1,630.9	7,229.0	Thous. AUM
Corn, Grain	11,789.9	1,873.2	13,663.1	37,991.4	17,771.5	55,762.9	Thous. bu.
Corn, Silage	313.1	---	313.1	523.9	---	523.9	Thous. tons
Sorghum, Grain	7,384.6	42,803.9	50,188.5	38,509.3	371,165.4	409,674.7	Thous. bu.
Sorghum, Silage and Forage	1,323.8	3,964.8	5,288.6	574.8	2,777.1	3,351.9	Thous. tons
Alfalfa Hay	433.0	1,165.9	1,598.9	91.3	455.7	547.0	Thous. tons
Other Tame Hay	7,553.9	2,791.0	10,344.9	1,172.2	837.8	2,010.0	Thous. tons
Other Crop Pasture	39,729.1	5,208.1	44,937.2	12,382.7	3,721.9	16,104.6	Thous. AUM
Other Feed Crops	12,423.7	2,159.0	14,582.7	1,667.6	491.4	2,159.0	Thous. tons
TOTAL	127,036.2	144,787.1	271,823.3				

soils and irrigation specialists as follows: "Use Soil Group A until exhausted, then Groups C, B and D until product requirements are satisfied."

Model B has served the purpose of identifying the consequences of further large scale development of water resources allowing water to be made available to agriculture at reasonable costs. The results show that product requirements can be satisfied with less land than is now used if we choose to do so. Water availability and yield increasing technologies can produce this result.

Small differences in state acreages between some of the tables of this section are due to computer round-off error.

Model C

Model C was designed to illustrate resource use and product output with no further development of water resources in Texas. It was assumed that present supplies of surface water would be maintained and that supplies of groundwater would be diminished over time by continued extraction and use throughout the state. Additional increases in demand for municipal and industrial water uses would cause the supplies of both surface and groundwater available to agriculture to be reduced. Projections of water supplies available to agriculture, with no further water resource development for the years 1980, 1990, 2000, 2010, and 2020, were made by the Texas Water Development Board and were used in the model as restrictions on the use of this resource. These projections are given in Table 3.4. Judgments about irrigations of crops in each of the 15 land resource areas, yield estimates for the future, and land resources available to agriculture were also in-

TABLE 3.4 PROJECTED IRRIGATED ACREAGE WITHOUT TEXAS WATER PLAN[1/]
(MODEL C)

Land Resource Areas	1980	1990	2000	2010	2020
		1,000 Acres			
East Texas Timberlands	33.0	41.0	53.9	66.8	79.6
Coast Prairie	462.1	453.2	444.3	435.4	426.5
Blackland Prairies	13.5	19.9	22.9	25.9	28.8
Grand Prairie	0.9	1.1	1.2	1.4	1.5
Cross Timbers (East and West)	11.2	11.2	11.7	12.2	12.7
North Central Prairies	14.1	11.5	10.8	10.1	9.4
Central Basin	0.1	0.0	0.0	0.0	0.0
Rio Grande Plain	1,004.5	844.2	842.1	840.0	838.0
Edwards Plateau (West)	7.6	2.8	2.8	2.8	2.8
Edwards Plateau (East)	51.1	60.3	61.8	63.3	64.7
Rolling Plains (West)	146.6	101.6	94.5	87.4	80.3
Rolling Plains (East)	80.7	81.2	80.6	80.0	79.4
High Plains	5,816.5	4,474.8	3,584.3	2,931.2	2,191.1
Trans-Pecos	289.7	246.9	205.3	163.6	122.0
Bottomlands	164.9	180.7	195.8	210.9	225.9
STATE TOTAL	8,096.5	6,530.4	5,612.0	4,931.0	4,162.7

[1/] Supplied by the Texas Water Development Board for this special study on Water Development for future Texas agriculture.

TABLE 3.5 PROJECTED REQUIREMENTS FOR MAJOR FARM PRODUCTS, 2000, TEXAS (MODEL C)

Commodity	Unit	2000
Cotton	Mil. lbs.	2,200.5
Rice	Mil. lbs.	2,125.6
Wheat	Thous. bu.	67,287.0
Peanuts	Mil. lbs.	293.7
Other Oil Crops	Thous. bu.	---
Vegetables	Thous. cwt.	51,962.0
Other Vegetables	Thous. cwt.	26,649.0
Sweet Potatoes	Thous. cwt.	1,589.0
Potatoes	Thous. cwt.	4,889.0
Grapefruit	Thous. tons	916.0
Other Citrus Fruit	Thous. tons	352.0
Other Fruits and Nuts	Mil. lbs.	123.9
Other Nonfeed Crops	Thous. bu.	2,778.0
Barley	Thous. bu.	10,131.0
Oats	Thous. bu.	31,380.0
Other Small Grain	Thous. bu.	3,754.0
Small Grain for Pasture	Thous. AUM	7,229.0
Corn, Grain	Thous. bu.	45,562.0
Corn, Silage	Thous. tons	524.0
Sorghum, Grain	Thous. bu.	413,725.0
Sorghum, Silage and Forage	Thous. tons	3,352.0
Alfalfa Hay	Thous. tons	574.0
Other Tame Hay	Thous. tons	2,010.0
Other Crop Pasture	Thous. AUM	16,105.0
Other Feed Crops	Thous. tons	2,159.0

fully utilized, the unused share of irrigation was distributed proportionately among other commodities within the soil group which were produced on both irrigated and nonirrigated acreage. On the other hand, irrigated commodity requirements were not always satisfied within the limits of available acres in a soil group. The deficiency of production and the shares of irrigable acres remaining unused were then transferred to the next soil group in which irrigable acreage was still available. When this shift of production requirement and irrigation share was made, priorities of water allocation between commodities were again followed within this soil group. If irrigation acreage shares were fully utilized, and production requirements demanded more acreage than was to be found in the soil group, the nonirrigated commodity requirements were transferred to available acreage in groups C, B, or D until requirements were satisfied or soil limitations were reached.

Projections of the acreages of agricultural land within the specified categories of use which will be needed to produce food and feed crops in the future were determined and are reported in Table 3.6.

Worthy of note in this model is the increased acreage of arable land required to produce food and fiber requirements. Because of the smaller supplies of water available to agriculture due to the assumption of no new water resource development, irrigation in 2000 was reduced to only 5.6 million acres. In Model B, 14.5 million irrigated acres were utilized. To make up for this lower utilization of irrigated acreage in Model C, 27.4 million acres of nonirrigated land were used for crop production in 2000, while only 12.7 million acres were used in

TABLE 3.6 MAJOR USES OF AGRICULTURAL LAND BY LAND RESOURCE AREAS, 2000
(MODEL C)

Land Resource Areas	Nonirrigated cropland	Irrigated cropland	Idle cropland	Tame pasture & meadow	Open range	Brushy range	Woodland range	Forest land	Other lands	Total
	1,000 Acres									
East Texas Timberlands	2,394.1	53.9	72.0	2,731.1	---	19.3	1,625.4	12,333.3	79.5	19,308.6
Coast Prairie	1,571.7	444.3	---	518.4	1,251.8	194.3	306.9	470.4	133.8	4,891.6
Blackland Prairies	4,142.3	22.9	115.5	3,004.3	446.4	641.8	1,277.9	1,021.3	35.4	10,707.8
Grand Prairie	1,439.7	1.2	123.0	129.0	3,386.2	2,694.9	1,766.9	550.2	21.7	10,112.8
Cross Timbers (East and West)	827.2	11.7	66.8	161.4	453.6	323.4	499.3	21.5	14.1	2,379.0
North Central Prairies	667.1	10.8	287.3	9.3	1,466.5	2,687.4	486.4	17.3	4.6	5,636.7
Central Basin	91.6	---	9.0	---	187.8	971.8	84.5	5.2	.7	1,350.6
Rio Grande Plain	3,639.0	842.1	124.6	25.1	2,459.7	13,283.1	564.1	15.7	39.7	20,993.1
Edwards Plateau (West)	---	2.8	9.2	---	5,573.2	3,261.4	466.9	7.8	3.9	9,325.2
Edwards Plateau (East)	125.0	27.8	80.1	14.6	4,244.7	2,851.1	2,622.3	91.3	20.3	10,077.2
Rolling Plains (West)	2,333.4	94.5	708.2	30.4	7,445.9	5,334.3	---	---	34.4	15,981.1
Rolling Plains (East)	1,285.5	80.6	849.4	35.7	1,602.7	3,034.2	83.1	8.2	50.1	7,029.5
High Plains	8,697.3	3,584.3	148.3	17.9	2,386.9	2,671.8	---	---	82.9	17,589.4
Trans-Pecos	---	205.3	134.6	---	8,421.8	7,041.4	304.0	40.3	3.4	16,150.8
Bottomlands	229.3	195.8	70.2	499.5	276.5	261.5	45.9	807.9	23.5	2,410.1
TOTALS	27,443.2	5,578.0	2,798.2	7,176.7	39,603.7	45,271.7	10,133.6	15,390.4	548.0	153,943.5

Model B. It is evident that the availability of water to agriculture is of the utmost importance to land use and crop production.

