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AGRICULTURAL AND WATER POLICIES AND THE ENVIRONMENT: AN ANALYSIS OF NATIONAL ALTERNATIVES IN NATURAL RESOURCE USE, FOOD SUPPLY CAPACITY AND ENVIRONMENTAL QUALITY

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An analysis of water needs and demands must simultaneously consider (a) exogenous variables affecting food demand, (b) government programs which control supply and increase food exports, (c) technological advance and (d) the pricing of water through public investment in irrigation developments. Include population level and distribution, national income and economic growths by regions, commercial exports the total demand for food produced in the United States and governmental policies. (a) interregional distribution of agricultural production and land use, (b) rates of improvement in agricultural technology, (c) various price levels for water used in agriculture, (d) alternative supply control programs and (e) restraints on the use of insecticides and fragile lands.

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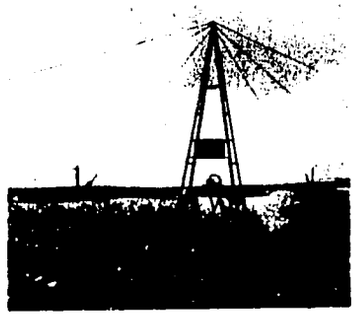

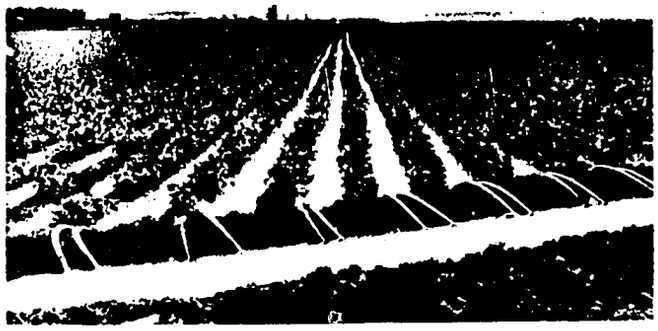

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AGRICULTURAL AND RURAL DEVELOPMENT
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PREFACE

American society has become increasingly concerned with several facets of economic and technological development. One element is population growth. With higher levels of population being projected for the future, particular distributions of industrial, urban and municipal demands for water will place rapidly growing pressures on its supply. However, economic development not only increases the demand for water but also utilizes technologies that produce outputs and byproducts which pollute streams and lessen water quality. Agricultural technology is closely related to these developmental problems in several ways: First, rapidly growing supply capacity based on modern technological inputs has caused farm prices and income to be depressed. Remedial measures have been large treasury outlays for programs of supply control, land retirement and price supports. Second, the modern inputs which cause agriculture to be so productive generate outputs which flow into streams as unused insecticides, nitrates, phosphates and animal wastes and may cause significant deterioration of water quality in particular streams and locations.

Concurrently with the development of a large food supply capacity and increasing public costs to restrain it, greater development of irrigated agriculture has occured with both public and private investment. Increased use of water in agriculture also has increased food supply capacity as well as the amount of public funds required to control production to obtain particular price and income goals. For example, general public policies for agriculture cause water in the West to be substituted for land in the East; then, over the entire nation, farmers are compensated for withdrawing land from production. To an extent, the public finances the development of irrigation to increase productivity and at the same time pays farmers for idling part of it to reduce production.

Because of this complex set of problems, this study was designed to integrate the variables relating to population growth, growing water requirements in nonfarm uses, commercial agricultural policies, public irrigation policies, and potentials in environmental improvement through agriculture. The study analyzes the potential supply capacity of American agriculture when retired land is allowed to return to production and water in the 17 Western States is allocated for future nonfarm uses. It also evaluates food production potential when certain restraints are placed on agricultural inputs which may create certain problems in water pollution and environmental quality. It evaluates whether water supplies are large enough to meet future nonfarm demand as population grows and industrial demands for water increase. It also determines whether supply capacity is large enough to meet food demands at reasonable real costs in the year 2000 if some irrigation water is diverted from agriculture and certain restraints are placed on the use of insecticides and fragile lands in agriculture.

This study was initiated through a contract between the National Water Commission and the Center for Agricultural and Rural Development, Iowa

State University. The authors are particularly indebted to Russell Thompson and Theodore Schad of the National Water Commission for their help and guidance. The policy model dealing with reduced use of insecticides was developed through a cooperative arrangement with Dr. David Pimentel of Cornell University. The policy model dealing with withdrawal of fragile lands was made cooperatively with Dr. John F. Timmons of Iowa State University and Dr. Sid L. Spahr of the University of Illinois with financial aid from the Committee on Agriculture and the Environment of the National Academy of Sciences.

Assisting with the formulation of the programming model, data processing and summarization of the results were Craig V. Fulton and Dennis L. Thomas. A large number of other persons also contributed greatly to the research through furnishing data or its sources, in evaluating the methodology and in processing the output of the various policy models.

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I. INTRODUCTION AND BACKGROUND

This study includes a combined analysis of potentials in commercial farm programs, public irrigation policies, land use and certain environmental restraints. These are interdependent elements of a total national policy affecting farm prices and income, treasury costs of attaining supply control and farm improvement, land use patterns as determined by supply control and environmental protection.

Over most of the last 40 years, the nation has used land retirement programs to reduce supply and bolster farm prices and income. Land retirement distributed over the entire nation has been attained through voluntary programs financed from the U.S. Treasury. Recent estimates indicate that the total annual costs of these land retirement and supply control programs approximate $5 billion (2). During this same period, the nation also has continued to invest in public irrigation projects which increase the supply capacity of agriculture. As more irrigation is developed, an increased amount of land must be retired under commercial farm programs to maintain farm price and income goals. The public programs which develop more irrigated land, on the one hand, and finance land retirement as a supply control means, on the other hand, have two basic effects: (1) They cause water in the 17 Western States to be substituted for land in the rest of the nation. This substitution results as added land is irrigated in the 17 Western States and land is withdrawn from production under public subsidy in other regions; (2) The public has a double cost in first investing in increased supply capacity through irrigation and second in investing in land retirement to reduce supply.

The outlook for supply capacity of U.S. agriculture and the potential amount of water available for irrigation may, however, change with the future. Continued population growth, especially in the 17 Western States, will greatly increase the demand for water for urban and manufacturing uses. Too, increased concern over water quality and pollution of streams through modern agricultural technology has encouraged proposals for reduced use of inputs such as insecticides, chemical fertilizers and fragile lands. Questions thus arise whether future population, food demands, environmental considerations and nonfarm uses of water will change the supply capacity of American agriculture.

One possibility would be that the diversion of water from irrigation to urban uses and restraints on insecticide and land fertilizer use might greatly reduce food supply capacity. If so, can the nation meet its future domestic and export demands for food at reasonable real costs? Will the supply of water be large enough to meet both the urban and farm requirements in the future? Would return to production of land now retired under government supply control programs allow the nation to meet future food demands with either (a) no further development of irrigated agriculture from surface water supplies or (b) some diversion of water from agriculture to urban, municipal and manufacturing uses? How would these possibilities be altered by reduced use of certain insecticides and fragile lands?

Would diversion of water to nonfarm uses and restriction on use of inputs with pollution potential cause food supplies to be extremely limited relative to demand? Or, would these diversions and restrictions only reduce food supplies to a better balance with demand, so that farm prices and income can rise with reduced treasury outlays for supply control and income supports?

This study has been made to appraise supply potentials in the year 2000. It evaluates the nation's needs for land and water in agriculture and its food supply potentials under various levels of population, farm programs, water prices, agricultural exports, technological advances and environmental controls. It also estimates levels of farm prices projected to prevail under various combinations of these several variables affecting the supply of and demand for food.

Background

An analysis of water needs and demands must simultaneously consider (a) exogenous variables affecting food demand, (b) government programs which control supply and increase food exports, (c) technological advance and (d) the pricing of water through public investment in irrigation developments. This study has been organized accordingly. It estimates future demands for land and water and projected levels of important variables for the year 2000. Exogenous variables projected to these points in time include population level and distribution, national income and economic growths by regions, commercial exports and the total demand for food produced in the United States. Given these projections, land and water demands for agriculture are then estimated within the context of all agricultural policies considered together. We examine land and water requirements and demands and potential food supplies under conditions which allow (a) an efficient interregional distribution of agricultural production and land use, (b) both trend and accentuated rates of improvement in agricultural technology, (c) various price levels for water used in agriculture, (d) alternative supply control programs and (e) certain restraints on the use of insecticides and fragile lands. Under one set of conditions, the demands for land and water in agriculture are analyzed assuming that retirement or supply control programs of the type used in recent years will be extended into the future.

The amount of irrigation water needed for agriculture obviously depends on whether supply control programs are in effect resulting in land being withheld from production. Conversely, the amount of land that must be withheld from production to attain specified price and income goals for farmers depends on the amount of irrigation water used in food production, the extent of public investment to increase water supplies to farmers and the pricing of water in farm uses. For the past 40 years, the government's primary means of improving farm income has been through programs which restrain food supplies by idling cropland. Direct payments and eligibility for nonrecourse commodity loans have encouraged farmers to divert land from crop production. At the same time, the public has continued to invest in water projects and irrigation developments which increase

the supply of food commodities. Effectively, each increment in food production forthcoming from newly irrigated land in the 17 Western States has required that cropland in other farming regions be retired from production. Hence, over the last 40 years, the public has been engaged in two opposite investment programs: one that develops more irrigated land and another that reduces domestic marketings by paying farmers for leaving land idle and by utilizing publicly assisted food exports and storage programs. Obviously, then, projections of future agricultural land and water use and national food supplies need to be made in the framework of all policies relating to agricultural productivity and food supplies. Had the public investment in irrigation been smaller over recent decades, the public could now invest less in programs to idle land and reduce commodity supplies as a means of increasing farm income. Simultaneously, the use of water in agriculture would be lessened.

Competing water needs

In addition to a study of overall agricultural policies, including both conventional farm programs and investments in irrigation, this analysis is directed toward total water needs of the nation. Recent projections indicate that the nation could, under expansion of water use by both the farm and nonfarm sectors, face a water shortage at future points in time. The demand for water is projected to expand rapidly as further population growth and economic development occur in regions of the West. Not only will growing demand cause critical competition for water but also important environmental and water quality problems are posed for the future. Given projected nonagriculture demands for water in the future, this study has the specific purpose of estimating the need or demands for water when irrigation developments are considered an integral part of all agricultural policies. In other words, by how much could future demand for water in agriculture be reduced if all idled cropland were returned to production? Other major policies that can affect future agricultural water demand include the prices that are attached to water use, the structure of import and export programs for food commodities and investments in enhancing technologies on nonirrigated land.

Water quality, community development and other distributive effects

The development, use and management of water in agriculture has important distributive effects relating to both income and environmental quality. Restrained supplies of water at one location can cause nonfarm economic growth to shift to other locations. Personal incomes are affected accordingly. The low price elasticities of demand for agricultural commodities can cause reduced incomes to farmers who produce under rainfed conditions while those in newly developed irrigated projects gain as yields increase by a greater proportion than prices decline. Hence, the public is faced with broad questions in the distributions of incomes and economic opportunities as it decides whether or not to invest in particular irrigation projects. These distribution problems arise not only as the water supply increases for one location and groups of users at the potential expense of others but also through the inelastic demand relationships and total market

restraints mentioned above.

The quantities and methods of water use in agriculture also have distributive effects through water quality. Spatially, the major interrelationships between agricultural water use and environmental problems are in regions of rainfed agriculture. However, certain aspects of water use and management in irrigated farming also have distributive and environmental effects through water quality.

Irrigation development and other policies affecting farm productivity and output have important effects on community development and income distribution. In communities of newly developed irrigation projects, development normally occurs with more intensive farming. The greater yields from irrigated farming have multiplicative effects through the nonfarm sector of the community as they increase the demand for capital, fertilizer and similar inputs. They also give rise to greater volume of farm commodities to be handled, stored and processed in the community. However, a greater output and development in newly irrigated areas has indirect effects on other distant communities as it reduces the intensity of farming and the amount of land needed for production in these other areas to attain domestic food demand levels. Hence, it also reduces the potential demand for nonfarm services and activities in the latter rural areas.

Of course, an important question of the future revolves around the amount of economic development allowed or restrained by water supplies in nonagricultural population centers of the Western States. If irrigation developments were ceased, more water would be available for industrial and urban locations. Hence, the extent of development in urban centers and rural communities that compete for water also present complex problems of developmental and income distribution.

Existing Policy Complex

The public concurrently invests in two types of agricultural policies: (1) developmental policies such as irrigation, research, extension education and soil conservation practices that increase yields and output and (2) compensation policies that attempt to offset this greater productivity through supply controls including direct payments to farmers to offset low prices resulting from increased output (20). Increases in yields have allowed the nation to produce a greater output from fewer acres (Table 1.1). Even though total land in crops was reduced by about 53 million acres between 1949 and 1969, total output increased by about 40 percent. In attempts to control output and reduce domestic marketings, cropland retired under government programs reached 64.7 million acres in 1962 and averaged 56.0 million acres over the period 1961-70. Exports under public assistance reached a peak in 1965 but averaged about 23 percent of total exports over the 1961-70 period (Table 1.2). Aside from farms contained in irrigation projects where yields are increased greatly by water added, farmers in aggregate can gain in income from developmental policies and improved technology only if programs exist which restrain supply and support prices. Because of low demand elasticities, increases in output that exceed the

Table 1.1. Acreage, yield and productivity of U.S. agriculture, selected years.

Year	Thousand acres of					Yield per acre				Index of		
	Feed grains	Wheat	Cotton	Soybeans	Total cropland	Feed grains	Wheat	Cotton	Soybeans	Total output	Crop output	Agric prod.
	(000 acres)				(mill. acres)	(tons)	(bu)	(bu)	(bu)	(1919 = 100)		
1919	133,667	73,700	32,906	n.a.	374	.64	12.9	165.9	n.a.	100	100	100
1929	138,434	63,392	43,232	708	379	.61	13.0	164.2	13.3	113	104	105
1939	129,266	52,669	23,805	4,315	363	.69	14.1	237.9	20.9	124	107	125
1949	131,374	75,910	27,439	10,482	387	.85	14.5	282.0	22.3	158	131	143
1959	130,124	51,716	15,117	22,631	358	1.15	21.6	461.0	23.5	187	147	168
1969	95,427	47,555	11,075	40,857	334	1.82	30.7	433.0	27.3	222	173	187

Source: (90, 93, 115, 116).

Table 1.2. Land under retirement, exports and CCC commodity stocks, 1961-70.[1]

Year	Total land retired under government programs	Exports		CCC stocks[3]		
		Commercial	Publicly assisted[2]	Feed grains	Wheat	Cotton
	(million acres)	(million dollars)		(000 tons)		(mill. bales)
1961	53.7	3,443	1,503	58,304	33,990	1,257
1962	64.7	3,572	1,570	57,704	33,900	367
1963	56.1	3,612	1,466	46,384	31,350	1,176
1964	55.5	4,627	1,441	41,440	29,460	1,489
1965	57.4	4,499	1,598	40,896	21,360	1,948
1966	63.3	5,288	1,388	29,732	17,160	2,539
1967	40.8	5,463	1,308	14,584	6,480	2,097
1968	49.3	5,013	1,298	10,132	3,270	312
1969	58.0	4,696	1,044	13,564	3,000	34
1970	59.7	5,664	982	15,944	5,040	555

[1]Source: (93, 163).

[2]Includes disaster relief, food aid and concessional sales during calendar year.

[3]On January 1 of year indicated.

rate of growth in population and exports will, if turned loose in the market, reduce revenue from farm marketings. Since agricultural production capacity has grown rapidly under public development policies and new technologies financed through industry, pressures on the government to support or improve farm prices and income have been reflected through supply control programs that remove part of the agricultural plant from production. As more water is used for irrigation, a greater amount of nonirrigated land must be idled to attain particular price and income goals. Even some irrigated land, after having been developed under public investment, has been and continues to be diverted from production through payments for keeping it idle.

Government payments and income in agriculture

Based on Brandow's figures (2), estimated public costs of programs to improve farm income were approximately $5 billion in 1971. Table 1.3 indicates the amount of land retired under government programs and the direct treasury payments to farmers, mainly for retiring this land, over the period 1961-70.[1] (Auxiliary costs of administration and varied price support programs are not included and, for example, are approximately $1.5 billion.) Direct payments to farmers, mainly for purposes of restraining or lessening supply, have come to be an important proportion of total net farm income. In the absence of public investment in irrigation, aggregate output of farm products would have averaged less over the last decade. Accordingly, to attain the same level of farm income, the public could have spent less on direct payments for supply control purposes. However, in addition to the effects of supply control brought about by payments for idling land, programs that provide price supports through nonrecourse loans and that lessen domestic marketings through publicly assisted food aid and export programs also contribute significantly to net farm income.

Net farm income in 1970 was $15.9 billion and included $3.7 billion in direct farm payments, with $3.3 billion of this paid for retirement of land under wheat, cotton, feed grain and soil bank programs. Estimates indicate that 1970 net income would have been only $9.9 billion under short-run conditions and $11.3 billion under long-run conditions in the absence of government programs (46, p. 34).[2] Obviously, then, those programs that promote a greater supply of farm commodities could have important impacts on farm income in the absence of farm programs. Similarly, the investment in supply control, direct payment and price support programs

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[1]About 90 percent of these payments were for land retirement at the end of the period. The other approximately 10 percent also relates to supply and prices and includes ASCS, Great Plains Conservation, Sugar Act and Wool Act payments.

[2]Short-run conditions refer to the immediate effects if all programs were terminated. Long-run effects refer to the conditions expected to prevail if all farm programs had been terminated for some time and adjustments were made accordingly in acreage and supply as farmers migrated from agriculture and shifted acreage.

Table 1.3. Land retired, direct payments to farms and net farm income, United States, 1961-70.[1]

Year	Land retired under			Direct program payments to farmers					Income		
	Feed grain, wheat and cotton programs	Long-term or soil bank	Total	Feed grains	Wheat	Cotton	Other	Total	From farming	From government payments	Total
	(million acres)			(million dollars)					(million dollars)		
1961	25.2	28.5	53.7	772	42	-	679	1,493	11,494	1,493	12,987
1962	38.9	25.8	64.7	841	253	-	653	1,747	11,468	1,747	13,215
1963	31.7	24.3	56.1	843	215	-	638	1,696	11,510	1,696	13,206
1964	38.0	17.4	55.5	1,163	438	39	541	2,181	10,085	2,181	12,266
1965	43.0	14.0	57.4	1,391	525	70	477	2,463	12,524	2,463	14,987
1966	47.6	13.3	63.3	1,293	679	773	632	3,277	12,976	3,277	16,253
1967	25.2	11.0	40.8	865	731	932	551	3,079	11,803	3,079	14,882
1968	35.7	9.2	49.3	1,366	747	787	562	3,462	11,363	3,462	14,825
1969	50.2	3.4	58.0	1,643	858	828	465	3,794	13,097	3,794	16,891
1970	56.2[2]	.1[2]	59.7[2]	1,504	871	919	423	3,717	12,222	3,717	15,939

[1]Source: (93, 125).

[2]Estimated.

needed to attain a given income level increases with investments in programs such as irrigation development which directly increases yield and output.

Other output-increasing technologies such as improved breeds and varieties, pest control, and nutrition of plants and animals serve in a similar manner with irrigation development and greater water use. The various technologies are similar with respect to their effect on aggregate output, prices and farm income. (For the same reason, however, for needed increases in output to meet population growth and increased exports, technologies represented by improved breeds, nutrition, husbandry and pest control can serve as substitutes for irrigation water in attaining corresponding national output levels.)

Substitutability of Technologies and Inputs

The various capital technologies developed for agriculture serve as substitutes for both land and labor. Over the period 1940 to 1970, U.S. agriculture added $63.6 billion in nonland capital while output increased by 73 percent and the farm labor force fell from 11.0 million to 4.2 million workers--a decline of 62 percent. While total crop output increased 31.6 percent between 1950 and 1970, total crop acreage declined by 41 million acres during the same period. This decline over 1950-70 in total cropland was accompanied by a $37.4 billion increase in nonland capital, an increase of 11.3 million acres in irrigated land and a decline of 5.7 million (58 percent) in farm workers.

The substututability of capital technology for land and labor is obvious. If new varieties, pest control and fertilizers increase crop yields from 60 to 100 bushels per acre, then the substitution potential is this: prior to the added technologies, 1,200 bushels could be produced on 20 acres; after the technologies are added, the same output can be produced on 12 acres. If an acre with a yield of 60 bushels requires 5 hours of labor before the added technologies but requires 6 hours for servicing the larger inputs and greater output after the yield-increasing technologies, the following labor quantities are involved: to produce 1,200 bushels, 100 hours before and 72 hours after the added technologies.

It is technological change of this type that has been important in increasing the productive capacity of U.S. agriculture and allowing a greater output to be produced with smaller labor and land inputs. Of course, in addition to effects of biological innovations and a smaller crop acreage, farm employment also has been reduced by mechanical innovations which are direct labor substitutes. These capital technologies used for crops grown under rainfed conditions and improved livestock practices also serve as substitutes for irrigation water. A given level of output can be attained through use of more capital technologies under rainfed conditions and less stream or ground water used for irrigation, or vice versa.

Water for crop irrigation serves similarly in substituting for nonirrigated land, total cropland and farm labor. Since it greatly increases

yields, greater farm use of water has large land-substituting effects. For example, if corn yields are 20 bushels before and 120 bushels after development of irrigated farming, these are the substitution effects: prior to irrigation, 1,200 bushels could be produced with 60 acres of land and 300 hours of labor when per acre labor requirements are five hours. However, if per acre labor requirements are eight after irrigation development, the 1,200 bushels can be produced with 10 acres of land and 80 hours of labor.

Water and capital technologies also serve as substitutes for each other. Typically, water used on newly irrigated land in western locations has, through the mechanisms of government programs and supply control, been substituted for land in other regions. In the above illustration, for example, if we suppose 2,400 bushels has been produced by 20 acres of nonirrigated land producing 60 bushels per acre plus 60 acres of land producing 20 bushels per acre, then this substitution is possible: the entire 2,400 bushels can be produced on 20 acres of newly irrigated land where the yield is increased from 60 to 120 bushels. The 60 acres of nonirrigated land (producing 20 bushels per acre) then can be displaced (or idled) while production remains at 2,400 bushels.

The substitutability of water and other technical inputs can be illustrated more formally through technical examples based on experimental data. The water-fertilizer response or production function in Equation 1.1 has been estimated for corn on Nunn clay loam in Colorado where G^* is pounds of corn (grain) per acre, W is irrigation water applied in inches and N is pounds of elemental nitrogen applied per acre.[3]

$$G^* = 4{,}579.50 + 549.20W + 10.90N - 29.96W^2 - 0.03N^2 + 0.06WN \qquad (1.1)$$

From this response function, it is possible to derive a "substitution (yield isoquant) equation" between water and nitrogen by representing quantity of water "required" as a function of the yield levels.

$$W = 0.15 + 0.00107N - [(9.15 + 0.00107N)^2 - 2.00G^* + 0.06186N^2 - 0.18260N - 76.43]^{.5} \qquad (1.2)$$

Using Equation 1.2, combinations of irrigation water (inches applied per acre) and nitrogen (pounds per acre) which will produce two yield levels have been derived in Table 1.4. As expected, a declining marginal rate of substitution of nitrogen for water is indicated and vice versa. Clearly, water is a substitute for fertilizer in attaining a given output level and vice versa.

The substitutability of water for land also can be illustrated from the response function in Equation 1.1. To illustrate the effects for water

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[3]These data result from a set of studies conducted cooperatively by the Center for Agricultural and Rural Development of Iowa State University, the Bureau of Reclamation of the U.S. Department of Interior and Colorado State University. For details on experimental design and statistical analysis, see (39).

Table 1.4. Yield isoquants for nitrogen fertilizer and irrigation water applied to corn, 100 and 130 bushels.[1]

Pounds N per acre	Inches water applied per acre
100 bushel yield	
0	2.10
50	1.06
100	0.44
150	0.16
200	0.16
130 bushel yield	
0	6.74
50	5.98
100	4.60
150	4.04
200	4.01

[1]Source: Derived from Equation 1.2.

alone, first set the level of nitrogen fertilizer at 100 pounds per acre. Next, since Equation 1.1 refers to per acre rates, multiply the right-hand side of the equation by A (acres). The resulting Equation 1.3 expresses grain production as a function of irrigation water and acreage (fertilized at 100 pounds per acre). For this land and year, yield alone for an acre

$$G = 5{,}369.50A + 555.20W - 29.962W^2A^{-1} \tag{1.3}$$

fertilized at 100 pounds of nitrogen is high. Hence, the marginal rates of substitution of land for water (and vice versa) are lower than normally would be the case for land of low rainfall. However, the equation expressing the marginal rate of substitution of applied irrigation water for the Nunn clay loam to which it is applied becomes:

$$\frac{\partial A}{\partial W} = \frac{59.92W - 555.20}{5369.5A + 29.96W^2A^{-2}} \tag{1.4}$$

These relationships, although restricted to a specific soil type, capital input, year and crop, indicate the direct nature of substitution possibilities between water and other resources. Actually, the rates of substitution will be even larger if we compare (a) the combined inputs of water and capital technologies on newly irrigated land as replacement resources for (b) nonirrigated land and complementary inputs on other land at the same or a different location. However, the formal relations indicated above systematically illustrate that society does have technical substitution possibilities in capital technologies for both land and irrigation water (and vice versa) in meeting food demand.

Development, Distribution and Output of Irrigated Agriculture

Expanded use of water in agriculture has come from both private and public investment. Total U.S. irrigated acreage increased from 14.6 million acres in 1929 to 25.8 million acres in 1949 and 43.3 million acres in 1969 (187, Neg. ERS 7061-69 (9)). While the increase over the period 1949-69 is considerably greater than that for 1929-49, the rate of increase evidently has been fairly steady at somewhat more than 800,000 acres per annum since 1949. The Economic Research Service estimates that 20 percent of the total value of crops produced in the United States comes from irrigated land (62). In 1959, the most recent census year for which published data are available, 92.5 percent of the irrigated land was in the 17 Western States (Figure 1.1). Data from the 1959 Census of Agriculture (Figure 1.2) show that of a total of 30.5 million irrigated acres in these 17 states, only 6.6 million were under federal projects while 23.9 million were non-federal (districts, individual farm, etc.). Non-federal developments dominate in acreage for water from both natural flows and ground water. Acreage under federal projects represents the majority source for land irrigated from storage sources (Figure 1.3). Figure 1.4 shows the distribution of irrigation water from

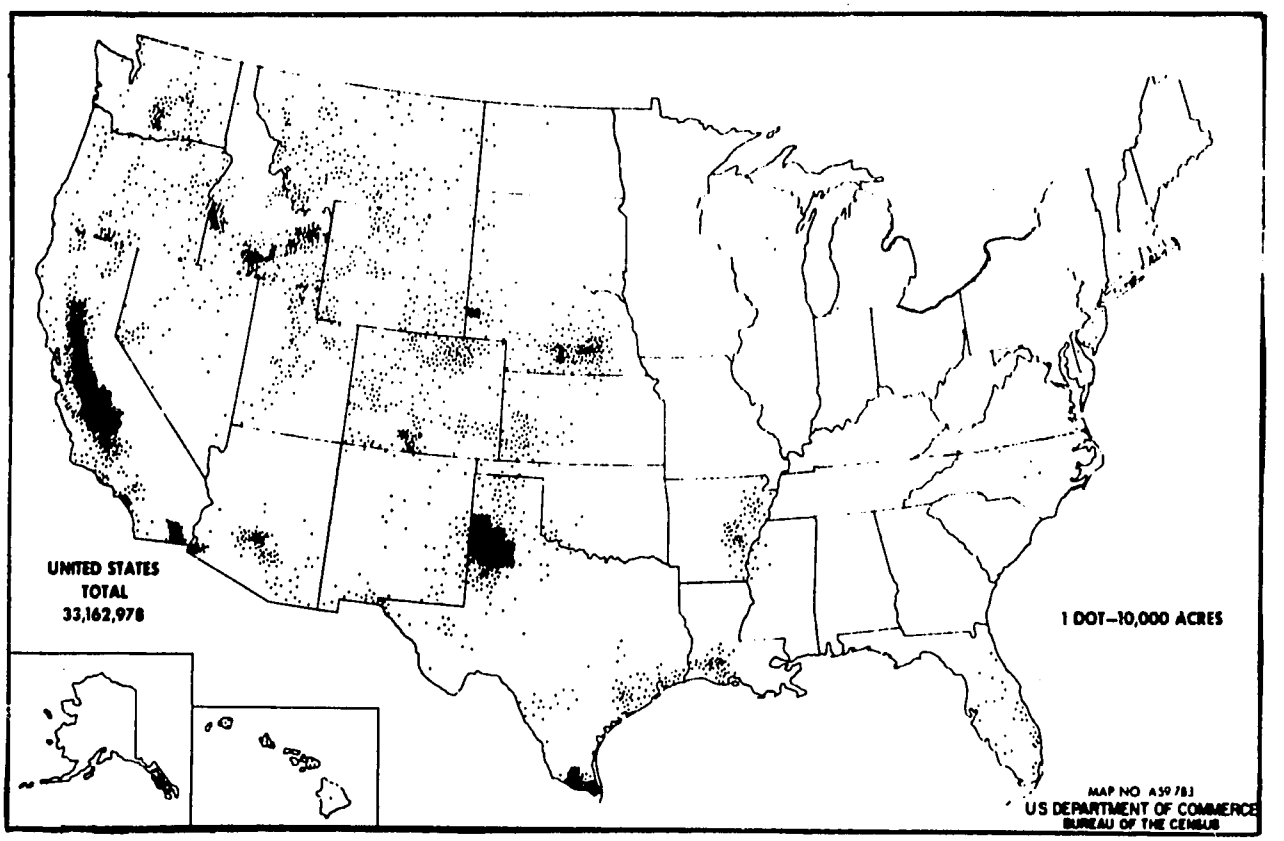

Figure 1.1. Acreage of irrigated land in farms, 1959. Source: (185).

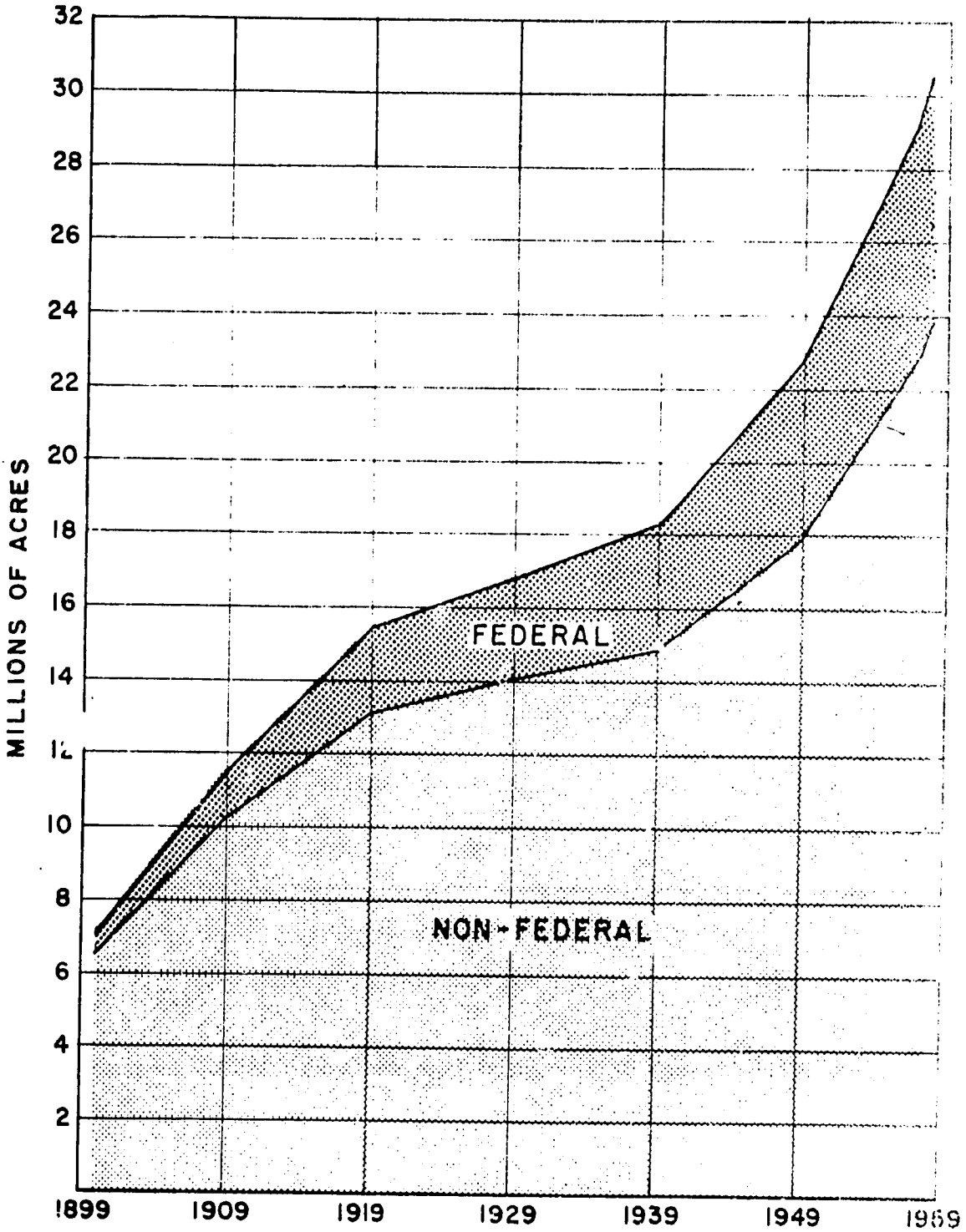

Figure 1.2. Irrigation development in the 17 Western States, 1899-1959. Source: (210).