Production of crops under the assumption and restrictions of Model C is listed in Table 3.7. Comparison of output with that of Model B gives further indication of the effect of the water supply limitation. Production of cotton is down 33 percent, vegetables are down 26 percent, grapefruit is reduced 38 percent, and peanuts are down 35 percent in 2000. This was the effect foreseen by the commodity specialists, who judged that diminished water supplies would seriously affect the competitive positions of Texas producers.

Food and feed requirements in Model C were satisfied in all areas of the state except in the Edwards Plateau (West), Trans-Pecos and the High Plains land resource areas. The High Plains area met requirements until the year 2020, when sizeable shortages were evidenced. Due to the restriction of the 1964 cropping pattern, when a land resource area evidenced an inability to meet its requirements, additional water was not transferred to the area. The deficiencies in production requirements for the land resource areas in which they occurred are shown in Table 3.8. Edwards Plateau (East) was consistently over supplied with water in relation to its projected share of production, while Edwards Plateau (West) and Trans-Pecos, though totally dependent on irrigation were just as consistently under supplied with water for agriculture.

Model D

Model D was designed to illustrate resource use and product output with water supplies as they were proposed under the preliminary Texas Water Plan of 1966. This preliminary plan proposed new impoundments on

TABLE 3.7 ACREAGE AND PRODUCTION OF AGRICULTURAL COMMODITIES, TEXAS, 2000 (MODEL C)

Commodity	Acreage (100's)			Production			Production Unit
	Nonirrigated	Irrigated	Total	Nonirrigated	Irrigated	Total	
Cotton	47,454.9	8,612.3	56,067.2	1,285.8	839.6	2,125.4	Mil. lbs.
Rice	---	4,118.2	4,118.2	---	2,125.6	2,125.6	Mil. lbs.
Wheat	19,536.8	5,864.3	25,401.1	34,672.8	32,566.0	67,238.8	Thous. bu.
Peanuts	3,227.8	120.4	3,348.2	267.3	28.5	295.8	Mil. lbs.
Other Oil Crops	---	---	---	---	---	---	Thous. bu.
Vegetables	5,003.1	512.1	5,515.2	42,667.7	9,078.9	51,746.6	Thous. cwt.
Other Vegetables	---	2,692.4	2,692.4	---	26,622.0	26,622.0	Thous. cwt.
Sweet Potatoes	142.5	28.0	170.5	1,037.7	551.5	1,589.2	Thous. cwt.
Potatoes	---	229.5	229.5	---	4,888.8	4,888.8	Thous. cwt.
Grapefruit	---	1,701.9	1,701.9	---	915.3	915.3	Thous. tons
Other Citrus Fruit	---	753.9	753.9	---	352.0	352.0	Thous. tons
Other Fruits and Nuts	665.4	105.3	770.7	95.3	24.4	119.7	Mil. lbs.
Other Nonfeed Crops	1,748.6	252.1	2,000.7	2,020.8	749.9	2,770.7	Thous. bu.
Barley	3,322.2	737.7	4,059.9	5,956.1	3,569.4	9,525.5	Thous. bu.
Oats	8,339.7	347.3	8,687.0	28,851.8	1,744.2	30,596.0	Thous. bu.
Other Small Grain	2,702.7	440.1	3,142.8	3,118.6	635.4	3,754.0	Thous. bu.
Small Grain for Pasture	19,778.9	1,025.2	20,804.1	6,470.1	714.9	7,185.0	Thous. AUM
Corn, Grain	11,827.8	960.4	12,788.2	36,735.9	8,824.0	45,559.9	Thous. bu.
Corn, Silage	313.1	---	313.1	523.9	---	523.9	Thous. tons
Sorghum, Grain	70,450.8	21,194.7	91,645.5	224,272.0	186,633.2	410,905.2	Thous. bu.
Sorghum, Silage and Forage	8,359.6	1,556.0	9,915.6	2,112.5	1,151.1	3,263.6	Thous. tons
Alfalfa Hay	819.2	839.4	1,658.6	199.5	325.9	525.4	Thous. tons
Other Tame Hay	10,984.5	608.3	11,592.8	1,828.3	175.5	2,003.8	Thous. tons
Other Crop Pasture	45,126.7	1,795.6	46,922.3	14,741.0	1,293.1	16,034.1	Thous. AUM
Other Feed Crops	14,627.7	1,285.1	15,912.8	1,875.3	292.4	2,167.7	Thous. tons
TOTAL	274,432.0	55,780.2	330,212.2				

TABLE 3.8 . COMMODITY PRODUCTION REQUIREMENT DEFICIENCIES IN MODEL C

Commodity	2000 Edwards Plateau W.	2000 Trans-Pecos	Production Units
Cotton	1.8	73.4	Mil. lbs.
Rice	- - -	- - -	Mil. lbs.
Wheat	- - -	48.2	Thous. bu.
Peanuts	- - -	- - -	Mil. lbs.
Other Oil Crops	- - -	- - -	Thous. bu.
Vegetables	48.8	176.5	Thous. cwt.
Other Vegetables	2.3	25.0	Thous. cwt.
Sweet Potatoes	- - -	- - -	Thous. cwt.
Potatoes	- - -	0.8	Thous. cwt.
Grapefruit	- - -	0.7	Thous. tons
Other Citrus Fruit	- - -	- - -	Thous. tons
Other Fruits and Nuts	0.2	4.1	Mil. lbs.
Other Nonfeed Crops	- - -	7.3	Thous. bu.
Barley	- - -	606.4	Thous. bu.
Oats	23.4	760.4	Thous. bu.
Other Small Grain	- - -	- - -	Thous. bu.
Small Grain for Pasture	28.8	15.2	Thous. AUM
Corn, Grain	- - -	2.0	Thous. bu.
Corn, Silage	- - -	- - -	Thous. tons
Sorghum, Grain	137.5	2,681.9	Thous. bu.
Sorghum, Silage and Forage	5.3	92.1	Thous. tons
Alfalfa Hay	5.7	42.9	Thous. tons
Other Tame Hay	6.1	- - -	Thous. tons
Other Crop Pasture	24.1	46.8	Thous. AUM
Other Feed Crops	.2	1.8	Thous. tons

major streams and rivers, further development of underground supplies in some areas of the state, and possible diversions of surface waters within the state. Projections of water supplies available to agriculture in the 15 land resource areas were made by the Texas Water Development Board and employed as restrictions on water availability in this model (6). These projections are given in Table 3.9.

The assumptions relative to factor proportions and prices which were made for Models B and C were included in the program for Model D. The inventory of lands provided the necessary restrictions on land use. Restrictions on food and fiber output for the state were based on the projected requirements listed in Table 2.6. Projections of livestock product requirements were converted to feed units needed for the production of the livestock. The resulting production restrictions are shown in Table 3.10.

Water allocation priorities among commodities of each land resource area remain the same in Model D as in Model C. Determinants of water distribution when the cropping pattern is forced to change due to soil group depletion was also programmed the same as in Model C. The only differences between Model C and Model D are the input data for available irrigable acres and commodity production requirements.

It is evident that the projections of food and fiber requirements for Texas appropriate to this model are less than those of Model B and greater than those of Model C. The explanation is obvious when assumptions of water supplies available to agriculture are recalled. In Model B the only limitation on water use for irrigation was an economic one. Water had a cost, which prevented its use on low value crops.