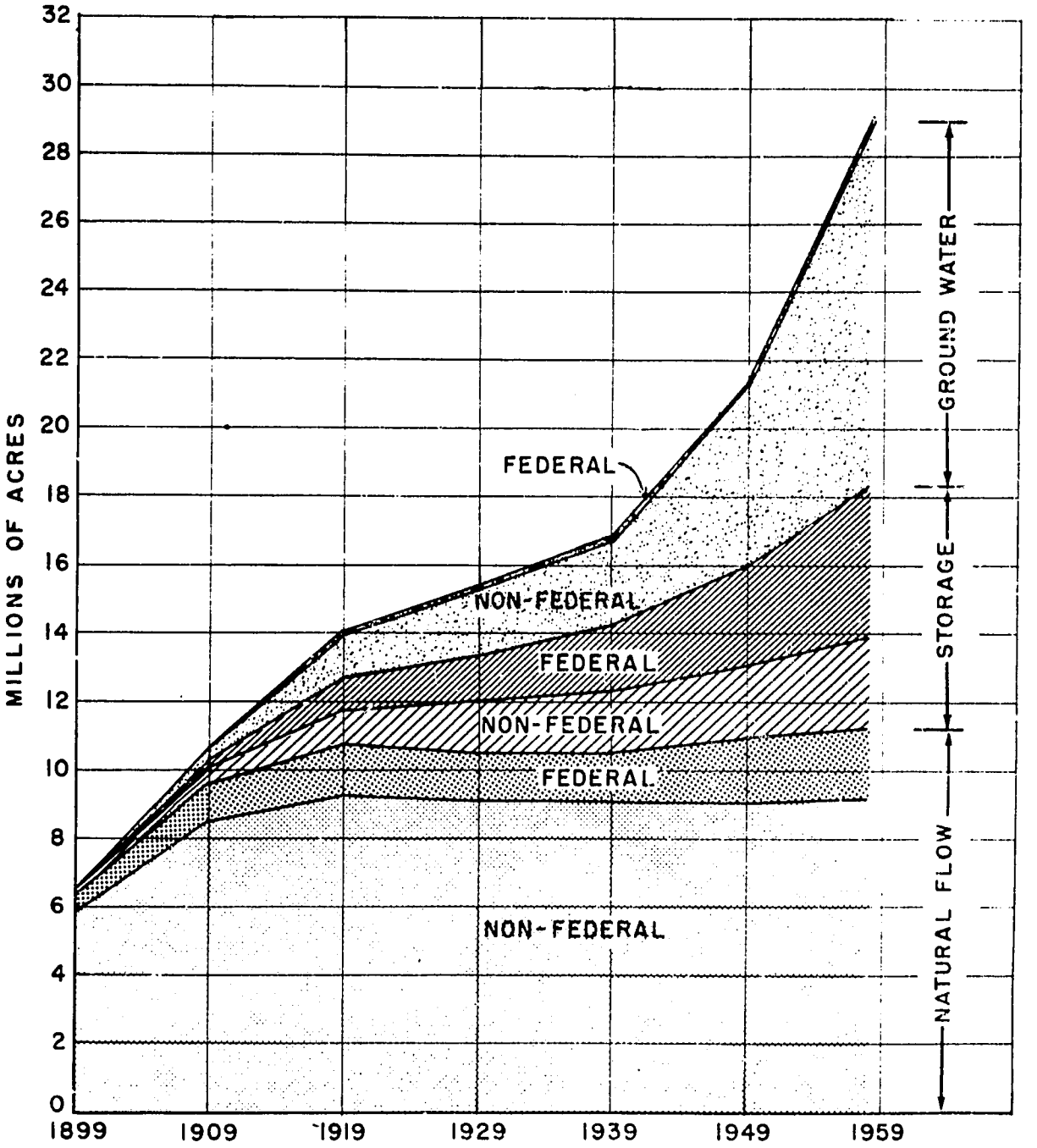

Figure 1.3. Source of water in irrigation development in 17 Western States, 1899-1959. Source: (210)

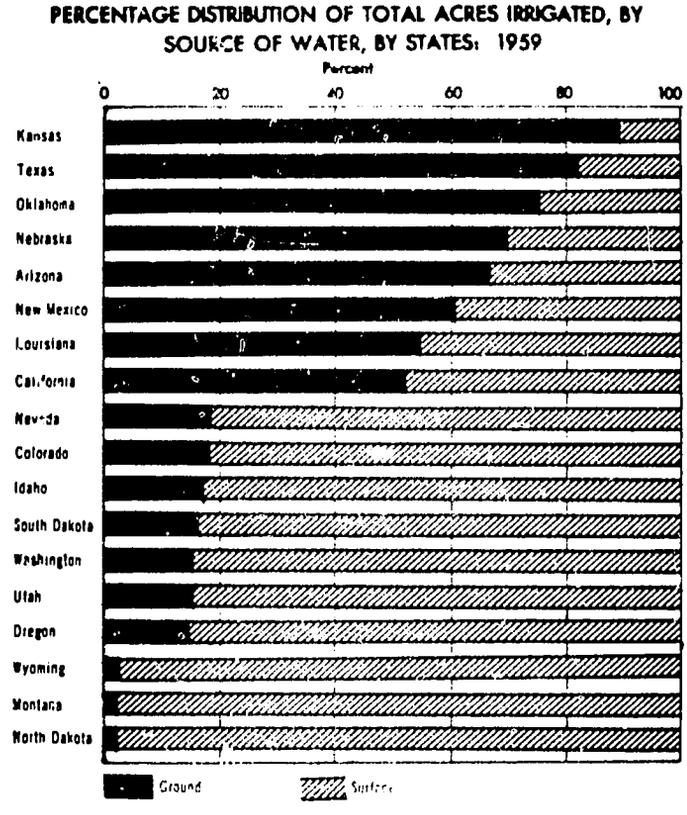

Figure 1.4. Percentage distribution of total irrigated area by source of water, 17 Western States, 1959. Source: (185).

ground water and surface sources for the 17 Western States. In recent years, the dominant increase in irrigated acreage has been from private investment of farmers in pump irrigation from ground water sources (Figure 1.3). Land irrigated from federal storage projects increased by 131 percent from 1939 to 1959. However, the acreage irrigated from ground water supplies, which are almost entirely developed and financed by individual farmers, increased by about 306 percent and dominated increased water use and additional land irrigated during the period. Irrigation from flowing water, under both federal and non-federal development, has been nearly static since 1919.

As Figure 1.5 indicates, irrigated acreage bears the highest proportion to total crop acreage in the 17 Western States. Because water is the main limiting resource in crop production, the proportion of the value of the crops produced on irrigated land in the 17 Western States is much greater than the proportion of the total crop acreage grown under irrigation. However, pasture and hay dominate all other crops in the use of irrigated land even in these states (Figure 1.6).

Irrigated farming and agricultural policy

For those unacquainted with the data, a belief prevails that the dominant source of investment and the large increment in investment in recent decades has been by the public through the Bureau of Reclamation (Figure 1.2). This is not true, however, since only 609,471 acres were added through public development while 6,449,313 acres were added through private development between 1939 and 1959 (181, 185). The respective amounts between 1919 and 1959 were 4,920,086 and 7,225,143. Hence, far more of the large increment in output due to higher yields on irrigated land is attributable to private investment than to public investment. To an extent, individual farmers who invest in tapping ground water supplies to produce higher yields and increase output are not unlike farmers elsewhere in the nation who invest in more fertilizer to boost yields and supply. Both invest in a category of inputs which is profitable to them because of yield increments under favorable costs and prices. True, further investment in water supplies and distribution by irrigation farmers has been profitable because prices have been supported through the various federal programs. Too, some public subsidy has gone into the development of private irrigation systems by means of technical help by technicians of SCS and cost-sharing under ASCS payments. Other farmers of the nation, however, have received exactly these same public benefits for the crops they produce and the inputs they emphasize. Farmers in the Corn Belt and Southeast, for example, use more fertilizer inputs because they are highly profitable under the price levels maintained by federal programs. SCS technicians have helped them attain higher yields through plans for drainage and for moisture conservation and greater soil productivity by means of contouring, terracing and other mechanical practices. Similarly, these and other yield-increasing practices and inputs have been extended over the Corn Belt, Southeast and agriculture generally through cost-sharing ASCS payments. Irrigation farming is not unique in the extent that its output has been furthered by favorable prices of outputs and inputs of federal programs.

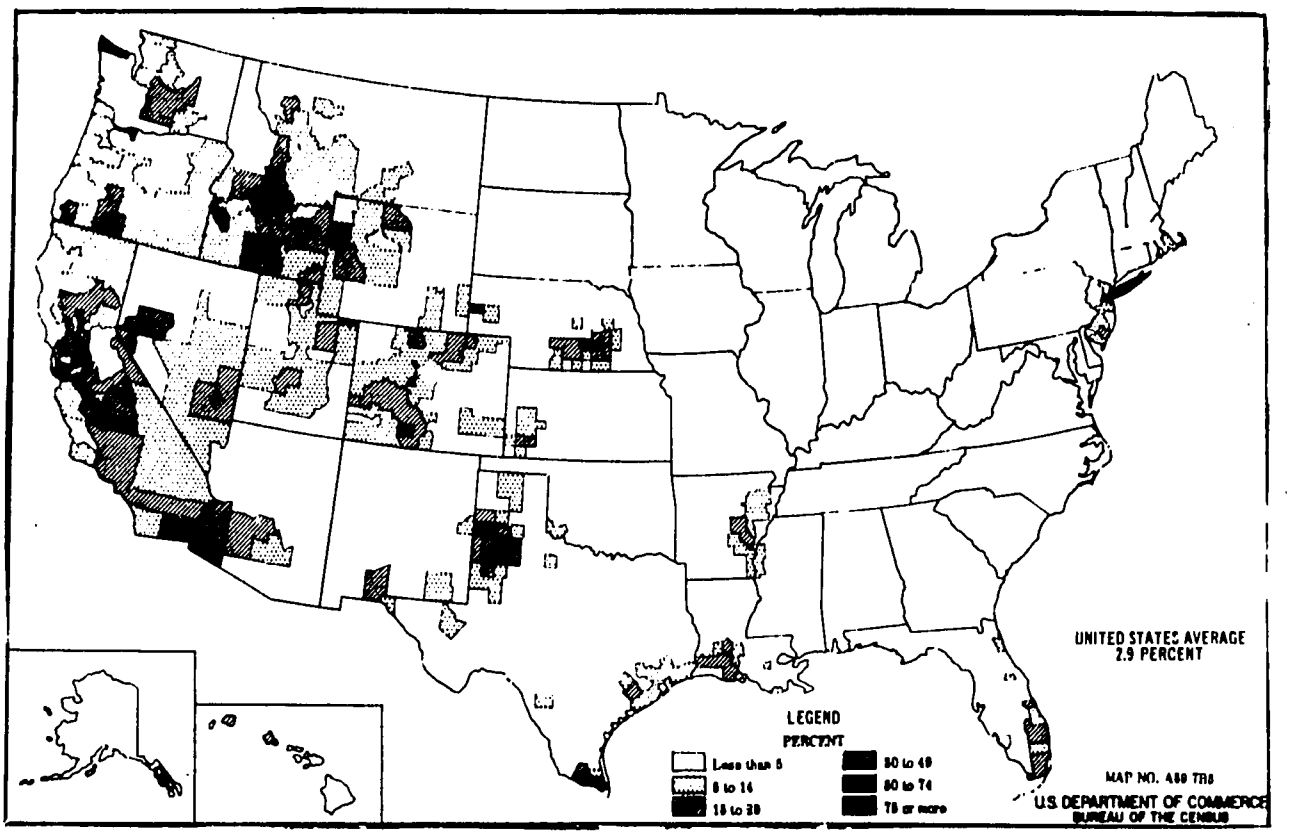

Figure 1.5. Irrigated land as a percent of all land in farms, 1959. Source: (185).

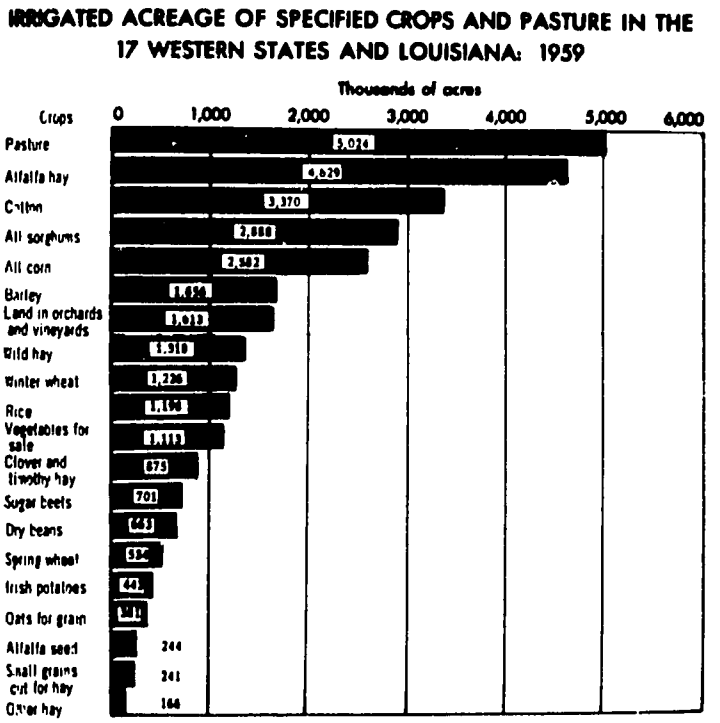

Figure 1.6. Irrigated acreage of specified crops and pasture in the 17 Western States and Louisiana, 1959. Source: (185).

The problem of prices and returns imputable to large supplies of agricultural products and highly inelastic demands for foods is not caused by farmers who invest in irrigation systems any more than it is caused by farmers who invest in other practices and inputs because it is profitable to them. The basic problem of all farmers, those depending on rainfall and (or) irrigation water, is the competitive structure of the market for farm products. Under these market conditions, it is profitable for the individual farmer, before the masses have done so, to invest in water, new varieties, more fertilizer and in other practices. However, when the masses of farmers follow a similar development, as they eventually do, the aggregative effect is a decline in total market revenue due to the inelastic demand for food. It has been the objective of federal programs to control or reduce supply to offset this aggregative effect when the mass of farmers use output-increasing practices and resources more rapidly than demand allows their absorption at favorable prices in the market. The need for such programs must be attributed to the actions of farmers who produce under rainfed conditions as much or more than to those who employ irrigation water. The latter account for only 20 percent of the total value of crops produced and emphasize fruits and vegetables which generally have higher price elasticities of demand than commodities such as pork, feed grains and wheat.

Hence, the important questions of water use are not those of needs and expenditures related to agricultural supply and pricing policy alone. Rather, the questions of future water use are those of allocations of this resource among the most urgent and highly productive alternatives as the nation's population and economic activity grow. The basic question analyzed in this study is: Can the United States meet future food demands without unreasonable real costs of food to consumers--considering the total natural resources available to agriculture, the prevalence of farm policies that have immobilized around 56 million acres of cropland and the potential need to reallocate some water from agriculture to municipal and industrial uses?

Institution rights, pricing and compensation

The allocation of water among competing crop and locational uses of agriculture is based, of course, upon a complex and deeply imbedded system of historical and legal rights. The distribution of water rights and uses among crop and locational alternatives generally bears little relationship to the marginal productivity of water in either physical or value terms. Hence, if required, it is possible that given water supplies could be allocated among crops and locations to allow (a) the same waters to produce a greater output or (b) the same output from a smaller amount of water. The lack of effective market and pricing mechanisms and the institutionalization of water rights prevents reallocation of water in terms of its marginal productivity to allow either of these accomplishments. It is possible, however, that a pricing structure and compensation methods can be established for both water and water rights to encourage these reallocations and benefit both producers acquiring larger water supplies and those releasing or selling water rights and supplies. These possibilities are

outlined in later sections. The output from models such as the one applied in this study provides a quantitative basis (or set of imputed values) for examining such pricing structures.

Previous Studies of Water Supply-Demand Balances

A number of studies have been made of current and future demands for water. The Water Resources Policy Commission, appointed in 1950, made recommendations for a comprehensive policy of water resources development. In its report, A Water Policy for the American People, the Commission stated that midway through the twentieth century two facets became compellingly clear (209, p. 2):

> The first is that water is limited in relation to the many and varied needs for its use. These needs will grow in size and complexity as the population grows and as industry develops. The second...is that the management, conservation, and use of our resources is inextricably bound up with the management, conservation, and use of our land and that both are essential to our expansion as a Nation.

The Commission also recognized the interregional relationships between land and water use (209, p. 6):

> Irrigation and drainage, navigation and flood control, the maintenance of underground water levels, the control of stream pollution resulting from human, animal and industrial wastes, the generation of electric power, the protection of salmon and other fish resources, the provision of ample domestic water supply - all these purposes have legitimate claims within any one basin; but if one is developed without regard for its effect on the others, conflicts and losses will result.

A Presidential Advisory Committee on Water Resources Policy was appointed in 1954. In its report, Water Resources Policy, the Committee stated the need for a sound water policy (63, p. XI).

> A sound water policy...must look toward an adequate supply of water for our people, prevent waste, reduce water pollution to its lowest practicable level, provide means for the best and most effective distribution of water, improve navigation, and take steps to check the destructive forces of water which destroy land, property and life. There are many different problems in different areas. It is neither practicable nor desirable to have only Federal responsibility. There is no single 'national' water problem.

The Committee made a number of recommendations on water rights, priorities for use of water, evaluation of water projects, authorization of water resources projects and cost sharing arrangements.

The U.S. Senate Select Committee on National Water Resources was established in 1959. The Chairman of the Committee was Senator Kerr and the Committee's report is commonly known as the Kerr Report. In its summary report, the Select Committee concludes (212, p. 15):

> ...the task confronting the Nation in the water field is one of meeting the growing demands on water resources in the most efficient manner consistent with accepted public aims.

The Select Committee recognized that if demands such as waste dilution, irrigation, outdoor recreation, and fish and wildlife conservation are to be met, the first and most important step toward getting the job done is (212, p. 2):

> ...development of increased public awareness and understanding of the Nation's water resources problems; of their effects on the Nation's economy; and of possible ways of solving them.

Facilitating this step was one of the primary objectives of the Select Committee on National Water Resources.

As a direct result of the Select Committee's recommendations, a Water Resources Planning Act (S.2246) was proposed in 1961 by President Kennedy (11, p. 160). During the following years a number of changes were made in the proposed bill, and the bill was not enacted until 1965 as the Water Resources Planning Act (PL 89-90). The bill consisted of three major provisions (11, p. 160): (1) establishment of the Water Resources Council, (2) establishment of River Basin Commissions and (3) grants to states for water resource planning and for pursuit of an active role in the comprehensive planning program of the Federal government. One of the first tasks of the Water Resources Council was to make an assessment of the nation's water resources. The Nation's Water Resources was completed and submitted to Congress in November of 1968. The report describes the nation's water and related land resources and their use and management problems.

Projections were made of water and related land use for 1980, 2000 and 2020. Water supplies and projected water withdrawals and consumptive uses were obtained for 19 river basins in the conterminous United States. In its findings, the Council does not report any basins as being water deficient by 2020. There are a number of basins, however, particularly the Upper Colorado and Lower Colorado river basins, where the consumptive use is more than 70 percent of the total available supply by 2020 (216, Figure 1-21).

In a more recent study, Wollman and Bonem calculated the total required flows (consumption) plus waste dilution and water available in 1960 and 2000 for 15 river basins in the United States (223, Table 82). Their results are summarized in Table 1.5. Although the Water Resources Council did not report any water deficit areas for either 2000 or 2020, Wollman and Bonem project water deficits in four river basins for 2000. The river basins are the Texas-Gulf, Rio Grande, Colorado and Great Basin.

Table 1.5. Total required flows (consumption) plus waste dillution and water available in 1960 and 2000 as reported in the Wollman-Bonem study by river basin.[1]

River basin	1960 Regulated flow	1960 Required flow	1960 Surplus or deficit	2000 Maximum regulated flow	2000 Required flow	2000 Surplus or deficit
	(million acre feet per year)					
North Atlantic	37.30	9.60	27.70	152.54	27.69	124.85
South Atlantic-Gulf	106.41	13.26	93.15	208.38	53.96	154.42
Great Lakes	13.78	9.44	4.34	71.20	28.56	42.64
Ohio	23.64	2.58	21.06	127.81	12.35	115.46
Tennessee	23.30	1.82	21.48	45.24	6.43	38.81
Upper Mississippi	17.70	2.07	15.63	51.67	5.96	45.71
Lower Mississippi	1.68	1.76	-0.08	39.44	5.95	33.49
Missouri[2]	34.72	14.97	19.75	46.83	22.22	24.61
Arkansas-White-Red	34.28	8.32	25.96	72.49	13.38	59.11
Texas-Gulf	17.25	13.85	3.40	29.01	29.96	-0.95
Rio Grande	3.36	5.59	-2.23	3.36	7.31	-3.95
Colorado[3]	12.77	16.20	-3.43	12.77	28.23	-15.46
Great Basin	6.05	6.45	-0.40	7.77	7.85	-0.08
Columbia-North Pacific	70.35	18.00	52.35	150.74	41.32	109.42
California-South Pacific	30.13	31.58	-1.45	51.86	47.70	4.16
United States	432.72	155.49	277.23	1,071.11	338.87	732.24

[1]Source: (223, Table 82). Assumes a medium level of economic growth and a minimum flow for waste dillution in 2000.

[2]Includes Souris-Red-Rainy flows and requirements.

[3]Includes Upper Colorado and Lower Colorado basins.

According to their study, the last three river basins also had a water deficit in 1960 along with the Lower Mississippi and California-South Pacific basins.

In summary, research and work on water over the past two decades have stressed the importance of a corrdinated land and water use policy determined on an interregional basis with emphasis in the most recent studies on the future water demand-supply situation.

In 1965 agriculture (irrigation and livestock water requirements) used 92.5 percent of all the water consumed in the 17 Western States and 85.3 percent of all the water used in the nation. For 2000, the Water Resources Council estimates that agriculture will use 82.2 percent and 72.6 percent, respectively (216, Tables 7-3-5 and 7-3-9). Since agriculture is and will continue to be the largest user of water, a study of future water requirements in agriculture is of primary importance, especially if a reallocation of water among alternative uses becomes necessary in the future. A study of future water needs in agriculture is also needed in light of recent presentations to Congress of broad proposals for water developments in the Western States (54, p. 1). The study should include an interregional analysis and consider both land and water use alternatives.

Objectives of the Quantitative Analysis

This study includes the application of a large-scale mathematical programming model to estimate demand or need for land and water used in agriculture. Projections are made for the year 2000. The analysis is made in the context of water needs and irrigation development as an integral part of overall land use, agricultural and food policy. We are concerned with the efficient use of water and agricultural resources generally when policy alternatives are used both for commercial farming and irrigated agriculture. Hence, we examine the demand for water in irrigation should current types of supply control programs be eliminated and all land currently retired be returned to production. We also examine the potential of meeting future food demands under alternative rates of population growth, economic development and farm exports under both (a) the absence of farm programs of current types and (b) the continuation of these programs. In the case where other restraints on agricultural supply are removed, the analysis suggests the amount of land which might be diverted from irrigation and, hence, the amount of water that might be made available to meet future nonfarm demands. Since water and other improved farm technologies can serve as substitutes for each other in attaining a given food output, examination is made of total acreage and irrigated production needed if the rate of technological advance in agriculture is accentuated beyond trend levels by public or other means. For these purposes, accentuated rates of technological advances for (a) crop production in the Southeast and (b) feed conversion rates for all U.S. livestock production are introduced into the programming model. Examination is made of the potential effects of alternative pricing policies for water on agricultural output and future water requirements. Finally, supply potentials are examined under conditions wherein restraints on the

use of insecticides and fragile lands might be exercized.

In general, the study is an analysis of the interregional distribution of agricultural production, land use and farm water demand or requirements under alternative futures with respect to commercial agricultural policy, technological advance, export levels of farm products, magnitude of the U.S. population and the pricing and public investment policies for agricultural water uses.

Commodities included in the analysis are corn, sorghum, wheat, barley, oats, soybeans, cotton, sugar beets, hay, pasture, fruits, nuts, rice, vegetables, milk, pork, beef, broilers, turkeys, eggs and lamb and mutton. All projections are for the year 2000.

II. BASIC MODEL USED IN THE ANALYSIS

The quantitative analysis has been made by means of a mathematical programming model. Since time limits did not allow incorporation of demand functions and formulation of a nonlinear objective function, the programming model is of purely linear construction. The linear model includes 5,426 real variables or activities and 3,220 equations including 1,650 limits or bounds on individual activities. The activities include those for crop production, livestock production, water distribution, commodity transformation, final domestic demands, net export demands, and commodity transportation.[1] Bounds on specific activities serve as restraints on land available for wild hay and pasture, domestic and net export demands and regional concentration of production. Other restraints are provided by equations for land, crop and livestock commodities, water, and certain intermediate products. The construction of the programming model is given in greater detail below.

Regions and Their Delineation

This programming model of interregional competition determines the location of crop and livestock production and water use, given resource availability and commodity demands in the year 2000. To reflect the interregional nature of the analysis, the United States was partitioned into sets of areas and regions appropriate for various restraints and demands.

Producing areas (PA)

Producing areas are delineated such that (a) a single activity can be legitimately defined to represent production of a crop in that area and (b) the set of producing areas can be used as the elements of sets of market and water supply regions. The United States is partitioned into 223 producing areas, each of which is an aggregation of contiguous counties (Figure 2.1). The producing areas are composed of subsets of the counties within water resources subregions defined by the Water Resources Council (218).

Water supply regions (WSR)

Since the supplies and uses of water are basic to the programming model, water supply regions are defined such that each approximately represents a physical region in which a water supply can be said to exist. In the western states, 51 water supply regions were constructed (Figure 2.2). Each is an aggregate of contiguous producing areas and is wholly contained within one of the river basins shown in Figure 4.1. The water supply regions closely approximate those defined by the Water Resources Council (216).

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[1] A set of land retirement activities was defined for certain solutions as described in a later section.

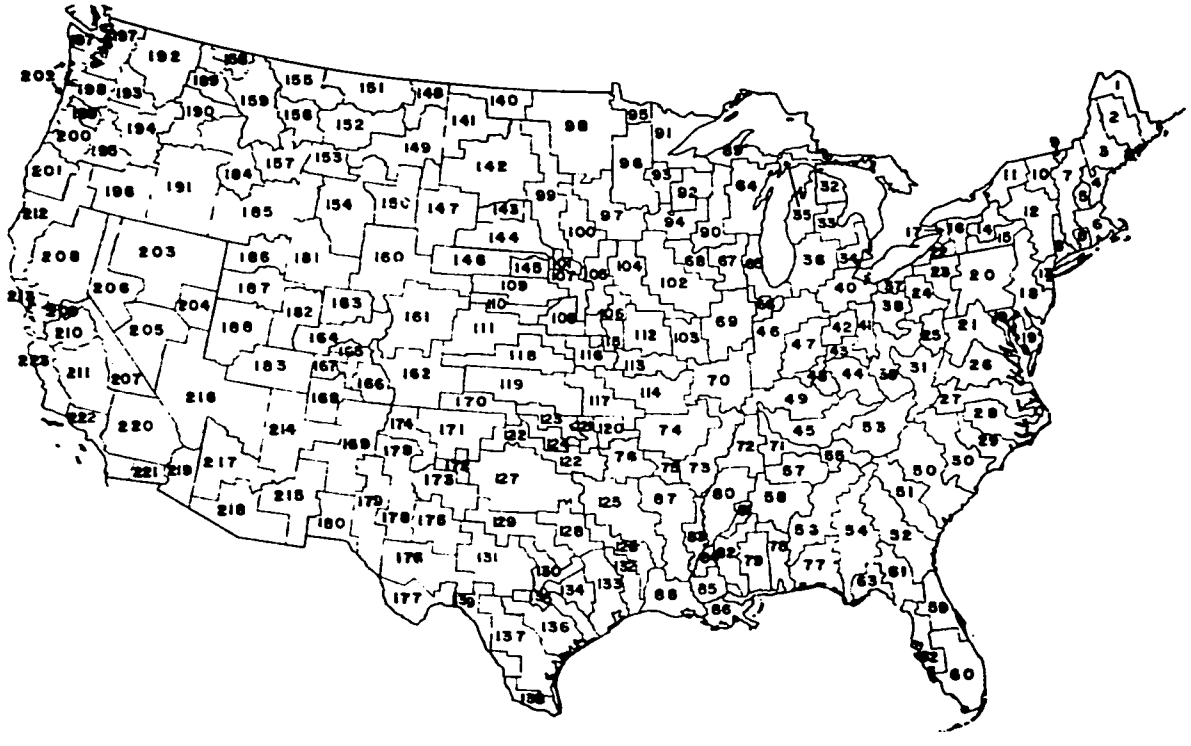

Figure 2.1. The 223 producing areas

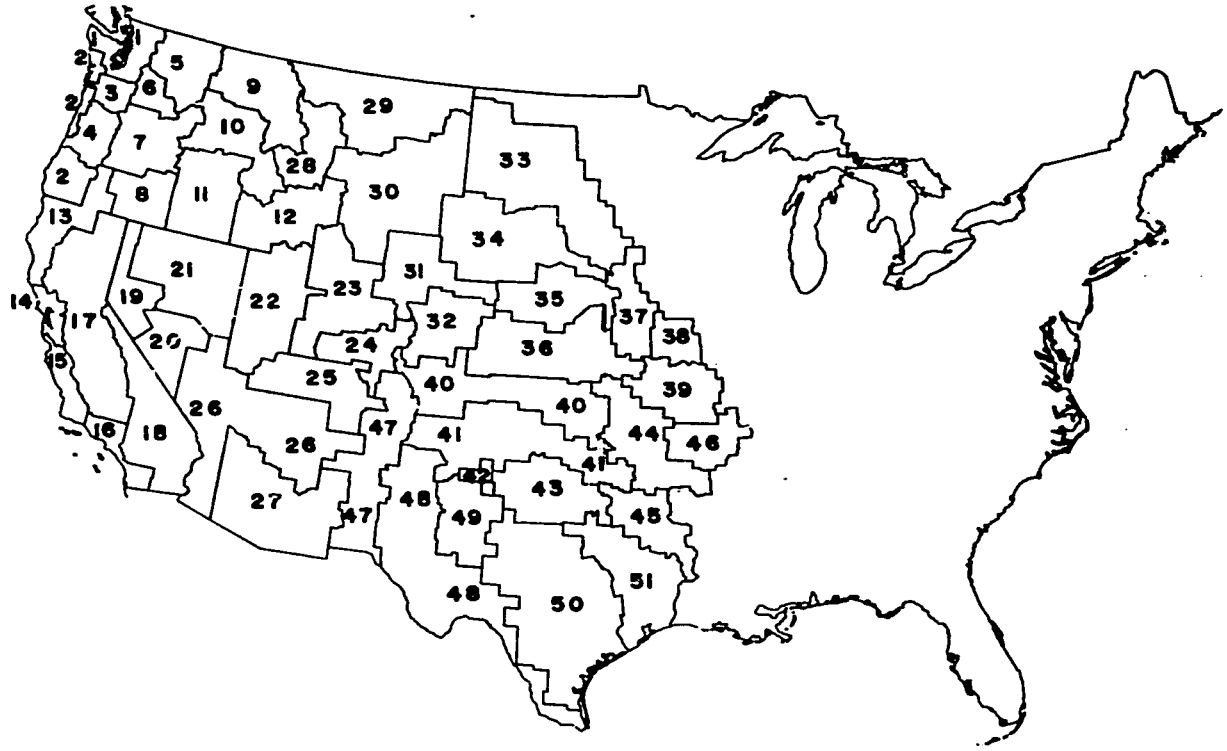

Figure 2.2. The 51 water supply regions

Consuming regions (CR)

Consuming regions are defined to represent regions in which a market can be said to exist. Based on "central place" theory, 27 consuming regions are delineated around major United States metropolitan areas and/or transportation centers. Each region is an aggregate of contiguous producing areas (Figure 2.3).

Activities

Over 5,000 activities are employed to represent production, purchase, transformation, transportation, and consumption of agricultural resources and intermediate and final products. Each activity level is allowed to vary such that $L_i \leqq X_i \leqq B_i$. Where X_i is the level of the ith activity, L_i is the minimum level of X_i allowed and B_i is the maximum level of X_i allowed, i.e., L_i is the lower bound and B_i is the upper bound on the ith activity. Generally, L_i is set at 0 and B_i is set at $+\infty$, but under certain circumstances L_i and(or) B_i is set at a specified finite real number as described below.

Final demand

1. A "population and industry" activity is defined for each of the 223 producing areas and, for each, L_i is set at the projected level of population of that PA. Coefficients are entered into the programming model for each such activity so that the following commodity and water supplies are depleted:

(a) beef, pork, and milk products based on demand relations;

(b) water (when the PA is in the WSR) based on quantities of water consumed for municipal, industrial, recreational and thermal electric power purposes;

(c) corn and sorghum, oats and barley, and wheat based on quantities used for milling, brewing, etc; and

(d) cotton lint and sugar beets based on quantities used for all purposes.

All coefficients in these activities are on a per capita basis.

2. One activity is defined for the national production of each of (a) broilers, (b) turkeys, (c) sheep and lambs, (d) eggs and (e) other animals such as horses and mules. The level of each activity is bounded so that L_i is equal to the national demand. Coefficients are defined to deplete the supplies of water, corn and sorghum, oats and barley, wheat, hay and oilmeals.

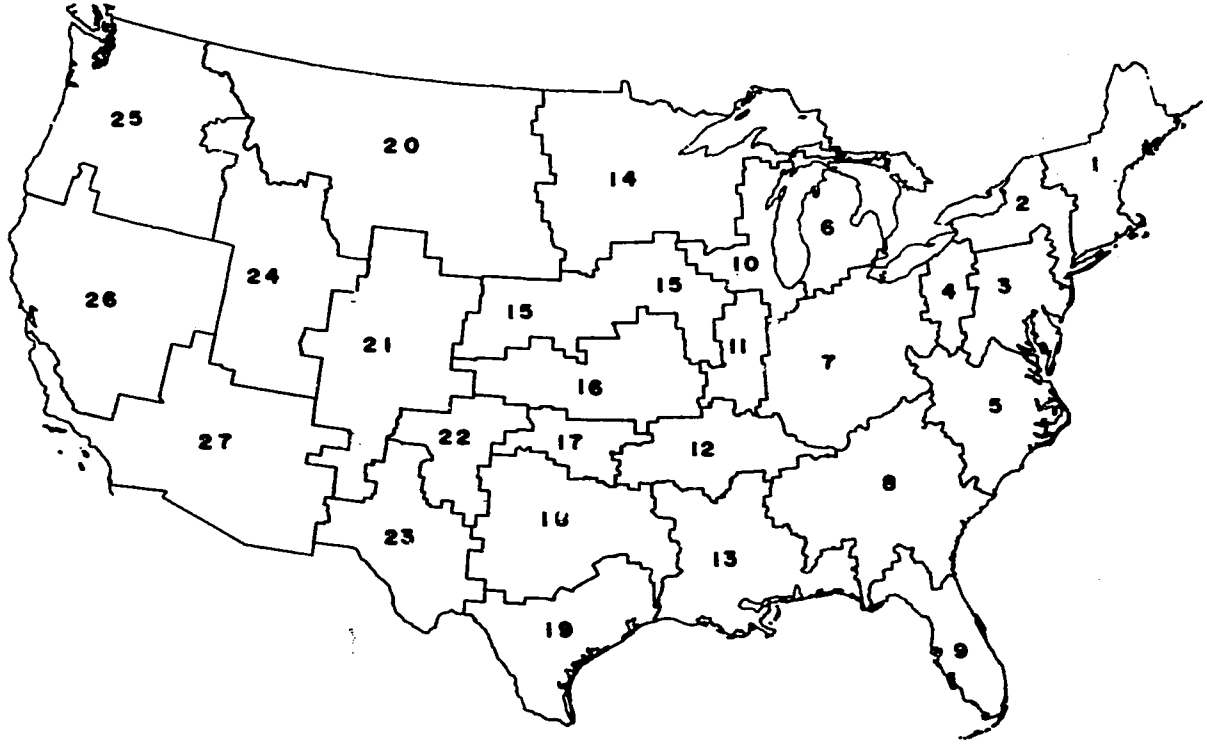

Figure 2.3. The 27 consuming regions

3. An activity is defined for the production of fruits, nuts, rice and vegetables and another is defined for onsight water uses in each water supply region. The level of each of these activities is bounded so that L_i is equal to the estimated water consumed by each kind of activity in the appropriate region. One coefficient is defined for each so that the water supplies in the regions are depleted by the amount of the activities.