TABLE 3.9 PROJECTED IRRIGATED ACREAGE WITH TEXAS WATER PLAN[1/]
(MODEL D)

Land Resource Areas	1980	1990	2000	2010	2020
		1,000 Acres			
East Texas Timberlands	33.0	41.0	53.9	66.8	79.6
Coast Prairie	517.8	543.7	565.0	586.2	607.6
Blackland Prairies	22.7	34.9	39.5	44.6	48.8
Grand Prairie	0.9	1.1	1.2	1.4	1.5
Cross Timbers (East and West)	11.2	11.2	13.0	14.4	16.7
North Central Prairies	29.5	36.6	42.8	48.9	55.0
Central Basin	0.1	0.0	0.0	0.0	0.0
Rio Grande Plain	1,554.7	1,738.4	1,799.0	1,859.6	1,919.9
Edwards Plateau (West)	7.6	2.8	2.8	2.8	2.8
Edwards Plateau (East)	57.8	71.1	73.1	75.0	77.6
Rolling Plains (West)	147.6	103.3	96.3	89.3	82.3
Rolling Plains (East)	83.8	86.2	85.9	85.6	85.4
High Plains	5,816.5	4,474.8	3,584.3	2,931.2	2,191.1
Trans-Pecos	289.7	246.9	205.3	163.7	122.0
Bottomlands	210.5	254.8	287.1	319.5	352.0
STATE TOTAL	8,783.4	7,646.8	6,849.2	6,289.0	5,642.3

[1/] Supplied by the Texas Water Development Board for this special study on Water Development for future Texas agriculture.

TABLE 3.10 PROJECTED REQUIREMENTS FOR MAJOR FARM PRODUCTS, 2000, TEXAS (MODEL D)

Commodity	Unit	2000
Cotton	Mil. lbs.	2,836.0
Rice	Mil. lbs.	2,356.7
Wheat	Thous. bu.	70,924.0
Peanuts	Mil. lbs.	383.5
Other Oil Crops	Thous. bu.	4,022.0
Vegetables	Thous. cwt.	57,158.0
Other Vegetables	Thous. cwt.	29,314.0
Sweet Potatoes	Thous. cwt.	1,725.0
Potatoes	Thous. cwt.	5,622.0
Grapefruit	Thous. tons	1,282.0
Other Citrus Fruit	Thous. tons	469.0
Other Fruits and Nuts	Mil. lbs.	141.4
Other Nonfeed Crops	Thous. bu.	3,043.0
Barley	Thous. bu.	10,191.0
Oats	Thous. bu.	31,704.0
Other Small Grain	Thous. bu.	3,764.0
Small Grain for Pasture	Thous. AUM	7,229.0
Corn, Grain	Thous. bu.	46,534.0
Corn, Silage	Thous. tons	524.0
Sorghum, Grain	Thous. bu.	395,481.0
Sorghum, Silage and Forage	Thous. tons	3,352.0
Alfalfa Hay	Thous. tons	574.0
Other Tame Hay	Thous. tons	2,010.0
Other Crop Pasture	Thous. AUM	16,105.0
Other Feed Crops	Thous. tons	2,159.0

For the crops like citrus fruits, grain sorghums, nuts, oil crops and other high value crops, Texas producers with their unlimited water supplies, were quite competitive. Their shares of national requirements were relatively large. In Model C the economic limitation was coupled with a technical one in which water supplies were relatively scarce. This caused an important limit on use to be imposed within each land resource area. The competitive positions of producers were expected to suffer and shares of U. S. requirements decline. Supplies of water in Model D (projected as acreage supported in irrigation) are somewhere between "abundant" and "scarce." The available water supplies to agriculture assumed for Model D are the most realistic of the four models. Projections of Texas' shares of national requirements are a reflection of the projected water supply.

The projected land area required to produce food and feed crops in Model D is shown in Table 3.11. In 2000 irrigated land acreage is projected to be 6.8 million acres and nonirrigated acreage will be 27.8 million acres. The irrigation land acreage for 1980, 2000 and 2020 as compared with that for Model C where there is no further water developed, is of particular interest.

Year	Model C	Model D
	thou. acres	thou. acres
1980	8,073	8,755
2000	5,578	6,780
2020	4,125	5,503

Development of water resources will sustain irrigated acreage at a level significantly higher than that possible with no further development. This was judged to be important to Texas' agriculture by the commodity specialists who estimated Texas' share of U. S. Food and Fiber

TABLE 3.11 MAJOR USES OF AGRICULTURAL LAND BY LAND RESOURCE AREAS, 2000
(MODEL D)

Land Resource Areas	Nonirrigated cropland	Irrigated cropland	Idle cropland	Tame pasture & meadow	Open range	Brushy range	Woodland range	Forest land	Other lands	Total
	1,000 Acres									
East Texas Timberlands	2,455.5	53.9	37.7	2,704.0	---	19.2	1,625.4	12,333.4	79.5	19,308.6
Coast Prairie	1,494.7	565.0	---	471.2	1,252.2	193.9	307.6	473.2	133.8	4,891.6
Blackland Prairies	4,307.0	39.5	110.8	2,827.7	446.4	641.8	1,277.9	1,021.3	35.4	10,707.8
Grand Prairie	1,466.4	1.2	96.4	129.0	3,386.2	2,694.9	1,766.9	550.2	21.7	10,112.8
Cross Timbers (East and West)	873.3	13.0	66.7	140.7	446.8	313.3	493.1	18.0	14.1	2,379.0
North Central Prairies	623.1	42.8	295.0	9.3	1,467.7	2,690.3	486.6	17.3	4.6	5,636.7
Central Basin	96.0	---	7.3	---	187.3	969.9	84.2	5.2	.7	1,350.6
Rio Grande Plain	2,279.7	1,799.0	132.0	25.9	2,504.9	13,620.3	575.6	16.0	39.7	20,993.1
Edwards Plateau (West)	---	2.8	9.2	---	5,573.2	3,261.4	466.9	7.8	3.9	9,325.2
Edwards Plateau (East)	125.8	30.5	76.6	14.6	4,244.7	2,851.1	2,622.3	91.3	20.3	10,077.2
Rolling Plains (West)	2,512.1	96.3	610.1	29.2	7,392.7	5,306.2	---	---	34.4	15,981.0
Rolling Plains (East)	1,396.5	85.9	733.2	35.7	1,602.7	3,034.1	83.1	8.2	50.1	7,029.5
High Plains	10,060.6	3,584.3	128.7	14.1	1,920.2	1,798.6	---	---	82.9	17,589.4
Trans-Pecos	---	205.3	134.5	---	8,421.9	7,041.5	304.0	40.3	3.4	16,150.9
Bottomlands	159.4	260.5	75.3	499.4	276.5	261.5	45.9	808.0	23.5	2,410.0
TOTALS	27,850.1	6,780.0	2,513.5	6,900.8	39,120.5	44,698.0	10,139.5	15,390.1	548.0	153,943.5

requirements.

Production of agricultural commodities with the assumptions and restrictions of Model D is shown in Table 3.12. Production of almost all crops is greater than that projected in Model C. This is especially true for time periods beyond 1980, when the significance of the water supplies produced by further development of this important resource is more evident. Crops most affected are the citrus crops, oil crops, vegetables, grain sorghum and other fruits and nuts.

Production goals for several commodities were not realized in Model D, but the deficiency was limited to certain land resource areas as shown in Table 3.13. These areas were unable to reach their projected production requirements as determined by the 1964 Texas cropping pattern. Deficiencies were evident by 1980 and became more pronounced and extensive as 2020 was approached. Edwards Plateau (West), and Trans-Pecos were areas of consistently insufficient commodity production, and the High Plains area again failed to reach its production goals in 2020. Commodities exhibiting the greatest shortage due to these area limitations were cotton, corn and sorghum grain, vegetables, and other fruits and nuts.

TABLE 3.12 ACREAGE AND PRODUCTION OF AGRICULTURAL COMMODITIES, TEXAS, 2000
(MODEL D)

Commodity	Acreage (100's) Nonirrigated	Acreage (100's) Irrigated	Acreage (100's) Total	Production Nonirrigated	Production Irrigated	Production Total	Production Unit
Cotton	58,508.0	13,169.1	72,127.1	1,464.0	1,263.6	2,727.6	Mil. lbs.
Rice	---	4,566.0	4,566.0	---	2,356.7	2,356.7	Mil. lbs.
Wheat	21,684.9	6,016.3	27,701.2	37,720.8	33,146.2	70,867.0	Thous. bu.
Peanuts	3,708.2	298.8	4,007.0	310.4	73.1	383.5	Mil. lbs.
Other Oil Crops	1,914.2	312.1	2,226.3	2,938.0	1,084.0	4,022.0	Thous. bu.
Vegetables	3,386.3	1,425.3	4,811.6	30,755.3	26,399.3	57,154.6	Thous. cwt.
Other Vegetables	---	2,960.8	2,960.8	---	29,281.2	29,281.2	Thous. cwt.
Sweet Potatoes	154.7	30.4	185.1	1,126.5	598.8	1,725.3	Thous. cwt.
Potatoes	---	264.0	264.0	---	5,621.7	5,621.7	Thous. cwt.
Grapefruit	---	2,381.6	2,381.6	---	1,281.0	1,281.0	Thous. tons
Other Citrus Fruits	---	1,004.4	1,004.4	---	469.0	469.0	Thous. tons
Other Fruits and Nuts	681.1	135.3	816.4	103.2	32.7	135.9	Mil. lbs.
Other Nonfeed Crops	1,915.3	275.6	2,190.9	2,213.5	820.5	3,034.0	Thous. bu.
Barley	3,418.7	720.0	4,138.7	6,055.8	3,451.1	9,506.9	Thous. bu.
Oats	8,392.6	360.1	8,752.7	29,023.4	1,794.6	30,818.0	Thous. bu.
Other Small Grain	2,703.5	453.3	3,156.8	3,107.3	656.7	3,764.0	Thous. bu.
Small Grain for Pasture	18,848.7	1,568.8	20,417.5	6,057.3	1,125.6	7,182.9	Thous. AUM
Corn, Grain	11,056.0	1,270.3	12,326.3	34,663.1	11,868.4	46,531.5	Thous. bu.
Corn, Silage	313.1	---	313.1	523.9	--	523.9	Thous. tons
Sorghum, Grain	65,238.7	22,072.5	87,311.2	199,764.9	192,707.1	392,472.0	Thous. bu.
Sorghum, Silage and Forage	7,587.8	2,054.0	9,641.8	1,816.9	1,435.4	3,252.3	Thous. tons
Alfalfa Hay	711.9	906.7	1,618.6	165.5	354.6	520.1	Thous. tons
Other Tame Hay	10,448.8	765.3	11,214.1	1,782.1	221.6	2,003.7	Thous. tons
Other Crop Pasture	43,122.2	3,115.5	46,237.7	13,838.4	2,189.8	16,028.2	Thous. AUM
Other Feed Crops	14,706.3	1,224.1	15,930.4	1,889.0	278.5	2,167.5	Thous. tons
TOTAL	278,501.0	67,800.3	346,301.3				

TABLE 3.13 COMMODITY PRODUCTION REQUIREMENT DEFICIENCIES IN MODEL D

Commodity	2000 Edwards Plateau W.	2000 Trans-Pecos	Production Units
Cotton	2.4	106.0	Mil. lbs.
Rice	---	---	Mil. lbs.
Wheat	---	57.0	Thous. bu.
Peanuts	---	---	Mil. lbs.
Other Oil Crops	---	---	Thous. bu.
Vegetables	43.0	217.9	Thous. cwt.
Other Vegetables	2.5	30.9	Thous. cwt.
Sweet Potatoes	---	---	Thous. cwt.
Potatoes	---	1.1	Thous. cwt.
Grapefruit	---	1.1	Thous. tons
Other Citrus Fruit	---	---	Thous. tons
Other Fruits and Nuts	2.0	5.3	Mil. lbs.
Other Nonfeed Crops	---	9.0	Thous. bu.
Barley	---	684.1	Thous. bu.
Oats	23.8	862.1	Thous. bu.
Other Small Grain	---	---	Thous. bu.
Small Grain for Pasture	29.0	17.0	Thous. AUM
Corn, Grain	---	2.4	Thous. bu.
Corn, Silage	---	---	Thous. tons
Sorghum, Grain	132.3	2,876.6	Thous. bu.
Sorghum, Silage and Forage	5.4	103.4	Thous. tons
Alfalfa Hay	5.7	48.2	Thous. tons
Other Tame Hay	6.2	---	Thous. tons
Other Crop Pasture	24.2	52.5	Thous. AUM
Other Feed Crops	.2	2.1	Thous. tons

Model E

An important limitation of the first four models was a procedure that did not allow shifts of crop production among land resource areas based on resource availability and/or comparative advantages in production. This limitation was a result of the use of the 1964 cropping pattern to allocate cropland to production, both irrigated and dryland. The spatial pattern of production was fixed, and as a result production requirements were not always met and resources were not efficiently used. In an effort to relieve the analyses of this important limitation, a model or resource use and production was developed which would provide for an economic allocation of resources and distribution of crop production. It included an appropriate objective function; it provided for measurement of returns in productive activities; and it accounted for land and water use in the production of agricultural commodities as these resources were optimally allocated and used. Limits on changes in crop production in the land resource areas were imposed in recognition of institutional factors which act to deter rapid shifts in locations of crops. These limits prevented rapid adjustments of resource use to accomplish economic efficiency, but they were a necessary concession to reality.

Methodology for Model E. The objective function chosen for the model was the maximization of net returns from crop production over time. Within the constraints of the model this function provides for optimum resource combinations and economic distribution of crop production within the state. It was felt that this objective function was realistic because the extent and location of productive processes tends to be determined by economic forces in the long run. The time period of concern here was 50 years, a long run for most planning efforts.

As in the four preceeding models, the state of Texas was divided into fifteen land resource areas of uniform environmental characteristics. Each area consists of some combination of nine soil capability groups, each with six land use categories. In addition to (1) assumptions about resource availability, (2) restrictions on production, and (3) estimates of production with projected yields, the model required (4) cost of production data relative to each crop or crop group and resource area, and (5) price data for each commodity.

A general block diagram of the procedure is shown in Figure 3.1.

Production and Resource Data. Input data for Model E, which are descriptive of land and water resources, kinds and qualities of soils, prospective crop yields, and crop and livestock requirements are identical to those of Model D. Specifically, the resource data were taken from the inventory of land, Table 1.1, and the projection of water supplies available to agriculture, Table 3.9.

Definition of Productive Processes. For each combination of land resource area, soil resource group, farming type and crop there exists a unique production process. This is due to variability in climatic factors, productivity of soils, tillage requirements, etc. among land resource areas. Each unique production process is represented in the model by an expected net return and a yield per acre.