4. One water export activity is defined for each WSR from which international export is made. Each is bounded so that L_i is equal to the legal requirement for export of water. One coefficient is defined to deplete the water supplies in those regions accordingly.

5. One national net export activity is defined for each of corn and sorghum, oats and barley, wheat, oilmeals, beef, pork, milk products and cotton lint. The level of each is set at the assumed net export level (always positive). Coefficients in each of these activities are defined to change the regional supplies of commodities--negative for exports and positive for imports.

Production

Production of the commodities demanded is determined as follows:

1. Crop production activities are defined for each producing area. To reflect agronomic or institutional constraints the B_i's are set at finite levels in some cases (e.g., one-half the total cropland in the case of soybeans). Since wild hay and pasture activities are not constrained by available cropland or hayland, B_i is equal to the land historically available for each of these activities. In the West, both dryland and irrigated activities are defined, and the programming model can choose between them during optimization. Coefficients are defined to indicate the use of land, consumption of water and the yield of the crop activities (Table 2.1).

2. Livestock production activities are defined for each producing area. For dairy and beef cow production, B_i is set at infinity while for beef feeding and pork production B_i is set at a finite level to represent institutional and(or) physical limits of geographic concentration of these activities. Coefficients are defined to indicate the use of feed nutrients, consumption of water, and the outputs of each activity (Table 2.2).

The protein, TDN and roughage requirements for each of the four kinds of livestock are separated to prevent nutrient-sharing. To accomplish this, activities are defined by consuming region for each kind of livestock that transform commodities into nutrients; e.g., the "transfer of hay for beef cows" activity depletes the regional supply of hay and augments the regional supplies of "beef cow protein", "beef cow TDN" and "beef cow roughage".

Water purchase and transfer

1. For each WSR, one activity is defined to simulate the purchase of water. The level of each activity is bounded so that B_i is equal to the

Table 2.1 Summary and structure of the crop production activities included in the programming model.

Activity[1]	Land used[2]	Commodities produced[3]
Corn - oats	cropland	corn grain, oats, corn silage
Barley	cropland	barley
Sorghum	cropland	sorghum grain, sorghum silage
Wheat	cropland	wheat
Sugar beets	cropland	sugar beets
Cotton	cropland	cotton lint, oilmeals
Soybeans	cropland	oilmeals
Tame Hay[4]	cropland or hayland[5]	hay
Wild hay	-	hay
Pasture on farms[6]	-	hay
Other pasture[7]	-	hay

[1]For the producing areas in the West, both dryland and irrigated activities are defined for each crop (except "other pasture" which is dryland only).

[2]Irrigated activities use irrigated cropland and water.

[3]All activities except cotton also produce aftermath pasture which adds to the supply of hay.

[4]Tame hay includes alfalfa and alfalfa mixtures, clover and timothy, lespedeza, small grains for hay and other hay.

[5]Irrigated tame hay uses either irrigated cropland or irrigated hayland and water.

[6]Includes cropland pasture and improved permanent pasture.

[7]Includes unimproved permanent and woodland pastures and public grazing lands.

Table 2.2. Summary and structure of the livestock production activities included in the programming model.

Activity	Supplies depleted	Commodities produced
Beef cows	protein for beef cows TDN " " " roughage " " " water	beef and veal feeders
Beef feeding	protein for beef feeding TDN " " " roughage " " " water feeders	beef
Dairy	protein for dairy TDN " " roughage " " water	beef and veal feeders milk
Hogs	protein for hogs TDN " " roughage " " water	pork

quantity of net surface runoff available in the WSR. A coefficient is defined to augment the usable water supply in the WSR.

2. Activities are defined for the flow of water between pairs of water supply regions. These flows represent both natural and man-made water transfers. The activity levels are bounded so that η_i represents the capacity of the system, river or stream, to carry water between the regions.

Transportation

Transportation activities are defined to permit specialization of production by geographic advantage and to account for the associated cost of transportation. Transportation is allowed between each pair[2] of adjacent consuming regions for each of eight commodities.[3] For each activity a positive coefficient is defined to represent augmentation of the commodity supply in the importing region, and a negative coefficient is defined to represent depletion of the commodity in the exporting region.

Restraints

In addition to the activity bounds already described, two general kinds of restraint equations are employed. First, land restraint equations allocate available land supplies among competing uses. The general form of the land restraint for the kth PA is

$$\sum_i X_i \, a_{im} \leqq R_k \qquad \begin{array}{l} k = 1,\ldots,223 \\ m = f(k) \end{array} \qquad (2.1)$$

where R_k is the land available in the kth PA;

a_{im} is the element of a matrix of coefficients whose rows correspond to the restraint equations and whose columns correspond to the activities;

i is the index of all activities, i = 1,..., 5426; and

m = f(k) indicates that the equation index (m) is a function (unspecified in this discussion) of k.

Second, commodity equations assure that water, intermediate products and final products are produced as they are used. The general equation for the vth product type in the nth CR (n = 0 for nationally defined restraints) is

$$\sum_i X_i \, a_{im} \gtrless 0 \qquad \begin{array}{l} n = 0,\ldots,27 \\ m = f(v, n) \end{array} \qquad (2.2)$$

---

[2]Additional activities are defined for certain well-established long-haul routes.

[3]The eight commodities are wheat, corn and sorghum, oats and barley, oilmeals, milk, beef, pork and feeders.

where the sign of the inequality is specific to the restraint as described below.

In the following discussions of the restraints, detailed algebraic forms are given. The symbolism and indexes used in the algebraic forms are found in Tables 2.3, 2.4 and 2.5.

Land restraints

Land equations of four types are defined by producing area: (1) total cropland and hayland, (2) cropland, a subset of total land; (3) irrigated total land, a subset of total land and (4) irrigated cropland, a subset of both cropland and irrigated total land.

1. Total land -- The equation for the kth PA is

$$\sum_{\alpha=1}^{7} (PDAC_{\alpha k} + PRAC_{\alpha k} + PDTH_k + PRTH_k) \leqq RLTT_k \qquad (2.3)$$

where $RLTT_k$ is the total land available in the kth PA. The restraint is that the land used by the annual crops[4] and tame hay[5] in the kth PA must not be greater than the total land available in the PA.

2. Cropland -- The equation for the kth PA is

$$\sum_{\alpha=1}^{7} (PDAC_{\alpha k} + PRAC_{\alpha k}) \leqq RLCT_k \qquad (2.4)$$

where $RLCT_k$ is the cropland available in the kth PA. The restraint is that the land used by the annual crops must not be greater than the cropland available.

3. Irrigated total land -- The equation for the kth PA is

$$\sum_{\alpha=1}^{7} (PRAC_{\alpha k} + PRTH_k) \leqq RLTR_k \quad PA_k \in WSR_j,\ j \neq 0 \qquad (2.5)$$

---

[4]The annual crops are corn grain, corn silage, grain sorghum, sorghum silage, oats, barley, wheat, soybeans, cotton and sugar beets.

[5]Tame hay includes alfalfa and alfalfa mixtures, clover and timothy, lespedeza, small grains for hay and other hay.

Table 2.3 Abbreviations for activities included in the programming model.

Activity type	Abbreviations	Index range	Index
Dryland annual crops	$PDAC_{\alpha k}$	$\alpha = 1,\ldots, 7$ $k = 1,\ldots, 223$	crop PA
Irrigated annual crops	$PRAC_{\alpha k}$		
Dryland tame hay	$PDTH_k$		
Irrigated tame hay	$PRTH_k$		
Dryland wild hay	$PDWH_k$		
Irrigated wild hay	$PRWH_k$		
Dryland improved & cropland pasture	$PDPF_k$		
Irrigated improved & cropland pasture	$PRPF_k$		
Other pasture	$PDPN_k$		
Animal production	$ANPD_k$	$\nu = 1,\ldots, 4$	type
Water purchase	$WRBY_j$	$j = 1,\ldots, 51$	WSR
Water natural flows	$WRTR_{jj'}$		
Water interbasin transfers	$WRIB_{jj'}$		
Water export	$WREX_j$		
Water used by fruits, nuts, rice & vegetables	$WRFV_j$		

Table 2.3. (Continued).

Activity type	Abbreviation	Index range	Index
Onsight water uses	$WROT_j$		
Net exports	$EXPT_\beta$	$\beta = 1,\ldots, 11, \neq 5,6$	commodity
Population & industry	$EUPI_k$		
Exogenous uses	$EUSE_\gamma$	$\gamma = 1,\ldots, 9$	type use
Transformation of feed commodities into nutrients for animal use	$TRFA_{\beta\ n}$	$\beta = 1,\ldots, 6$ $\nu = 1,\ldots, 4$ $n = 1,\ldots, 27$	commodity livestock type CR
Transportation	$SHPT_{\beta nn'}$	$\beta = 1,\ldots, 10, \neq 5,6$	commodity

Table 2.4. Abbreviations for restraints included in the programming model.

Restraint	Abbreviations	Index range	Index
Cropland	LCT_k [2]	$k = 1, \ldots, 223$	PA
Total land	LTT_k [2]		
Irrigated cropland	LCR_k [2]		
Irrigated total land	LTR_k [2]		
Water	WTR_j	$j = 1, \ldots, 51$	WSR
Commodities	$COM_{\beta n}$	$\beta = 1, \ldots, 12$ $n = 0, \ldots, 27$	commodity CR[1]
Nutrients	$NTR_{\gamma \nu n}$	$\gamma = 1, \ldots, 3$ $\nu = 1, \ldots, 4$	nutrient livestock type
Objective function	OBJ		

[1]Cotton lint ($\alpha = 11$) and sugar beets ($\alpha = 12$) restraints are defined for the nation only ($n = 0$). All other commodity restraints are defined by consuming region ($n = 1, \ldots, 27$).

[2]The right hand side values of these rows are designated with the prefix "R".

Table 2.5. Indexes for all activities and restraints included in the programming model.

Value	Index				
	α	β	γ	ν	μ
1	wheat	corn	wheat milling	beef cows	protein
2	corn-oats	barley	corn milling	beef feeding	TDN
3	sorghum	oilmeals	barley milling	dairy	roughage
4	barley	wheat	broiler prod.	hogs	-
5	soybeans	hay	turkey prod.	-	-
6	cotton	silage	sheep prod.	-	-
7	sugar beets	beef	other animals	-	-
8	-	milk	oilmeals	-	-
9	-	feeders	egg prod.	-	-
10	-	pork	-	-	-
11	-	cotton lint	-	-	-
12	-	sugar beets	-	-	-

where $RLTR_k$ is the irrigated total land available in the kth PA. The restraint is that the irrigated land used by the irrigated annual crops and tame hay must not be greater than the irrigated annual crops and tame hay must not be greater than the irrigated total land available. This equation is only defined for PA's that are within a WSR.

4. Irrigated cropland -- The equation for the kth PA is

$$\sum_{\alpha=1}^{7} PRAC_{\alpha k} \leqq RLCR_k \quad PA_k \in WSR_j,\ j \neq 0 \tag{2.6}$$

where $RLCR_k$ is the irrigated cropland available in the kth PA. The restraint is that the irrigated cropland used by the irrigated annual crops must not be greater than the irrigated cropland available.

<u>Water</u>

One water restraint is defined for each WSR so that for WSR_j

$$WRBY_j + \sum_{j'=1}^{51}\left[WRTR_{j'j} - WRTR_{jj'} + WRIB_{j'j} - WRIB_{jj'}\right]$$

$$- WREX_j - WRFV_j - WROT_j$$

$$+ \sum_{k\epsilon j}\left[\sum_{\alpha=1}^{7} (PRAC_{\alpha k})\ (a_m) + (PRTH_k)\ (a_m) + (PRWH_k)\ (a_m) + \sum_{\nu=1}^{4} (ANPD_{\nu k})\ (a_m)\right]$$

$$+ (EUSE_4)(a_m) + (EUSE_5)(a_m) + (EUSE_6)(a_m) + (EUSE_7)\ (a_m) + (EUSE_8)(a_m)$$

$$+ \sum_{k\epsilon j} (EUPI_k)\ (a_m) \geqq 0 \tag{2.7}$$

Note that e.g., (EUBR) (a_m) is the product of the activity level EUBR and the coefficient defined for that activity in the restraint (m) being discussed. The restraint is that the amount of water supplied through surface runoff and transfer from other WSR's must at least equal the consumption by irrigated crop production, livestock production, M&I, exports from the WSR and onsight uses.

Crop commodity restraints

Crop commodity restraints are defined for each of 8 commodities. For sugar beets and cotton lint the restraints are national, while for the other six commodities the restraints are by consuming region.

1. The restraint for the βth commodity in the nth CR is given by

$$\sum_{k\varepsilon n}\left[\sum_{\alpha=1}^{7}(PDAC_{\alpha k})(a_m) + \sum_{\alpha=1}^{7}(PRAC_{\alpha k})(a_m) + (PDTH_k)(a_m)\right.$$

$$+ (PRTH_k)(a_m) + (PDWH_k)(a_m) + (PRWH_k)(a_m) + (PDPN_k)(a_m)$$

$$\left. + (PDPF_k)(a_m) + (PRPF_k)(a_m)\right] - \sum_{\nu=1}^{4} TRFA_{\beta\nu n} + (EXPT_\beta)(a_m)$$

$$+ \sum_{k\varepsilon n}(EUPI_k)(a_m) + \sum_{\gamma=1}^{9}(EUSE_\gamma)(a_m)$$

$$+ \sum_{n'=1}^{51}\left[SHPT_{\beta n'n} - SHPT_{\beta nn'}\right] \geqq 0 \qquad \begin{array}{l}\beta = 1,\ldots,6\\ n = 1,\ldots,27\end{array} \qquad (2.8)$$

The restriction is that the availability of the commodity in the nth CR must at least equal the quantity used in livestock feed, milling and brewing, plus net export from the CR.

2. The national restraint for sugar beets is given by

$$\sum_{k=1}^{150}\left[(PDAC_{7k})(a_m) + (PRAC_{7k})(a_m) + (EUPI_k)(a_m)\right] \geqq 0 \qquad (2.9)$$

and the national restraint for cotton is given by

$$\sum_{k=1}^{150}\left[(PDAC_{6k})(a_m) + (PRAC_{6k})(a_m) + (EUPI_k)(a_m) + (EXCT)(a_m)\right] \geqq 0 \qquad (2.10)$$

In each case the restraint is that production must equal or exceed use.

Livestock commodity restraints

Livestock commodity restraints are defined in each consuming region for each of the four commodities (β = 7, 8, 9, 10). The restraint for the βth commodity in the nth CR is given by

$$\sum_{k\epsilon n} \left[\sum_{\nu=1}^{4} (ANPD_{\nu k})\ (a_m) + (EUPI_k)\ (a_m) + (EXPT_\beta)\ (a_m) \right]$$

$$+ \sum_{n'=1}^{27} \left[SHPT_{\beta n'n} - SHPT_{\beta nn'} \right] \geqq 0 \qquad (2.11)$$

The restriction is that the production of the commodity must equal or exceed the sum of the use as an intermediate product (feeders only), consumption, and net export from the region.

Nutrient restraints

One restraint is defined for each type of nutrient used by each type of livestock activity by consuming region.

1. The TDN restraint for the νth livestock type in the nth CR is given by

$$\sum_{\beta=1}^{6} (TRFA_{\beta\nu n})\ (a_m) + \sum_{k\epsilon n} (ANPD_{\nu k})\ (a_m) \geqq 0 \qquad (2.12)$$

and requires that the nutrients may be used only in the amounts produced by the transformation activities.

2. The protein restraint for the νth livestock type in the nth CR is given by

$$\sum_{\beta=1}^{6} (TRFA_{\beta\nu n})\ (a_m) + \sum_{k\epsilon n} (ANPD_{\nu k})\ (a_m) \geqq 0 \qquad (2.13)$$

which is the same form as the TDN restraint.

3. The roughage restraint for beef cows is of the same form as the TDN and protein restraints. However, the roughage restraints for the other livestock types is

$$\sum_{\beta=1}^{6} (TRFA_{\beta\nu n})\ (a_m) + \sum_{k\epsilon n} (ANPD_{\nu k})\ (a_m) \leqq 0 \qquad (2.14)$$

The significance of the change in sign of the inequality is that we restrict the amount of roughage the livestock are allowed (or are physiologically able) to consume.

The Objective Function

The objective in obtaining a solution for the programming model is to minimize the cost of meeting food and fiber demands given land and water resources. For each activity, a unit cost of production is defined. This unit cost excludes the cost of inputs provided by the other activities in the programming model (including land), but includes all other relevant costs. For example, the cost of the beef feeding activity includes labor, capital, and veterinary costs but excludes the cost of feeders, feed and water which are generated within the programming model.

The formal objective is given by

$$\min \sum_{i=1}^{5426} X_i \, C_i \tag{2.15}$$

where X_i is the level of the ith activity and C_i is the unit cost of that activity.