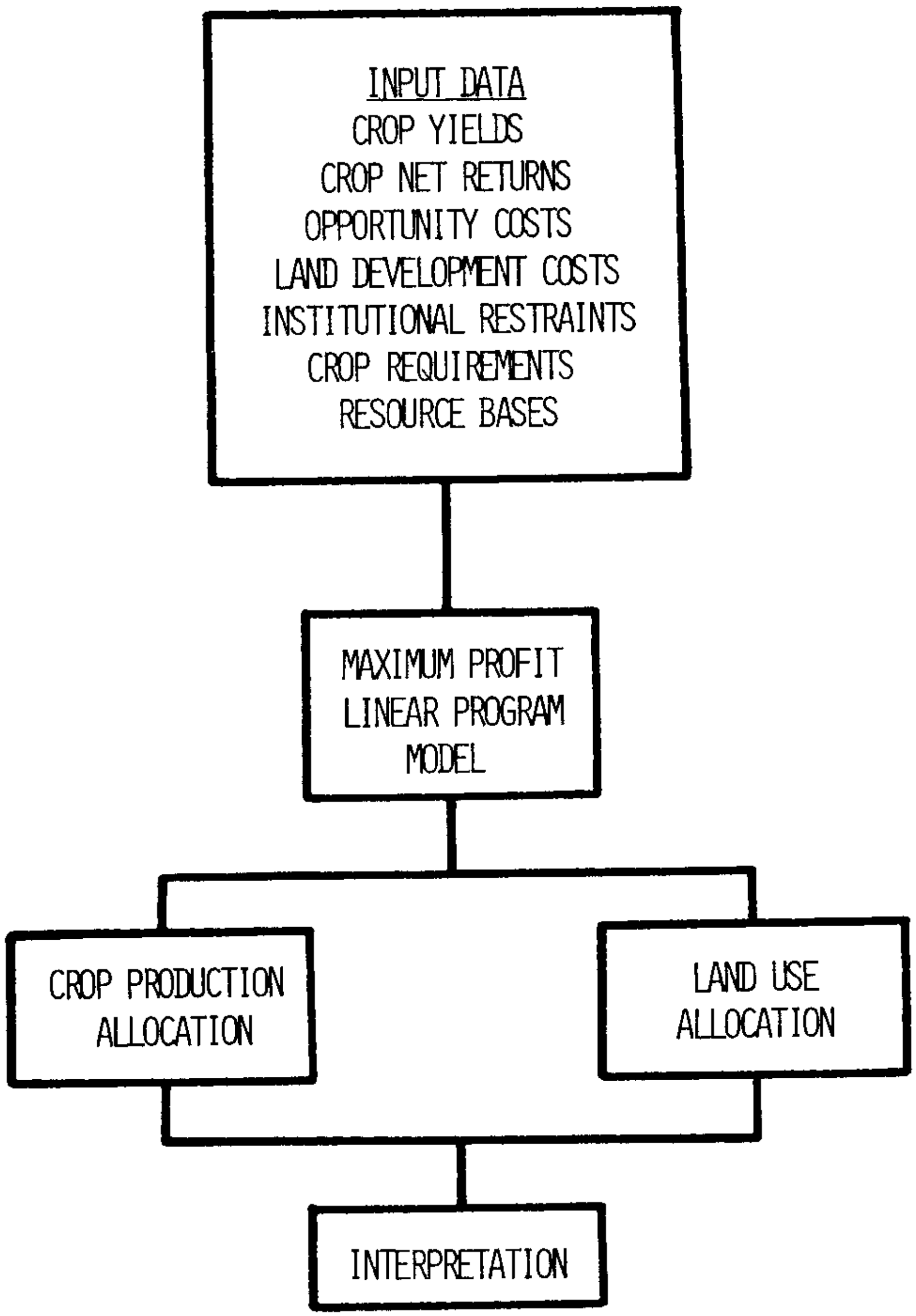

Figure 3.1 Block Diagram of Agricultural Profit Maximization Model.

Definition of the productive processes which are possible for each commodity in the model was obtained from crop production records and specialists' observations which reflect crop preference, farming methods and yields in specified land resource areas and soil groups. The model does not permit expansion of a productive process into a location where there is not history of previous production, but it does permit an increase in activity and land use changes, including transfers of land from other uses into cropland, to support such an increase. This restriction could be relaxed if production data for new locations was available.

Budgets for Productive Processes. Essential to the solution of the model are net return data which must be produced from budgets representative of all crops in all land resource areas. The data necessary for these budgets were generally available, but they were found in numerous sources and had to be carefully related to achieve consistency (10, 13, 15, 16, 17, 30, 31, 33, 34, 41). A particular data problem was the relativity of production information in terms of management levels, technological adaptation and timeliness. Much of the data was outdated and required adjustment based on recommendations of production specialists.

Basic budgets for each crop in each land resource area were developed. Crop budgets were then varied according to soil group characteristics, historic production practices, yields assigned to the soil group, type of farming, and harvest costs. Data coordinated to the base year of this study, 1964, were used in developing the budgets.

Development of these data is important to a realistic solution, but it did not hold a position of primary importance in this analysis. The main objective was the development of the analytical model. Future use of the model for resource planning purposes will require refinement of the data and the budgets.

Derivation of net return data which are representative of crop production processes in the various soils and land resource areas under dry land and irrigated farming is described in this equation:

$$R_{ijkn} = (P_{in} + S_{in} - H_{in})\, Y_{ijkn} - V_{ikn}A_{ij} - B_{ijk} \tag{1}$$

$$(i=1,2...15;\ j=1,2...9;\ k=1,2;\ n=1,2...25)$$

where,

i = the land resource area
j = soil resource group
k = farming type (irrigation or dry)
n = enterprise, crops 1-25, livestock grazing 26-30

and,

P = Commodity price per commodity unit,

S = Secondary income from this enterprise per commodity unit,

H = Harvest cost per commodity unit,

V = Typical variable production costs per acre,

A = Cost adjustment factor for soil resource groups,

B = Relative soil maintenance cost per acre,

R = Net return per acre.

For the purpose of Model E, net return per acre for each productive process is held constant. This assumption was judged to be realistic and is supported by Cochrane in his description of the "Agricultural treadmill" [4].

Crops produced under both irrigated and nonirrigated conditions required a supplementary budget. Variable cost of irrigation farming practices such as those associated with ditching, pumping costs, greater cultivation and different cultural practices were included in the production costs.

Opportunity Earnings. To account for the use of agricultural land not in crops production, net returns for enterprises such as cattle and sheep production were computed. These returns are treated as opportunity earnings, i.e. earnings which are possible when lands suited for crops are not so used. Recognition of these alternative uses of land insure against transfer of range lands into marginal return crop production processes without recognition of the prevailing earning opportunities.

Opportunity earnings were based partially on animal-unit-month of forage capacity measures for all land resource areas as compiled by E. J. Dyksterhuis (2). Net returns which are representative of animal-unit production of beef cattle per acre were computed from this base information. These base data were adjusted to returns per acre from the "productive animal-unit" by a constant derived from common productive parameters.

The simple equation expressing derivation of opportunity earnings is:

$$R_{ijm} = \frac{(E)\ (F_{ijm})}{G} \qquad (2)$$

where the subscripts are as previously defined, with

m = land use category, e.g. cropland, range, woodland, etc.

and,

E = A constant value representing typical net return to an animal unit,

F = The number of animal-units per year of forage production capacity in various land use categories for each land resource area,

G = A constant representing a producing animal unit.

Land Development Costs. The demands of productive processes for cropland in a soil group may exceed the quantities available in a particular land resource area. To accommodate these demands, land use conversions are permitted at a cost which is computed as the development cost necessary for conversion.

Representative land development costs for the extremely varied land resource areas and soil types were sought from Soil Conservation Specialists and Farm Management Specialists in each land resource area. Development costs were quite variable, depending on the soil group. The amortized dollar cost for each land use conversion is the cost (exclusive of the opportunity earnings attributed to non-cropland uses) at which new land is brought into crop production.

Institutional Factors. Institutional factors such as crop acreage allotments, water rights, crop preferences and customs plus asset fixity in farm firms and comparative immobility of farm operators have significant effects on resource use and location of crops production. They tend to act as barriers to change; they fix production processes to areas for short to intermediate periods of time. They are accounted for in Model E by constraints on changes in cropland in land resource areas over the period of the analysis. They were established as upper and lower bounds to changes in the use of cropland in each time period as follows: 1980, ±15 percent; 2000, ±45 percent; 2020, ±75 percent. Exceptions to these constraints are found in four land resource areas where rapidly increasing population and urban development make more stringent restrictions necessary.