Considering only the activities with nonzero C_i's the objective function becomes

$$\min \left\{ \sum_{k=1}^{223} \left[\sum_{\alpha=1}^{7} (PDAC_{\alpha k}) (C_i) + \sum_{\alpha=1}^{7} (PRAC_{\alpha k}) (C_i) + (PDTH_k) (C_i) \right.\right.$$
$$+ (PRTH_k) (C_i) + (PDWH_k) (C_i) + (PDPF_k) (C_i) + (PRPF_k) (C_i)$$
$$\left. + (PDPN_k) (C_i) + \sum_{\nu=1}^{4} (ANPD_{\nu k}) (C_i) \right] + \sum_{j=1}^{51} \left[(WRBY_j) (C_i) \right.$$
$$\left.\left. + \sum_{j'=1}^{51} (WRTR_{jj'}) (C_i) \right] + \sum_{n=1}^{27} \sum_{n'=1}^{27} \sum_{\substack{\beta=1 \\ \beta \neq 5,6}}^{10} (SHPT_{\beta nn'}) (C_i) \right\} \tag{2.16}$$

The Land Retirement Policy Model

For solutions requiring simulation of current kinds of land retirement programs, the programming model is slightly altered. Activities are defined to represent land retirement and restraints are defined to limit production and concentration of retired land.

1. A Land Retirement Activity ($LRET_k$) is defined with coefficients (+1) in the LCT_k, LTT_k and LRR_k restraints for the kth Producing Area ($k = 1,\ldots,223$). For each, a bound B_i is set at the maximum allowable retirement of land in that PA.

2. A restraint LRR_k is defined for each PA:

$$\sum_{\alpha=1}^{4} (PDAC_{\alpha k} + PRAC_{\alpha k}) \leqq RLRR_k \qquad (2.17)$$

where $RLRR_k$ is the maximum allowed combined acreage of the crops in the program. ($\alpha = 1,\ldots,4$).

3. The total land restraints are altered:

$$\sum_{\alpha=1}^{7} (PDAC_{\alpha k} + PRAC_{\alpha k} + PDTH_{\alpha k} + PRTH_{\alpha k}) + LRET_k \leqq RLTT_k \qquad (2.3.1)$$

4. The cropland restraints are altered:

$$\sum_{\alpha=1}^{7} (PDAC_{\alpha k} + PRAC_{\alpha k}) + LRET_k = RLCT_k \qquad (2.4.1)$$

The alteration of the total land and cropland restraints has the significance that (a) the nonuse of land is a specified bounded activity ($LRET_k$) and (b) tame hay production can no longer occur on cropland not used for annual crops.

5. Bounds are placed on the cotton and sugar beet activities to reflect maximum allowed production in the producing areas.

III. MODEL PARAMETERS AND THEIR DETERMINATION

Many coefficients used in this study are derived directly from regional programming models previously developed at Iowa State University (4, 14, 22). However, the addition of water supplies and water using activities to the programming model necessitated new methods and procedures to generate the coefficients in the areas and regions where water use is considered. The following sections outline procedures used to estimate the coefficients relating to: land restraints, water supplies and prices, water transfers, crop and livestock activities, feed transfer activities, transportation activities, domestic and export demands and the policy model variations studied. Although methods of specifying and measuring coefficients are outlined here, greater detail is given in our report to the National Water Commission (21a).

Land Restraints

Land restraints of four types are defined for the annual crops and tame hay included in the programming model[1]: (1) cropland, (2) total land, (3) irrigated cropland and (4) irrigated total land. Land available for crop production is assumed to equal the maximum acreage harvested in past years, including land in government retirement programs. Crops not included in the present study are assumed to have a land base equal to that occupied in past years. Thus the cropland and hayland base in the year 2000 is nearly the same as in 1964, but the total land base, including all pastures and wild hay, is slightly higher (Table 3.1, Normal column). Most of the increase in the total land base comes from improved and cropland pasture which is projected to increase from 93.4 million acres in 1964 to 117.8 million acres in 2000. Woodland and unimproved pasture are projected to decrease 7.0 million acres because of reseeding, brushing or other pasture improvement practices resulting in the pasture being classed improved by the year 2000 (22).

Although future nonfarm land uses have not been directly incorporated as variables of the programming model, it seems that the total quantity of land needed for these purposes will not place pressures on farm cropland requirements and food supplies up to the year 2000. According to Krause (40, p. 5):

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[1]The annual crops included in the programming model are corn for grain, corn silage, sorghum for grain, sorghum silage, sorghum forage, wheat, oats, barley, soybeans, cotton and sugar beets. The tame hay activity includes regional rotation mix of alfalfa and alfalfa mixtures, clover and timothy, lespedeza, small grain hay, grass silages and other hay.

> In general, it looks like urban uses won't take much cropland. An increase of 80 million people would take at most about 20 million acres of land. Based on past experience, we estimate that about half of this, or 10 million acres, might be cropland. This is about 2 percent of our present 430 million acres of cropland. The effect would probably be less than that because much cropland in the east is already in the reversion process due to economic disadvantage.

A recent study by the U.S. Department of Agriculture, Economic Research Service, indicates that 49 million more acres, excluding that currently held out of production under land retirement programs, could be farmed if the need arose (94). If brought into production, this added cropland would represent 15 percent of total U.S. acreage now devoted to the 59 principal crops. U.S. Department of Agriculture economists estimate that, based on production costs and prices, 33 million acres of this added land could be used for major field crops such as soybeans, corn, rice and cotton. A considerable amount of this land is annually being converted into cropland. It comes from the 243 million acres of land in Classes I-III now used for forests, pasture and range. In an earlier study, Upchurch (219, pp. 215-223) estimated that at a cost of $30-50 billion, 150 million additional acres could be converted to cropland. Some of this 150 million acres would require irrigation and water. Given these total opportunities, however, the demand for cropland for urban, transportation, recreational and other nonfarm uses will not offset the land that could be converted to crops without irrigation. Conversion already is taking place and is profitable at the price levels maintained under commercial farm programs.

Land restraints for the free-market policy models

The cropland base in producing area i, LCT_i, is defined as

$$LCT_i = \sum_{k \in i} \sum_{j=1}^{11} X_{kj}^t \qquad (3.1)$$

$$i = 1,\ldots,223$$
$$j = 1,\ldots,11$$
$$k = 1,\ldots,3067$$

where X_{kj}^t is total harvested acreage of the jth annual crop[2] in the kth county in the ith producing area (Figure 2.1) as reported in the 1964 Census of Agriculture (186). Summing over all producing areas for this

[2]See footnote 1.

restraint corresponds to the total cropland acreage given in Table 3.1 (p.71; Normal column). The total land base in producing area i, LTT_i, is defined as

$$LTT_i = LCT_i + \sum_{k \epsilon i} \sum_{j=1}^{6} Y_{kj}^t \qquad (3.2)$$

$i = 1,\ldots,223$
$j = 1,\ldots,6$
$k = 1,\ldots,3067$

where

LCT_i is as defined above; and

Y_{kj}^t is the total harvested acreage of the jth hay crop[3] in the kth county in the ith producing area as reported in the 1964 Census of Agriculture (186).

Summing this restraint over all producing areas corresponds to the sum of the cropland and tame hay acreages given in Table 3.1 (Normal column).

The maximum irrigated acreage is projected to equal 37.5 million acres in 2000, assuming no further public development of new lands after 1980. The irrigated cropland base in producing area i, LCR_i, is defined as

$$LCR_i = \sum_{k \epsilon i} \sum_{j=1}^{11} X_{kj}^I \qquad (3.3)$$

$i = 1,\ldots,223$
$j = 1,\ldots,11$
$k = 1,\ldots,3067$

where X_{kj}^I is the irrigated harvested acreage of the jth annual crop[4] in the kth county included in the ith producing area as reported in the 1964 Census of Agriculture (186). Summing over all producing areas for this restraint corresponds to the total cropland acreage in Table 3.2 (Normal column).

The irrigated total land base, LTR_i, is defined as

$$LTR_i = LCR_i + \sum_{k \epsilon i} \sum_{j=1}^{6} Y_{kj}^{I'} \qquad (3.4)$$

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[3]See footnote 1.

[4]See footnote 1.

$i = 1,\ldots,223$
$j = 1,\ldots,6$
$k = 1,\ldots,3067$

where Y^I_{kj} is the irrigated harvested acreage of the jth hay[5] in the kth county included in the ith producing area.

The irrigated activities are defined only for those producing areas included within the 51 water supply regions. Summing over all producing areas for this restraint corresponds to sum of cropland and tame hay in Table 3.2 (Normal column).

Each of the four land bases, LCT_i, LTT_i, LCR_i and LTR_i, is adjusted for under-counting of the harvested acreage by the 1964 Census of Agriculture (186) when compared with the harvested acreage reported in Crop Production 1965 Annual Summary (168). Adjustments also are made in the cropland and total land bases to account for land in government retirement programs in 1964. The irrigated acreages reported in the 1964 Census of Agriculture (186) are adjusted upward based on ratios determined from irrigated acreages by state in 1964 and 1969 as reported in popular irrigation publications (225,226), to reflect additional land brought under irrigation between 1964 and 1969. Also, the adjusted estimates of irrigated acreages are increased to reflect new lands in Bureau of Reclamation projects that have a potential of being developed and irrigated by 1980 (206).

Land used for pasture and wild hay is not included in the land restraints for the free-market policy models. In the structure of the programming model, pasture cannot substitute entirely for hay since pasture does not use land from any of the four land bases defined above. Therefore, two pasture land restraints are defined in each producing area, and a third restraint, for irrigated pasture, is defined in each producing area included in a water supply region. The first two types of pasture restraints reflect the different kinds of pastures (i.e., cropland and improved pasture versus unimproved and woodland pastures and public grazing lands). They are developed from projections by Heady and Mayer (22) and the acreages of each type of pasture as reported in the 1964 Census of Agriculture (186). The third restraint, defined only for producing areas included in a water supply region, reflects the irrigated pasture acreage as reported in the 1964 Census of Agriculture (186).

Wild hay production activities also do not use land from any of the four land bases. The dryland and irrigated wild hay production activities are restrained by upper bounds determined from the 1964 Census of Agricul-

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[5]See footnote 1.

ture (186). The total acreage available in the programming model for dryland pasture and wild hay is given in Table 3.1 and the corresponding irrigated acreages in Table 3.2.

Land restraints for the land retirement policy model

An annual land retirement program is simulated in a modification of the programming model (Model C). This variation simulates the farm commodity programs used to regulate the level of farm output during the decade 1961 to 1971. Land retirement is on a partial-farm basis with a minimum level of participation equal to 75 percent of the level of retirement actually experienced in 1969 (106, 108), or

$$LRET_{LBi} = .75 \sum_{m \epsilon i} A_{jm} \tag{3.5}$$

$i = 1,\ldots,223$
$j = 1$ for the feed grain program, 2 for the wheat program and 3 for the cotton program
$m = 1,\ldots,3067$

where

$LRET_{LBi}$ is the lower bound on land retirement in producing area i and
A_{jm} is the acres of land retired under program j in county m in 1969.

The maximum level of land retirement permissable in any one producing area is equal to one-half of the total cropland base in the area, or

$$LRET_{UPi} = .5\ LCT_i \tag{3.6}$$

$i = 1,\ldots,223$

where

$LRET_{UPi}$ is the upper limit on the number of acres that may be retired in producing area i and
LCT_i is the total acreage of the cropland base in producing area i.

In the land retirement policy model, in addition to land retirement, the total acreage of wheat and feed grains in each producing area is restricted to 112 percent of the harvested acreage of wheat and feed grains reported in 1964 (186).

The cotton and sugar beet programs are simulated by upper bounds on

the production activities in each producing area where cotton and sugar beet activities are defined. The upper limit on each cotton activity is set equal to the actual harvested acreage reported in 1964 (186). The bound on a sugar beet activity in a producing area is equal to twice the harvested acreage in 1964 (186). Sugar beet bounds were adjusted in certain areas to account for rapid acreage increases during the period 1965 to 1969 (107).

Land restraints for the fragile lands policy model

Model F measures the impact on land and water use with fragile lands removed from crop production in 2000. Fragile lands are defined to include the blow lands, wash lands and wetlands that would have detrimental effects on the quality of water, air, vegetative cover, wildlife and other natural resources if subjected to agricultural uses. More specifically, fragile lands are defined to include soils and areas in land-capability Classes V, VI, VII and VIII as reported by the U.S. Department of Agriculture in the updated National Inventory of Soil and Water Conservation Needs, (113a). According to this study (113a, p. 1):

> Soils in Classes V, VI, VII and VIII are generally not suitable for growing ordinary field crops...

In addition, Class IV lands in certain areas of the Great Plains are removed from cultivated crop production to reduce wind erosion, but hay and pasture production still is allowed on these lands.[6]

By using data available in the National Inventory (113a), land available for dryland and irrigated crop production in the programming model (Tables 3.1 and 3.2, Normal column) is adjusted to account for fragile lands, included in the "Normal" land base. In general, the adjustment can be shown as

$$L_i^F = L_i^N \left(1 - \frac{A_i^F}{A_i^T}\right) \qquad (3.7)$$

$$i = 1,\ldots,223$$

[6]The fragile lands policy model was formulated and applied through financial aid from the National Academy of Sciences and through private communication with Dr. John F. Timmons, Department of Economics, Iowa State University, Ames, Iowa and Dr. Sid L. Spahr, Department of Animal Science, University of Illinois, Urbana, Illinois, December, 1971.

where

L_i^F is the acres of land available for crop production in the ith producing area in the fragile lands policy model (i.e., LCT_i, LTT_i, LCR_i, LTR_i, etc., adjusted for fragile lands; Tables 3.1 and 3.2, Fragile lands column);

L_i^N is the acres of land available for crop production in the ith producing area, in the policy models that allow agricultural use of fragile lands (Tables 3.1 and 3.2, Normal column);

A_i^F is the acres of fragile lands (land-capability Classes V, VI, VII, VIII and IV in certain areas of the Great Plains as determined from the National Inventory) used for hay, pasture and (or) annual crop production in the ith producing area (113a); and

A_i^T is the total acres of land (all land classes) used for hay, pasture and (or) annual crop production in the ith producing area (113a) as summed from the National Inventory.

Land available in the programming model after the fragile lands adjustment is reported in Tables 3.1 and 3.2 (Fragile lands column). After the adjustment for fragile lands, total land available for annual crops, hay and pasture production is 656.3 million acres less than the "Normal" land base. Of the total reduction in the land base, only 1.8 million acres is from the irrigable land base (Table 3.2). Nearly 97 percent of the fragile lands removed are taken from land available only for pasture production. Only a small amount, relatively speaking, of the more productive cropland and hayland is removed from production (Table 3.1).

Water Supplies

The water supply in this study is measured by surface runoff, except in seacoast regions where desalination is allowed. Provisions also are made for exports of water to Canada and Mexico, for interbasin transfers of water and for natural stream flows.

Mining of underground water supplies is not allowed in the programming model. Many of the closed underground water supplies will likely be depleted by the year 2000 (27), and the amount of water available on a continuous basis from others is not known with any degree of accuracy. The mean annual runoff, however, includes some unknown amount of water that eventually leaves the surface runoff channels and enters underground streams and acquifers. This "potential" underground water probably is included in the surface runoff data and, therefore, is included in the water supply. Given this condition, inclusion of certain underground water supplies would lead to double counting. On the other hand, some underground movement of water never appears as surface runoff, thus the poten-

tial water supply is understated in some regions (223). In the long run, however, most ground water cannot be continuously mined; this is the primary reason for excluding it from the study.

The water supply in each of the 51 water supply regions is a function of the total reservoir storage and the mean annual runoff in the region (Table 3.3). These supplies are calculated as follows: First, the total storage capacity of reservoirs in each water supply region is determined by adding the active conservation and joint use capacities[7] for storage dams in the region as obtained from the Bureau of Reclamation[8], the Army Corps of Engineers (68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88) and a survey of reservoirs in the United States in 1963 (45). Second, the mean annual runoffs reported in Table 3.3 are determined from The Nation's Water Resources (216). Then, by using the relationships between reservoir storage and mean annual flow (Table 3.4) developed by Lof and Hardison (42), the net water supply as a proportion of the mean annual runoff is determined. Since the work by Lof and Hardison is available only for major river basins, it is assumed that all water supply regions in a major river basin exhibit the same relationship between gross water supply and total reservoir storage.

The gross water supply in each water supply region is determined by interpolating between the points reported in Table 3.4. Water supplies are calculated first for all water supply regions and then the gross water supplies are adjusted, based on the work by Lof and Hardison (42), for reservoir evaporation, giving a net water supply in each of the water supply regions (Table 3.3).

The relationship between reservoir storage and percentage of the mean annual runoff available for use, given in Table 3.4, is shown graphically for the Colorado River Basin in Figure 3.1. For example, using the higher curve and given a ratio of total storage to mean annual runoff equal to 1.003, the gross water supply would equal 0.85 multiplied by the mean annual flow. From the lower curve, the net water supply would equal 0.79 multiplied by the mean annual flow.

Water Demand

Demand for water depends on (1) intake uses, (2) onsite uses and (3) flow uses. Intake uses include water for irrigation, livestock, municipal and industrial uses, rural domestic, mining and thermal electric power.

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[7]Active conservation capacity is water storage available for irrigation, municipal and industrial uses, power, fish and wildlife or other direct uses. Joint use capacity includes storage area of the reservoir allocated to flood control during part of the year and to active conservation for the remainder of the year.

[8]Unpublished data obtained through private communication with D. W. Davis, U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado, March, 1971.

Onsite uses include water for swamps, wetlands, reservoir evaporation, recreation and fish and wildlife. Flow uses include water for estuaries, navigation, waste dilution, stream channel losses and also some fish and wildlife and recreation (223, p. 8).

Water, during the course of its use, is both withdrawn and consumed. Water withdrawn is water taken from its source; in general some is returned for further use. Water consumed is water lost into the atmosphere either through evaporation and transpiration, or incorporated into a product. In this study, water lost through deep percolation also is considered consumed. All water consumed is lost and cannot be re-used. For example, most water withdrawn for cooling purposes in a thermal electric plant is later returned to its source for further use. Only a small amount of the water withdrawn for cooling is consumed. Reservoir evaporation is an example of water consumption.