The General Model. The model can be summarized in discrete mathematical terms as follows:

maximize

$$TR = \sum_{i=1}^{15} \sum_{j=1}^{9} \sum_{k=1}^{2} \sum_{n=1}^{30} R_{ijkn} X_{ijkn} + \sum_{i=1}^{15} \sum_{j=1}^{9} \sum_{m=1}^{6} C_{ijm} T_{ijm} \qquad (3)$$

subject to

$$L_{ij} \geq \sum_{k=1}^{2} \sum_{n=1}^{30} X_{ijkn}, \ (i=1,2...15;\ j=1,2...9) \qquad (4)$$

$$W_i \geq \sum_{j=1}^{9} \sum_{n=1}^{30} X_{ijkn}, \ (i=1,2...15;\ k=1) \qquad (5)$$

$$D_n = \sum_{i=1}^{15} \sum_{j=1}^{9} \sum_{k=1}^{2} Y_{ijkn} X_{ijkn}, \ (n=1,2...30) \qquad (6)$$

$$Z_{im} \geq \sum_{j=1}^{9} X_{ijm}, \ (i=1...15;\ m=2...6) \qquad (7)$$

$$U_i \geq \sum_{j=1}^{9} \sum_{k=1}^{2} \sum_{n=1}^{30} X_{ijkn}, \ (i=1,2...15) \qquad (8)$$

$$Q_1 \leq \sum_{j=1}^{9} \sum_{k=1}^{2} \sum_{n=1}^{30} X_{ijkn}, \ (i=1,2...15) \qquad (9)$$

$$L_{ijm} \geq \sum_{k=1}^{2} \sum_{n=1}^{30} T_{ijm}, \ (i=1,2...15;\ j=1,2...9;\ m=2...6) \qquad (10)$$

and, $X \geq 0$, $T \geq 0$, $Z \geq 0$

where

TR = Total net return for state
R = Expected net return per acre
X = Level of activity in acres
C = Amortized cost of developing land from other land-use categories into cropland
T = Level of activity of undeveloped land into cropland in acres
L = Quantity of land available for agriculture in acres
W = Quantity of land available for irrigated agriculture in acres
Y = Expected yield per acre
D = Total projected demand or requirement for specified commodities in Texas
Z = Livestock grazing enterprises (alternatives to crop production) in acres
U,Q = Arbitrary quantities of cropland acreage which are composed as upper and lower bounds of cropland utilization.

The Analytical Tool. The analytical tool appropriate to this model is linear programming. This is a method of solving a system of equations for either a maximum or minimum value for a specific objective function. In this case, it was used to develop a course of action that would lead to efficient resource use in the production of specified quantities of agricultural commodities. International Business Machine MPS 360 linear programming software was used in the analysis. Table 3.14 is a generalized, pictorial representation of the input matrix for the MPS 360 program.

The linear program selects the crop activity (production process) yielding the highest net return and directs production to this activity within constraints of the model. If the cropland in the affected soil group is exhausted before any other constraint limits production in that activity, land in non-crop uses may be transferred, at a cost, to use in the process. If the net return, with development cost, is still highest for the selected activity, production continues until some constraint is encountered or the commodity requirement is satisfied.

TABLE 3.14 TABULAR ILLUSTRATION OF LINEAR PROGRAM FOR MODEL E

Row Names	RHS No. of Units	RHS Sign	Land Resource Area-1 Activities Crops	Land Resource Area-1 Activities Non-Crops	Land Resource Area-1 Activities Development	Land Resource Area-n Activities Crops	Land Resource Area-n Activities Non-Crops	Land Resource Area-n Activities Development
Net Returns (OBJF)		N	RR. R	RR. R	CC. C	RR. R	RR. R	CC. C
Resource Area-1								
Cropland Use								
A	X	L	1		-1			
B	X	L	1		-1			
.	.	.	.		.			
I	X	L	1		-1			
Other Uses								
A	X	L		1	1			
B	X	L		1	1			
.	.	.		.	.			
I	X	L		1	1			
Irrigation	W	L	10. 0					
Cropland Utilization								
Upper	U	L	11. 1					
Lower	Q	G	11. 1					
Accumulator, non-crop uses								
Pasture	X	G		-1				
.	.	.		.				
Forest	X	G		-1				
Resource Area-n						Area-n coefficients		
Texas Production Requirements								
Cotton	D	E	.5					
Rice	D	E	.2					
.	.	.	.					
Other Tame Hay	D	E	.7					

Every crop activity is representative of a unique, alternative opportunity to produce a commodity with a combination of natural resources and technical inputs. Technical inputs are assumed to be a part of the process, and natural resources are assumed to be developed for production. Each crop activity is represented in the linear programming model by its output per acre. Economic output of each process is in the form of a net return to land and management. Physical output of each process is in the form of a yield per acre which is subtracted from the total requirement for each respective commodity upon selection for production. The objective of the linear model is the maximization of net returns.

Production of twenty-five different crops is accounted for in the model. In accord with the production requirements approach adopted for this analysis, every crop has a prespecified requirement for the state at each period. While the linear program was developed to allocate production of these crops in a way that will maximize net return per acre to land and management, seven crop groups--Vegetables, Other Vegetables, Grapefruit, Other Citrus Fruit, Other Fruits and Nuts, Other Nonfeed Crops, and Other feed Crops--were programmed in a different manner outside of this model. Some of the seven crops, such as oranges and grapefruit, have been produced in only one location. For others sufficient data could not be compiled to allocate them by a more competitive method. Production of the seven crops was planned on the basis of the historic pattern of production among the land resource areas. Acreage and production data were drawn from Model D. The acreages utilized by these seven crop groups were made unavailable to the crops competing for resources in this model. This automatically gave the seven crops primary consideration for land use, but in most cases the acreage was not significantly large.

Those crops remaining in competition for resources in this study were (1) Cotton (2) Rice (3) Wheat (4) Peanuts (5) Other Oil Crops (6) Sweet Potatoes (7) Potatoes (8) Barley (9) Oats (10) Other Small Grain (11) Small Grain for Pasture (12) Grain Corn (13) Corn Silage (14) Grain Sorghum (15) Sorghum Silage and Forage (16) Alfalfa (17) Other Tame Hay (18) Other Crop Pasture.

There are no production requirements for non-crops (livestock enterprises) so there is no competition among these production processes and the 25 production processes requiring cropland. Production requirements for livestock grain and cultivated forage are accounted for in specified enterprises.

The transfer of land from other uses into cropland use is accomplished through land resource development at a cost. This is an activity which is initiated at the entrepreneur level and is represented in the program as an additional cost of production. Total cost includes consideration of land clearing as well as land conditioning. This model assumes that the cost of land development is paid over a period of time. The cost is amortized and charged as a reduction to the annual net return for the enterprise for which the land was developed.

The cropland constraint was calculated by applying the upper and lower bounds limitations for 1980, 2000, and 2020 to acreages of cropland in land resource areas in 1964 after adjustment for increasing other uses. The constraint was thus conditioned by effects of institutions on land use changes and by encroachment of highways, airports, etc. on agricultural lands. It is shown in Table 3.15 as a maximum and minimum constraint on cropland. The minimum cropland acreage for each land resource is progressively smaller at each period, while maximum cropland acreages are larger in each time period, reflecting the increasing long term flexibilities of resources.

Water resource availability for irrigation is constrainged in the model by the levels presented in Table 3.9.

Production requirements for all twenty-five agricultural crops accounted for in this model were shown in Table 3.10. The quantity of product noted at each time period constitutes a requirement as well as a limitation for the production of each competing crop.

<u>Output of the Program</u>. The allocation of resources for crops production in Texas for 1980, 2000 and 2020 which is suggested by output of the program is shown in Tables 3.16, 3.17 and 3.18. It is consistent with requirements for production in these time periods and with the objective function, i.e. maximization of net returns from crop production. Data for all three time periods are reported for Model E because they are not published elsewhere.

The tables show the acreages used for agricultural production among each of the land use categories for all land resource areas. Cropland utilization is divided into the three subcategories (1) non-irrigated (2) irrigated and (3) idle, to account for the specific disposition of acreages in this use. Idle cropland was not permitted to transfer into other land use categories as might be the case in actual

TABLE 3.16 MAJOR USES OF AGRICULTURAL LAND BY LAND RESOURCE AREAS, 1980
(MODEL E)

Land Resource Areas	Nonirrigated cropland	Irrigated cropland	Idle cropland	Tame pasture & meadow	Open range	Brushy range	Woodland range	Forest land	Other lands	Total
					1,000 Acres					
East Texas Timberlands	2,105.2	13.3	827.6	3,146.7	---	18.8	1,520.1	11,953.1	79.5	19,595.3
Coast Prairie	1,324.5	486.4	588.8	1,104.2	1,272.1	185.2	295.7	447.6	133.9	5,838.3
Blackland Prairies	4,049.2	.4	1,225.0	3,273.1	427.4	614.5	1,251.4	985.2	35.4	11,861.6
Grand Prairie	1,374.1	.9	284.1	188.0	3,461.9	2,764.7	1,840.6	563.5	21.7	10,459.5
Cross Timbers (East and West)	781.0	10.2	235.2	199.4	428.7	311.3	493.3	29.4	14.1	2,502.4
North Central Prairies	720.4	2.3	26[illegible]	16.5	1,415.3	2,018.4	[illegible]	17.4	4.6	5,650.0
Central Basin	22.1	.0	40.9	---	189.3	976.9	85.9	[illegible]	.7	1,381.1
Rio Grande Plain	2,526.2	541.3	779.8	56.7	2,586.1	14,256.9	589.7	16.4	39.7	21,392.8
Edwards Plateau (West)	---	7.6	8.5	---	5,592.7	3,270.9	468.7	7.9	3.9	9,360.2
Edwards Plateau (East)	274.2	.4	50.0	21.0	4,156.2	2,849.3	2,620.7	91.2	20.3	10,083.3
Rolling Plains (West)	2,395.8	.3	831.2	74.6	7,424.5	5,312.8	---	---	[illegible]	16,073.5
Rolling Plains (East)	1,572.9	.6	574.0	49.6	1,564.7	2,999.5	82.3	8.1	50.0	6,901.7
High Plains	7,093.3	1,478.5	2,057.5	26.1	4,070.5	2,998.6	---	---	62.9	[illegible]
Trans-Pecos	---	289.6	82.7	---	8,439.9	7,057.0	305.3	40.1	3.4	16,218.0
Bottomlands	490.1	1.0	105.3	521.0	261.6	2[illegible]7.7	43.4	763.8	23.5	2,457.4
TOTALS	24,739.0	2,832.8	8,056.6	8,676.6	41,290.9	46,382.5	10,086.2	14,929.0	548.0	157,571.7

TABLE 3.17 MAJOR USES OF AGRICULTURAL LAND BY LAND RESOURCE AREAS, 2000
(MODEL E)

Land Resource Areas	Nonirrigated cropland	Irrigated cropland	Idle cropland	Tame pasture & meadow	Open range	Brushy range	Woodland range	Forest land	Other lands	Toral
					1,000 Acres					
East Texas Timberlands	1,251.6	20.5	1,678.7	3,081.6	---	18.3	1,542.7	11,705.6	79.5	19,378.5
Coast Prairie	1,490.6	451.4	365.2	795.8	993.0	149.7	248.2	295.9	133.9	4,923.7
Blackland Prairies	4,268.0	.8	556.0	2,915.4	385.8	554.9	1,104.2	888.5	35.4	10,709.0
Grand Prairie	2,395.5	1.2	82.0	181.8	2,725.5	2,382.2	1,779.7	544.8	21.7	10,114.4
Cross Timbers (East and West)	501.2	6.2	454.2	191.5	419.6	300.3	376.2	28.1	14.1	2,291.4
North Central Prairies	376.6	42.8	715.5	16.4	1,412.1	2,563.5	487.9	17.4	4.6	5,636.8
Central Basin	67.9	---	42.2	---	185.1	965.5	83.9	5.2	.7	1,350.5
Rio Grande Plain	2,777.8	918.5	162.9	55.2	2,520.8	13,896.9	574.8	16.0	39.7	20,962.6
Edwards Plateau (West)	---	2.8	13.3	---	5,571.9	3,258.7	466.9	7.8	3.9	9,325.3
Edwards Plateau (East)	90.6	3.5	144.4	21.0	4,239.5	2,847.6	2,619.1	91.2	20.3	10,077.2
Rolling Plains (West)	1,979.7	96.3	1,119.3	73.9	7,351.1	5,260.3	---	---	34.4	15,915.0
Rolling Plains (East)	1,759.0	4.6	545.1	49.4	1,552.3	2,831.0	82.0	8.1	50.0	6,881.5
High Plains	7,400.5	3,584.3	132.4	22.7	3,428.8	2,963.4	---	---	82.9	17,615.0
Trans-Pecos	---	205.4	170.3	---	8,402.5	7,025.8	303.9	39.9	3.4	16,151.2
Bottomlands	671.1	1.0	5.0	515.1	256.4	141.6	42.9	755.2	23.5	2,411.8
TOTALS	25,030.1	5,340.3	6,186.5	7,919.8	39,444.4	45,159.7	9,712.4	14,403.7	548.0	153,744.9

TABLE 3.18 MAJOR USES OF AGRICULTURAL LAND BY LAND RESOURCE AREAS, 2020.
(MODEL E)

Land Resource Areas	Nonirrigated cropland	Irrigated cropland	Idle cropland	Tame pasture & meadow	Open range	Brushy range	Woodland range	Forest land	Other lands	Total
					1,000 Acres					
East Texas Timberlands	1,682.5	79.1	1,445.0	2,908.2	---	17.7	1,498.3	11,122.8	79.5	18,833.1
Coast Prairie	1,078.3	588.3	15.7	612.3	747.9	115.2	191.0	227.6	133.9	3,710.1
Blackland Prairies	4,365.7	1.3	97.0	2,608.7	213.4	359.5	1,010.5	981.8	35.4	9,673.3
Grand Prairie	1,542.3	1.5	68.1	173.7	3,154.5	2,526.1	1,658.1	520.7	21.7	9,666.7
Cross Timbers (East and West)	498.5	7.3	429.6	181.4	388.5	284.4	356.3	26.6	14.1	2,186.7
North Central Prairies	834.2	55.0	257.1	16.4	1,408.1	2,569.2	472.5	16.8	4.6	5,633.9
Central Basin	77.8	---	43.1	---	185.0	953.8	83.9	5.0	.7	1,349.3
Rio Grande Plain	3,922.0	1,244.3	57.1	53.7	2,449.1	13,503.1	558.5	15.6	39.7	21,843.1
Edwards Plateau (West)	---	2.8	13.3	---	5,569.1	3,257.1	466.7	7.8	3.9	9,320.7
Edwards Plateau (East)	394.6	.5	44.8	21.0	4,100.6	2,788.7	2,617.3	91.1	20.3	10,078.9
Rolling Plains (West)	2,991.4	82.3	170.1	73.8	7,341.4	5,253.3	---	---	34.4	15,946.7
Rolling Plains (East)	2,136.4	85.4	179.4	49.2	1,531.1	2,719.8	77.6	7.6	50.1	6,836.6
High Plains	9,861.3	2,191.1	130.1	22.4	2,384.6	2,737.7	---	---	82.9	17,410.1
Trans-Pecos	119.8	3.2	250.8	---	8,357.6	6,988.2	302.3	39.7	3.4	16,065.0
Bottomlands	665.3	226.1	1.4	423.0	187.6	25.0	38.2	715.6	23.5	2,305.7
TOTALS	30,170.1	4,568.2	3,202.6	7,143.8	38,018.5	44,098.8	9,331.2	13,778.7	548.9	150,859.9

practice. In this model it is accounted for in the idle cropland subcategory.

The effect of this categorization is to indicate (1) the agricultural resource adjustment that would be required by the optimal solution, and (2) the volume of currently developed cropland that would not be utilized in the solution.

These tables indicate that total land available to agriculture at each period is reduced by approximately four million acres. As previously noted this reduction is distributed throughout all categories of the land classification including cropland, but excluding "other lands".

In 1980 total cropland utilization was 27.5 million acres while eight million acres were idle, unnecessary for production requirements. Production processes involving irrigation utilized 2.8 million acres. A comparison of 1980 cropland use in Model E with that in 1964 reveals one significant difference in acreages utilized. Irrigated cropland was reduced from almost eight million acres in 1964 to less than three million acres in 1980. Food and fiber requirements for 1980 were satisfied without five million acres of land which were irrigated in 1964. Total nonirrigated cropland for the state was approximately the same though slightly reduced in 1980. Total cropland including idle cropland was reduced six hundred thousand acres. Increased yields were a factor important to reduced land requirements. Higher net returns for dry land production of some crops were the reason for the shift away from irrigation in 1980. The two land resource areas which contained the greatest amount of irrigated cropland in 1964 were still leaders in this respect in the optimal solution, 1980.