Water consumption is the important indicator of water demand. Water withdrawals cannot be used as the true indicator because some water withdrawn can be re-used, although not always near the point where it is withdrawn. Therefore, although both withdrawals and consumption of water are estimated in this study, only water consumed takes from the supply of water or is used to determine water shortages, scarcities or surpluses. To incorporate water demand into the programming model requires estimates of water-use (consumption) coefficients for most demands.

Intake uses

Water-use coefficients are estimated for each irrigated crop activity in the programming model to reflect water needed for plant growth in addition to that provided from precipitation (1, 10, 13, 24, 59, 61, 67, 201, 203, 220). Withdrawal coefficients also are calculated to indicate the diversion requirements needed to supply the water consumed. Gross delivery requirements, GDR_{ij}, in producing area i for crop j[9] are

$$GDR_{ij} = \frac{CU_{ij} - EP_i}{(IE_j)\ (CE_i)} \tag{3.8}$$

$i = 1,\ldots,124$
$j = 1,\ldots,33$

[9]The 11 annual crops and 6 hays defined in footnote 1 plus wild hay and pasture plus the 14 specialty crops potatoes, rice, tomatoes, lettuce, sweet corn, carrots, onions, melons, cabbage, other vegetables, lemons, grapes, citrus and deciduous fruits and nuts.

where

CU_{ij} is the acre feet of water required by the jth crop in the ith producing area;

EP_i is the effective precipitation in the ith producing area or the water available after rainfall is adjusted for evaporation and deep percolation;

IE_j is the irrigation efficiency of the jth crop or the efficiency of the crops in using the water applied (Table 3.5) and is affected by plant density and the ability of plants to retain water in the ground for use; and

CE_i is the canal efficiency in the ith producing area or efficiency of the delivery system between the reservoir or diversion point and the farm delivery gate. It is calculated for each area from data on Bureau of Reclamation projects (202).

The net diversion requirement, NDR_{ij}, or water consumption coefficient for each irrigated crop activity is calculated as

$$NDR_{ij} = CU_{ij} - EP_i + (1-RF)\left[GDR_{ij} - (CU_{ij} - EP_i)\right]$$

$$= CIR_j + (1-RF)\left[GDR_{ij} - CIR_{ij}\right] \qquad (3.9)$$

$i = 1,\ldots,124$
$j = 1,\ldots,33$

where

GDR_{ij}, CU_{ij} and EP_i are as previously defined in (3.8);

CIR_{ij} is the crop irrigation requirement of the jth crop in the ith producing area;

RF is the return flow or the proportion of the water delivered that is not consumed and is returned for re-use in the region. The return flow is assumed to be 55 percent in all river basins except the Columbia-North Pacific, where 60 percent is used (211); and

$GDR_{ij} - (CU_{ij} - EP_i)$ is the water diverted but not directly consumed by crops.

The water coefficients (NDR) for hays and pasture are adjusted to account for water needed by the seed crops.

Fruits, nuts, rice and vegetables are treated as exogenous in the programming model. An activity is defined, however, to account for projected water requirements of these specialty crops in the year 2000.[10]

[10]The 14 specialty crops included in this study are listed in footnote 9.

The procedure followed is explained in detail in Appendix A.

Livestock water-use coefficients are taken from (6, 53, 95). For livestock, withdrawals are assumed to equal consumption and consumption is assumed the same for all counties in a state.

To allow water consumption to vary with the location and level of population, other (nonagricultural) intake uses are estimated on a per capita basis. Water withdrawal and consumption coefficients for municipal and industrial uses, rural domestic, thermal electric power and recreation are taken from (5, 8, 9, 48, 49, 50, 53, 56, 57, 58, 59, 60, 61, 213, 214, 215, 220, 221). Water used for recreation is included in the per capita figure, although it is normally included in onsite and flow demands.

Onsite uses

Onsite uses include water for swamps, wetlands, reservoir evaporation, recreation and fish and wildlife. In this study, water used for recreation is included with intake uses. Also, the water supply as discussed in the "water supplies" section, already includes an adjustment for reservoir evaporation. Estimates of water for the remaining onsite uses in 2000 are taken from (5, 8, 9, 48, 49, 50, 53, 56, 57, 58, 59, 60, 61, 213, 214, 215, 220, 221). Since surface runoff data already accounts for current swamps, wetlands, etc., only additional onsite water consumption above current levels is included in water demands for 2000.

Flow uses

Flow uses include water for estuaries, navigation, waste dilution, stream channel losses and some recreation and fish and wildlife. Estimates of water used for recreation and fish and wildlife are included with intake and onsite water demands. Also, stream channel losses are assumed to be accounted for in the surface runoff figures used. Water used for estuaries is not included in this study, since reliable estimates are not available. Water for navigation, however, is included in the water demand for certain areas of the nation (213, 214, 215).

Waste dilution flows are not included in projected water demands. Treatment is assumed to handle most waste problems by 2000. Any required waste dilution flows are assumed satisfied by municipal and industrial water withdrawals and waste water reclamation.

Water Prices

Water costs are included in the programming model to (1) reflect current water costs in agriculture and (2) determine points on the agricultural demand curve for water and, consequently, initial estimates of water that could be released from agriculture for nonfarm uses.

Present water prices are used in the six basic policy models analyzed (Models A, B, C, D, E and F). In these policy models, the price per acre foot of water in water supply region j, P_j, is a weighted average of present water costs to farmers in Bureau of Reclamation irrigation projects (206) or

$$P_j = \sum_{i \epsilon j} (CA_i/AF_i)(WD_i) / \sum_{i \epsilon j} WD_i \qquad (3.10)$$

$i = 1,\ldots,136$
$j = 1,\ldots,51$

where

CA_i is the cost of water per acre to farmers in the ith project;
AF_i is the acre feet of water delivered per acre to farmers in the ith project; and
WD_i is the total acre feet of water delivered to all farmers in the ith project.

If Bureau of Reclamation data were not available for a region, the water price in the most immediate upstream region was used. These estimated water prices are adjusted to account for farm waste and deep percolation and to get costs per acre foot of water consumed (Table 3.6). No correction is required for canal losses since the deliveries, WD_i, are measured at the farm.

Water Transfers

Water transfer activities are included in the programming model to allow (1) natural stream flows, (2) interbasin transfers, (3) water exports to Mexico and Canada and (4) water augmenting and desalination in selected regions.

For water supply regions linked by natural channels, activities are defined to allow surplus water to be used in downstream regions. To account for evaporation and channel capacities, each of these activities is restricted to a maximum level of 70 percent of the upstream water supply. Costs are assigned to these natural flow transfers so that the upstream water price plus the transfer cost is greater than the price of water in the receiving region. No cost is assigned if water in the upstream region is priced higher than water in the downstream region.

Existing interbasin transfers are allowed in the programming model in selected regions (Table 3.7). No cost is assigned to these transfers since the facilities are already constructed. Also, prices on the upstream water buying activities will prevent the transfer at zero cost. Each of

Table 3.7. Interbasin water transfers included in the study and the maximum amount of water transferred in 2000.

Project	Maximum water transferred
	(millions of acre feet)
Colorado - Big Thompson Project	0.337
Boulder Canyon Project	4.400
Platte - Niobrara subbasin to Kansas River subbasin	0.190
Canadian River subbasin to Colorado River subbasin	0.051
Central Arizona Project	1.135

these activities is restricted to the projected capacity of the project to transfer water in the year 2000 (48, 49, 50, 61, 220, 221).

Water export activities are defined for exports to Mexico, the Souris-Red-Rainy river basin and Canada. The lower bound on the Mexico activity is set at 1.5 million acre feet in accord with the Mexican Treaty of 1944 (61) and the water is transferred from the Lower Colorado river basin. Another activity allows for the export of 1.1 million acre feet of water annually from the Missouri river basin to the Souris-Red-Rainy river basin via the Garrison diversion project (50). A third export activity is defined to account for the expected increased depletion of the Upper Milk River by Canada in the year 2000 (50).

Desalination activities are defined for all seacoast water supply regions to allow for augmentation of the water supply. A price of $100 per acre foot is assigned to these activities approximating the best estimates available of the cost of large-scale desalting schemes under present technologies (25). A water augmenting activity with a high cost is defined in the Lower Colorado river basin to prevent an unfeasible solution in the event of a water shortage to satisfy the exogenous water requirements projected for that region in 2000.

Crop Activities

Dryland and irrigated crop production activities are defined for

corn grain-oats-corn silage, sorghum grain-sorghum silage, wheat, barley, soybeans, cotton, sugar beets, tame hay, wild hay, cropland and improved pasture and other pasture in a producing area if at least 1,000 acres of the individual crop were harvested in the area in 1964 or if the crop makes up a significant part of the area's production.

Crop yields in 2000

Crop yields[11] in 2000 are determined by a procedure that uses a fifty-year trend of aggregate state yields reported in (96, 97, 98, 99, 100, 102, 103, 104, 105, 109, 168, 169, 170, 171, 172, 174, 175, 178, 179) to adjust a series of interpolated dryland and irrigated yields constructed from census year data (180, 182, 184, 186).[12] First, the fifty-year aggregate trend for each crop in each state was used to reduce the slopes of the more rapidly rising sixteen-year trends of dryland and irrigated county yields available from census year data (180, 182, 184, 186). Then, the adjusted county observations were weighted by the proportion of the acres of each crop in each county making up a producing area in 1964 to get producing area yields (186). Finally, multiple crop activity yields were determined by weighting the yields of the appropriate crops by the proportion of the acres that each crop was of the total acres of the aggregate crop activity in the producing area in 1964 (186). The tame hay yield was constructed by weighting the average yield of alfalfa and alfalfa mixtures, clover-timothy and other hay (excluding wild hay) based on the acres of each in each producing area in 1964 (186).

Pasture yields are determined differently. The yield of dry cropland pasture (in hay equivalents) in a producing area is assumed to be 75.0 percent of the tame hay yield if the tame hay yield is less than 4 tons and 70.0 percent of the tame hay yield if it is more than 4 tons per acre. A similar relationship is used to determine the yield of irrigated cropland pasture with the irrigated cropland pasture yield being 85.0 percent of irrigated tame hay yield if it is less than 4 tons and 80.0 percent of irrigated tame hay yield if it is greater than 4 tons per acre.[13] Heady and Mayer estimate that the yield of improved pasture is equal to 88.0 percent of the yield of cropland pasture (22). Thus, given the dryland and irrigated yields for each of cropland pasture and improved pasture, aggregate dryland and irrigated yields in a producing area are calculated by weighting the two component yields by the projected acreage of each type of pasture in the producing area in 2000.

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[11] Yields are determined for corn grain, corn silage, sorghum grain, sorghum silage, wheat, oats, barley, soybeans, alfalfa, clover-timothy, wild hay, cotton, sugar beets and other hay.

[12] For a detailed description of the method used, see Appendix B.

[13] Private communication with Dr. Frank Schaller, Department of Agronomy, Iowa State University, Ames, Iowa, August, 1971.

The yield of unimproved permanent pasture, woodland pasture and pasture on public lands has not changed significantly between 1949-54 and the present. Hence, no change is projected to occur by 2000. It is assumed that the relationships among each of these three kinds of pasture and cropland pasture as developed by Jennings in 1949 (37) will still prevail in the year 2000. These relationships are then used to estimate the state yield of unimproved pasture, woodland pasture and public lands in 2000. Assuming all counties in a state have the same yield, the yield for a producing area is an average of the estimated county yields weighted by the acreage of each of the three kinds of pasture in each county in the producing area in 2000.

Aftermath pasture yields (pasture from harvested grains and hayland) are calculated as a proportion of the yield of cropland pasture based on Jennings' (37) estimates of aftermath pasture yield in cropland pasture equivalents for each of the 48 states. First, an average yield of aftermath pasture per acre of cropland and hayland[14] was calculated for each state to give a value to assign to each county in the state. Then the county yields were summed to get producing areas yields based on the acreage of annual crops and tame hay in each county in 1964 (186). Finally, these yields were included as hay production for the annual crop activities and added to the hay yields for tame hay and wild hay activities in each producing area.

Crop costs in 2000

Costs for the 9 annual crops (corn grain, corn silage, sorghum silage, sorghum grain, oats, barley, wheat, cotton and soybeans), tame hay and wild hay are calculated by weighting component costs mostly developed by Eyvindson (14). Costs in producing area i for crop j for a dryland or irrigated activity, C_{ijk}, are defined as

$$C_{ijk} = \frac{\sum_{m \epsilon i} (((M_{jkm} + P_{jm} + F_{jkm} + O_{jkm})(Y_{2ijk}/Y_{Aijk}) + L_{jkm})(1+r_m))A_{jkm}}{\sum_{m \epsilon i} A_{jkm}} \quad (3.11)$$

$i = 1,\ldots,223$
$j = 1,\ldots,11$
$k = 1$ for a dryland activity, 2 for an irrigated activity, 3 for total activities
$m = 1,\ldots,3067$

[14] See footnote 1.

where

M_{jkm} is the machinery cost for crop j for activity k in county m;[15]

P_{jm} is the pesticide and other chemical costs for crop j in county m with the same application on dryland and irrigated acres;[15]

F_{jkm} is the fertilizer costs for crop j for activity k in county m;[16]

O_{jkm} is the miscellaneous costs for crop j for activity k in county m including grain drying, liming, cotton ginning and seed costs for cotton, hays and silages;[17]

A_{jkm} is the acres of crop j for activity k in county m in 1964 (186);

Y_{2ijk} is the projected yield in 2000 in producing area i for crop j;

Y_{Aijk} is the average of the 1959 and 1964 yields of crop j in producing area i (184, 186);

L_{jkm} is the labor cost for crop j for activity k in county m;[18] and

r_m is the interest rate charged for production credit in county m (114).

The ratio of yields in Equation (3.10) is used to increase the non-labor cost per acre proportionate to the increase in yields. In this way, non-labor costs per unit of output remain constant and any lower per unit cost is a result of lower labor costs. The cost for a multiple crop activity is determined by weighting the individual crop costs involved by the 1964 harvested acreage of the individual crop reported in the 1964 Census of Agriculture (186). (also see Appendix C.)

Per acre costs for sugar beets are developed from regional publications (2, 7, 66).[19] They are projected to the year 2000 by the same procedure

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[15]Determined from work by Eyvindson (14).

[16]For producing areas not included in a water supply region, fertilizer costs are from Eyvindson's calculations on the aggregate regional data of Ibach and Adams (30). Fertilizer use for dryland and irrigated activities in a water supply region is determined from the crop response work reported by Ibach and Adams (29).

[17]Determined from work by Eyvindson (14).

[18]The labor costs are based on the hours of labor per acre determined by Eyvindson (14) and the state wage rates from (173). This cost is then projected to 2000 assuming a similar percentage reduction in hours per acre as occurred over the period 1949 to 1969 for each specific crop.

[19]Costs for sugar beet production also were obtained through private communication with Rodney Paul, FPED, U.S. Department of Agriculture, Ames, Iowa, July, 1971.

used for other crops and are assigned to the producing areas with more than 1,000 acres harvested in 1969 (179). Costs for cropland and improved pasture are estimated from preharvest costs of tame hay (4). Pasture costs are then projected to 2000 based on the projected yield increase of cropland and improved pasture. The cost for other pasture, unimproved and woodland pastures and public grazing lands is determined from the grazing rates charged on public lands (164, 198, 199, 200).

Bounds are placed on soybean activities to restrict production to half the cropland base in each producing area. This procedure is used to simulate the practice of not following soybeans with soybeans as a disease prevention measure. The only other bounds on crop production in the programming model are for pasture and wild hay as explained previously in the land restraints section.

Yield and cost adjustments for the insecticide limitation policy model (Model E)

Yields of corn grain, corn silage and cotton are reduced to simulate the effect of eliminating insecticides on these crops.[20] The adjustment in yields can be shown as

$$Y_{Nijk} = Y_{Pijk}\left[1 - \left(\frac{R_{ij}}{100}\right)\left(\frac{T_{ij}}{100}\right)\right] \qquad (3.12)$$

$i = 1,\ldots,223$
$j = 1$ for corn grain, 2 for corn silage and 3 for cotton
$k = 1$ for dryland activities, 2 for irrigated activities

where

Y_{Nijk} is the new projected yield without the use of insecticides of the kth type of activity of the jth crop in the ith producing area;

Y_{Pijk} is the projected yield per acre in 2000 with the use of insecticides of the kth type of activity of the jth crop in the ith producing area;

R_{ij} is the estimated percentage reduction in yield per acre treated of the jth type of crop in the ith producing area with the elimination of insecticides (same for dryland and irrigated); and

T_{ij} is the percentage of the acres treated with insecticides of the jth crop in the ith producing area (same for dryland and irrigated).

[20] The reduction in yields and costs of eliminating insecticides in corn and cotton production were obtained through private communication with Dr. David Pimental, Department of Entomology, Cornell University, Ithaca, New York, December, 1971.

Costs of production for corn grain, corn silage and cotton are adjusted as follows:

$$C_{Nijk} = C_{Pijk} - [(I_{ij})(\frac{T_{ij}}{100})] \qquad (3.13)$$

$i = 1,\ldots,223$
$j = 1$ for corn grain, 2 for corn silage, 3 for cotton
$k = 1$ for dryland activities, 2 for irrigated activities

where

C_{Nijk}	is the new projected cost without the use of insecticides of the kth type of activity of the jth crop in the ith producing area;
C_{Pijk}	is the projected cost in 2000 with the use of insecticides of the kth type of activity of the jth crop in the ith producing area;
I_{ij}	is the cost of insecticide and application per acre treated of the jth crop in the ith producing area (same for dryland and irrigated); and
T_{ij}	is as defined for Equation 3.12.

These new adjusted yields and costs are then used in the insecticide limitation policy model (Model E).