Production of the commodity requirements in year 2000 required approximately the same amount of non-irrigated cropland acreage in Model E as was utilized in 1980. However, an increase of two and one-half million acres in irrigation production was necessary to satisfy the food and fiber requirements for 2000. Production processes involving irrigation were selected in the program according to their capacity to produce net returns. With the increased food and fiber requirements they were competitive with processes involving dryland. Total crop-land utilized was again similar to that of 1964. Cropland left idle in the output for this period was approximately six million acres, two million less than that idle in 1980.

In 2020, non-irrigated cropland in Model E increased by more than five million acres to thrity million, while irrigated cropland acreage declined. Reduced water supplies available to agriculture affected the solution for this period. In addition, restraints on shifts or movements of crops among land areas were virtually removed. Total cropland utilized in 2020 amounted to one-half million acres more than that which was used in 1964. Irrigated cropland acreage was half that of 1964, while nonirrigated acreage in 2020 was five million acres greater than that of the base period. Idle acres were reduced from 6.1 million to 2000 to 3.2 million.

A comparison of the projections of uses of agricultural land in Model E and Model D is interesting [2]. It should be recalled that in Model D, crop production and land use were projected on the basis of the 1964 production pattern, and irrigated farming had priority over non-irrigated processes as long as water was available. Each land resource area had prespecified commodity production requirements which could not be transferred to other areas. Major uses of agricultural land allocated by these criteria were presented for the year 2000 in Table 3.11. Both models used the same levels of production requirements and essentially the same resources for productive processes. Slight differences are apparent in acreages available to each land use category in the various time periods due to a difference in methods of reducing available acreages to account for increasing use of land for urban, commercial and industrial expansion. Water resource availability was the same in both studies.

Total cropland acreages in both models for the year 2000 were similar. However, there is a large difference in the level of idle cropland between these models. In 2000 idle cropland in Model D was 2.5 million acres, while it was 6.2 million acres in Model E. Idled cropland acreage was not reallocated to an alternative productive use in either of the models. It represents an area of significant economic adjustment for the agriculture industry.

Another significant difference in the output of these two models is in the acreages of cropland employed in irrigation. In Model D there were projected higher levels of irrigated farming for 2000. The difference is largely a result of the analytical methods employed for each. In Model D, the use of irrigation in crop production was forced, to the point of depletion of available water supplies or satisfaction of production requirements. This was due to the assumption that crops which could be produced with or without supplemental water would be irrigated. It was judged that irrigation was superior to dry land production so far as net returns to producers were concerned. This is not necessarily the case, as the solution of Model E makes evident.

It is important to recognize that Model D, which projected production according to a fixed production pattern, utilized a greater amount of total cropland and a greater amount of irrigated farming and still did not fully satisfy production requirements for all three time periods. If resources had been available within the specified production areas, production to satisfy requirements would have widened the difference between cropland acreage utilization of these models. The production deficiencies of Model D were shown in Table 3.13.

Quantities of land converted to cropland and cropland left idle in Model E are shown in Table 3.19. Development of land in other uses for use in cropland increased more than two fold among time periods. Such land conversion was not possible in Model E unless the net return from a specified production process was still optimal after reduction by the cost of land development. Total cropland development in Texas for these periods were respectively 986.8, 2,425.0, and 5,384.8 thousands of acres. It is apparent that this model required the development of certain, specified qualities of soil, while it did not require the use of other, apparently less productive soils.

While some land was converted for use in crops production, other cropland acreages were left idle. When not needed these acreages were left as slack resources, but they were held available for future uses.

TABLE 3.19 CROPLAND ACREAGES DEVELOPED AND IDLED BY MAXIMIZATION OF NET RETURNS AT EACH PERIOD

Land Resource Areas	1980		2000		2020	
	Developed	Idle	Developed	Idle	Developed	Idle
East Texas Timberlands	--	827.6	--	1,678.7	378.0	1,445.0
Coast Prairie	--	588.8	291.9	365.2	240.8	15.7
Blackland Prairies	10.6	1,225.0	79.8	556.0	340.1	97.0
Grand Prairie	651.0	284.1	913.0	82.0	115.8	68.1
Cross Timbers (East and West)	22.3	235.2	--	454.2	9.0	429.6
North Central Prairies	177.6	366.0	226.0	715.5	240.0	257.1
Central Basin	12.0	40.9	.8	42.2	11.9	43.1
Rio Grande Plain	--	779.8	--	163.1	1,479.4	57.1
Edwards Plateau (West)	--	8.5	--	13.3	--	13.3
Edwards Plateau (East)	85.9	50.0	--	144.4	192.9	44.8
Rolling Plains (West)	--	831.2	--	1,119.3	--	170.1
Rolling Plains (East)	27.4	574.0	185.7	545.1	305.2	179.4
High Plains	--	2,057.5	622.7	132.4	1,796.9	130.1
Trans-Pecos	--	82.7	--	171.4	--	250.8
Bottomlands	--	105.3	105.1	5.0	274.8	1.4
TOTALS	986.8	8,056.6	2,425.0	6,187.8	5,384.8	3,202.6

Conclusions. The analytical method of Model E has produced a solution to the resource allocation-crop production problem which suggests a significant reallocation of land among competing agricultural uses and a geographical redistribution of production. Comparison of projected cropland acreages for 1980, 2000 and 2020 with acreages actually used for crops in 1964 show them to be declining through the year 2000. At the same time, crop production increases to satisfy food and fiber requirements. The pattern of production is projected to change also. There are changes in cropland acreages among land resource areas, brought about by shifts in locations of some crop production, diminished quantities of resources (water), and other factors.

An obvious conclusion to be drawn from this model is the sufficiency of Texas resources to produce the specified production requirements without large scale land conversions for additional cropland. Indeed, until year 2020, there are more cropland acres idled, as production is optimally located, than are converted to cropland. This resulted even while institutional restraints forced some non-optimal production processes into the early solutions.

Equally important in the solution of Model E is the distribution and amount of irrigated farming in Texas. Texans have been concerned about the available water supply for agriculture and have shown this concern by appropriating millions of dollars for study of tremendous water resource development. This solution suggests that food and fiber requirements can be met without large acreages of irrigated cropland. The method used in the analysis does not of course account for the risks associated with dry land production and the variability of output which is characteristic of dry land agriculture. It does provide for measures and comparisons of net returns to irrigated and dry land acres and it allocates resources and directs production according to those returns. This is a procedure which is logical and realistic.

Limitations. Disaggregation of land resources, and recognition of warying land-use capabilities, was felt to be a step forward in analytical procedure. The wide range of crop production processes and the alternatives for land use outside of this array of processes were also progressive. However, the lack of consideration of different levels of technology and management, i.e. the use of average farm and average farmer concepts, prevented the model from indicating alternative solutions which could be studied for planning implications.

Unless farms are expected to become completely specialized in commodity production, it must be concluded that there was insufficient consideration of farm diversification of enterprises in this model. Many farms engage in more than one productive process and use the same technical and natural resources in each of them. A small difference in net returns for a productive process among land resource areas may not cause significant changes in organization of crop enterprises and shifts of crop production. Diversified firms may lose more than they can gain by greater specialization. Add to this the fixities involved in farm firm investments and technology, and locational shifts of production become significantly less likely.

The model does not recognize market complexities and differences. Each commodity is treated in the aggregate; qualities of product are averaged. Areas do not produce commodities of equal quality, due to environmental differences, varietal differences, etc. and a more thorough analysis would account for these conditions. The model could be expanded to account for market complexities.

Because allocations of production were assigned on the basis of optimal net return, the budgetary work in this study has a profound influence on the results of the analysis. The accuracy of the data, the consistency of the data and the completeness of the budgets themselves become important to the solution for the state. Inaccurate representation of potential profits leads to erroneous solutions. Additional work should be directed to improved data. This must be the major emphasis in further research with this model for Texas.

The application of research resources to the development of accurate budgetary data should make possible improved models that will serve well the planners of water resource development. Land resource planners would have a similar interest in such models because they would likewise provide direction to their planning efforts and lend support to their objectives.

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