Yield adjustments for the fragile lands policy model (Model F)

When fragile lands are removed from production, the average yield of crops in the producing area should increase since production will be concentrated on more highly productive land. With crop production permitted on all classes of land, the average yield of the kth type of activity of the jth crop in the ith producing area, Y_{Pijk}, can be written as

$$Y_{Pijk} = W_{1ijk}Y^1_{ijk} + W_{4ijk}Y^4_{ijk} + W_{6ijk}Y^6_{ijk} + W_{7ijk}Y^7_{ijk} + W_{8ijk}Y^8_{ijk} \qquad (3.14a)$$

$i = 1,\ldots,223$
$j = 1,\ldots,15$[21]
$k = 1$ for dryland activities, 2 for irrigated activities

[21]The fifteen crops include corn grain, corn silage, sorghum grain, sorghum silage, wheat, oats, barley, soybeans, cotton, sugar beets, tame hay, wild hay, cropland and improved pasture, woodland and unimproved permanent pasture and public grazing lands.

where

W_{1ijk} is a weighting factor or the acres of the kth type of activity of the jth crop grown on land Classes I through III divided by the total acres grown of the jth crop in the ith producing area (113b);

W_{4ijk} is a weighting factor (see W_{1ijk}) that measures the importance of Class IV land in the ith producing area (113b);

W_{6ijk} is a weighting factor (see W_{1ijk}) that measures the importance of Class VI land in the ith producing area (113b);

W_{7ijk} is a weighting factor (see W_{1ijk}) that measures the importance of Class VII land in the ith producing area (113b);

W_{8ijk} is a weighting factor (see W_{1ijk}) that measures the importance of Class VIII land in the ith producing area (113b);

Y^1_{ijk} is the yield per acre on land Classes I through III of the kth type of activity of the jth crop in the ith producing area;

Y^4_{ijk} is the yield per acre on Class IV land of the kth type of activity of the jth crop in the ith producing area;

Y^6_{ijk} is the yield per acre on Class VI land of the kth type of activity of the jth crop in the ith producing area;

Y^7_{ijk} is the yield per acre on Class VII land of the kth type of activity of the jth crop in the ith producing area; and

Y^8_{ijk} is the yield per acre on Class VIII land of the kth type of activity of the jth crop in the ith producing area.

Since Class V land includes wetlands and cranberry bogs, it is assumed not to be used for crops included in this study. Given the following relationships between the crop yields included in Equation 3.14a, the yield of crops grown on nonfragile lands (Classes I through III and IV) can be determined.[22]

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[22]These relationships were determined after private communication with Dr. John F. Timmons, Department of Economics, Iowa State University, Ames, Iowa; Dean A. R. Bertrand, Texas Tech University, Lubbock, Texas; and Dr. Guy Smith, U. S. Department of Agriculture, Washington, D. C., December, 1971.

$$Y^4_{ijk} = .5Y^1_{ijk} \quad (= 1.0 \text{ if Class IV land is not treated as fragile land})$$

$$Y^6_{ijk} = Y^7_{ijk} = .4Y^1_{ijk}$$

$$Y^8_{ijk} = .3Y^1_{ijk}$$

Substituting these relationships into Equation 3.14a, we obtain

$$Y^1_{ijk} = \frac{Y_{Pijk}}{(W_{1ijk} + .5W_{4ijk} + .4(W_{6ijk} + W_{7ijk}) + .3W_{8ijk})} \qquad (3.14b)$$

Thus, given the weights determined from the National Inventory (113b) and the average projected yield, Y_{Pijk}, determined as explained in the "crop yields" section above, the average yield of each crop on nonfragile lands is determined. Since the tillage practices used on the different land classes is not available, no cost of production adjustments are made for this policy model (Model F).

Livestock Activities

Livestock production activities (hogs, beef cows, beef feeding and dairy) are defined for each of the 223 producing areas based on the work of Eyvindson (14). Eyvindson's coefficients for these activities are weighted into the producing areas based on the production of each kind of livestock in each county in 1964 (186). Feed conversion rates for each kind of livestock are projected from their 1964 base using an adjusted historic national trend of feed consumption per unit of output. Milk per dairy cow and calves per beef and dairy cow are the only output coefficients projected for 2000. Since output of the hog activity is carcass weight of pork from 100 pounds of live-weight pork, changes in the efficiency of pork production are reflected through changes in feed requirements. Since output per head of cattle fed has not changed significantly in the past, no change is projected between 1964 and 2000.

Nonfeed costs for the endogenous livestock activities are projected to increase proportionately to changes in output. This procedure maintains constant nonfeed costs per unit of output for hogs and beef feeding. Nonfeed costs for beef cows are projected to increase by state proportional to the increase in the output of calves per cow by state. Nonfeed costs for dairy cows are projected to increase proportional to the increase in milk production per cow. For a complete description of the procedures used to calculate coefficients for the endogenous livestock activities, see Appendix D.

Coefficients for the exogenous livestock production activities (lamb

and mutton, broilers, turkeys, eggs and horses and mules) are explained in the later section on final demands.

Technological Advance

The policy models included in this study incorporate two different assumptions about technological advance in 2000.

Trend technology

Eight of the nine policy models incorporate trend technology. As used in this study, trend technology means simply that the past rate of change in a parameter is assumed to continue into the future. Linear regression is the method of projection most frequently used in this study. Intercept and slope coefficients are determined and then used to extrapolate past changes to determine projected (future) values of the parameter (e.g., crop yields).

Advanced technology

Under advanced technology (Model D), the productive capacity of agriculture is improved using two assumptions about technological advance in 2000. First, feed requirements per unit of output for the beef and pork sectors nationally are assumed to be less than those under trend technology projections.[23] The overall feed efficiency of the pork sector is assumed to approach the level now obtained under research conditions, about a 20 percent improvement over the trend technology projection. The calving rate of beef cows is assumed to reach 125 percent, about 30 percent higher than the trend technology projection. (The higher calving rate assumes that new techniques to induce multiple births will be widely adopted.) The feed efficiency of fed beef is projected to improve about 70 percent over the trend technology projection. The trend technology projections for dairy and other livestock and poultry are not adjusted since they already reflect vast technological improvements over the past two decades.

Second, the productive capacity of the Southeast is assumed to increase for both crops and livestock relative to the rest of the nation. (In the remainder of the United States, trend technology projections are used for crops.) Yields of crops in producing areas in the Southeast are assumed to "catch up" to yields in the Corn Belt at a rate of 2 percent per year of the difference between the projected yield of a crop in a producing area in the Southeast and the average projected yield of that same crop in the Corn Belt. Thus, after 30 years, 80 percent of the difference will have disappeared. If, under the trend technology projections, the yields in the Southeast already exceed or equal the average projected in the Corn Belt, no further adjustments are made. For livestock, the same adjustment

[23] These new rates were determined after private communication with Dr. Lanoy Hazel, Department of Animal Sciences, Iowa State University, Ames, Iowa, August, 1971.

rule is used but both the Corn Belt and Southern Plains are used as the average base from which the deviations are measured. Crop and livestock costs in the Southeast also are adjusted to reflect the higher per-acre and per-animal costs of the new technologies and production practices. These changes assumed for the Southeast would come from larger farms, adoption of new farming practices such as multiple cropping and new breeds of livestock.

Feed Transfers

Transfer activities are defined to convert the crop commodities produced into nutrients required for livestock production. Outputs from each of the crop activities in the programming model are accumulated as supplies of corn-sorghum, oats-barley, wheat, oilmeals, silage and hay in commodity transfer rows in each consuming region. Demands for crop commodities then deplete these regional supplies. The feed transfer activities are used to transfer the crop commodity supplies into TDN, protein and roughage used for dairy, beef cows, fed beef and pork production.

Specific transfer activities are defined for each type of livestock to prevent nutrient sharing. Specific transfer activities also are defined for each of the crop commodities based on the nutrient content of feeds appendix in Morrison (52). It is assumed that the nutrient content of each individual grain is uniform across the nation. The nutrient content of hay, however, is allowed to vary by region based on the 1964 proportion of each type of hay production made in the region in 1964 (186). Similarly, the nutrient content of silage is allowed to vary by region. Finally, since the feed requirements for roughage do not include fiber from the grains and oilmeals, no feed transfers are necessary to convert the various grains and oilmeals into roughage.

Transportation Activities

Transportation activities are defined to allow for the movement of eight commodities[24] between adjacent consuming regions. By allowing only trans-shipment activities, the size of the transportation sector is minimized since each consuming region is only connected by transportation to its adjacent consuming regions rather than to each of the 26 other consuming regions.[25]

Data for costs and the corresponding distances are determined for each of the eight commodities from data in Carload Waybill Statistics (34,

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[24]The eight commodities are corn grain and grain sorghum, oats and barley, wheat, oilmeals, milk, beef, pork and feeders.

[25]Some long-haul transportation activities are defined where direct transportation routes presently exist that do not move through the central points of the intermediate consuming regions.

35, 36), Freight Commodity Statistics (31, 32, 33), and a U.S. Department of Agriculture publication on milk hauling costs (51). By using regression analysis, coefficients are determined for the following:

$$C_j = F(M_j)$$
$$= e^{a+bM_j}$$
$$j = 1,\ldots,8 \qquad (3.15)$$

where

C_j is the cost per mile transported for commodity j; and

M_j is the distance over which commodity j is transported.

Then the distance between the center points of the adjacent consuming regions is determined. These distances are used in each of the commodity equations (3.15) to determine the transportation costs. A detailed description of the transportation sector in the programming model is given in Heady, et al. (21a) and Appendix E.

Final Domestic Demands

Demands for the commodities produced in the programming model are entered on a per capita basis for each of the 223 producing areas to allow aggregation of the results into the noncongruent consuming and water supply regions. The per capita demands in each region are transferred into effective total demand by means of the "population and industry" activity. (See part II, "final demand.")

Demands for endogenous livestock and crops

The demands for beef and veal and pork are determined from the equations developed by Waugh (222). The equations first were inverted from price dependent to quantity dependent and then solved using prices expected to prevail in 2000 and the level of per capita income as projected by the Office of Business Economics (196). A maximum per capita income of $4,000 (1957-59 prices) was used in the equations to restrict the effect of income on food as incomes increase and since the equations were developed at an income level near $2,000. In the year 2000, all regions are projected to have per capita incomes greater than the $4,000 maximum, thus regional variations in income did not result in regional differences in per capita consumption of beef and veal, pork or broilers.

The demands (pounds per capita) determined for beef and veal and pork are used as coefficients in the population and industry activity to

create a demand in the relevant consuming region. The projected per capita demand for dairy products in whole milk equivalents is based on the trend in per capita consumption of milk products over the 22 years 1948 to 1969 (149).

Per capita demands for corn and sorghum, oats and barley and wheat also are included in the population and industry activity to account for the uses of these commodities not directly associated with the endogenously determined activities (i.e., livestock feed). Demands for these commodities in 2000 are assumed to equal the 1967-69 national average per capita uses for milling, brewing, and other uses of the respective commodity (143). Sugar beet demand (in sugar beet equivalents) is assumed to equal the 1967-69 average per capita consumption of sugar adjusted for cane sugar production (143). The per capita consumption of cotton lint is projected to decline following past trends (123).

Per capita consumption levels used in the programming model are reported in Table 3.8. Per capita consumption in 2000 of all types of meats except lamb and mutton is projected to increase over present levels. Per capita consumption of beef and veal would increase by 41.0 lbs. to 157.7 lbs. in 2000, and the increase in pork would be 1.3 lbs. and in broilers would be 1.6 lbs. Thus, a large increase is projected in beef production to meet the increased per capita demands and the resulting total demand created by the projected population. Production of other livestock commodities would need only increase a little more than proportionate to the population to meet the projected demands. Per capita consumption of dairy products on a whole-milk equivalent basis and per capita consumption of eggs are projected to decline from present levels by the year 2000 (Table 3.8) following trends of the past two decades. Per capita consumption of the various grains would change only slightly as consumers change their consumption patterns to include less of these energy-rich commodities and more of the protein commodities or commodities which can be adapted readily to "snack" uses.

Demands for exogenous livestock and crops

Commodities exogenous to the programming model[26] are incorporated through national activities bounded at levels corresponding to their projected requirements, domestic plus export, for 2000. Production of these activities is allocated among each consuming region based on 1964 and 1969 production in the nation. Feed requirements for the exogenous livestock are removed directly from the corn-sorghum, oats-barley, oilmeals, wheat or roughage rows of the appropriate consuming regions. By using this procedure, no transfers are required to convert crop activity outputs to TDN, protein or roughage. But no changes in the ration can result as the "model determined" values of various feed stuffs change or production

[26]The location of the production of broilers, eggs, turkeys, lamb and mutton, other livestock (mostly horses and mules) and fruits, nuts, rice and vegetables is determined exogenous to the programming model.

technologies indicate that different rations are preferred. Each of these national activities has a lower bound in the programming model equal to the national projected demand in 2000.

The demand for broilers on a ready-to-cook basis is determined using another of Waugh's equations (222). The per capita demands for eggs and lamb and mutton are determined by projections from time series consumption data (143). Other livestock (horses, mules, goats, etc.) are assumed to be distributed equally over all consuming regions, with their production set at their 1964 levels (186).

Projected demands for fruits, nuts, rice and vegetables in 2000 are based on work by Dean,et al. (12). For a discussion of these projections, see Appendix A. For a detailed discussion of the estimation of exogenous and endogenous demand for the commodities discussed above, see Appendix F.

International Trade

Two levels of exports are hypothesized for the year 2000. Level I assumes no further growth in world demand for U. S. exports while Level II assumes a substantial increase in exports over the present. Under Level I, exports of farm products are assumed to equal average 1967-69 commercial and government exports. Under Level II, total feed grains and wheat exports are projected to increase 1.9 percent per year and oilmeal exports are assumed to increase 2.5 percent per year over the next 30 years. Thus, by the year 2000, exports under Level II are nearly twice as high as under Level I. Exports of eggs, broilers and turkeys are assumed to equal average 1967-69 levels under both Level I and Level II exports. The levels of exports for 2000 are summarized in Table 3.9.

Exports of the crop commodities are allocated among the 27 consuming regions based on average 1967-69 shipments from U. S. ports (110, 111, 112, 113).[27] Exports of the poultry products are added to their projected domestic demands and the totals are then converted into feed requirements and allocated among the 27 consuming regions based on the share of U. S. production of each product in each of the consuming regions in 1964 (186).

Imports of livestock products are assumed to equal average 1967-69 per capita levels (Table 3.10). Imports of beef and veal, pork and dairy products are allocated according to the projected distribution of population and are subtracted from the respective projected demands in each consuming region. Projected imports of lamb and mutton are subtracted from the projected domestic demand for lamb and mutton. This adjusted quantity is then used as the bound on the lamb and mutton activity in the programming model.

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[27]Only a national export requirement is specified for cotton lint.

Population Levels

Several population levels have been used in this study (Table 3.8). Domestic population is the major variable causing demand for food to increase in the United States. Hence, three levels of population have been used: 280 million, 300 million and 325 million. The 300 million population level is used as the benchmark for comparisons. Under the possibility that a major slowdown in the population growth rate might be attained within the next 30 years, a population of 280 million has been used for four sets of solutions. Finally, because of the possibility that population growth rate might be greater than that (300 million) considered most probable, a population of 325 million has been used for Model D, which assumes an accentuated rate of technological advance and large exports. The latter combination of variables is used to determine agricultural policy and water needs under maximum foreseeable demand conditions.

Table 3.1. Land available in the United States for crops included in the study.

Item	1964[1]	2000	
		Normal	Fragile lands policy model
	(000 acres)		
Cropland	264,018	264,111	249,490
Tame hay	57,067	58,007	53,997
Wild hay	10,347	10,347	8,398
Improved & cropland pasture	93,437	117,776	87,579
Woodland and unimproved pasture	533,230	526,418	212,233[2]
Public grazing lands	291,384	291,384	-
Total	1,249,483	1,268,045	611,697

[1]Source: (168, 186).

[2]Includes public grazing lands.

Table 3.2 Land available for irrigation in the 17 Western States for crops included in the study.

Item	1964[1]	2000	
		Normal	Fragile lands policy model
	(000 acres)		
Cropland	14,129	18,557	18,047
Tame hay	6,734	7,442	7,149
Wild hay	1,355	1,355	1,009
Improved & cropland pasture	5,093	5,093	4,403
Other	4,572	5,092	5,092
Total	31,883	37,539	35,700

[1]Source: (186).

[2]Includes fruits, nuts, vegetables, rice and field seed crops for which water is allocated in 2000.

Table 3.3. Mean annual runoff, total reservoir storage and estimated water supply in 2000 in the 51 water supply regions.

Region	Mean annual runoff[1]	Total reservoir storage	Estimated net water supply	Region	Mean annual runoff[1]	Total reservoir storage	Estimated net water supply
	(million acre feet per year)						
1	39.20	4.80	12.18	27	2.36	4.63	1.91[2]
2	60.40	0.72	37.56	28	5.59	2.61	3.06
3	14.87	1.26	3.45	29	3.78	14.88	3.02[2]
4	27.60	1.83	5.25	30	10.00	1.76	3.36
5	7.53	12.20	7.00[2]	31	2.73	4.92	2.18[2]
6	3.25	1.13	1.86	32	1.87	2.01	1.41
7	11.16	0.98	2.66	33	3.21	37.33	2.57[2]
8	0.99	0.33	0.58	34	2.34	7.38	1.87[2]
9	29.55	9.94	16.61	35	3.98	0.18	0.49
10	23.05	0.44	13.18	36	5.75	3.37	2.74
11	7.94	4.65	6.30	37	3.82	0.15	0.50
12	9.73	5.38	7.56	38	5.53	3.23	2.69
13	29.00	1.77	10.73	39	12.02	4.23	4.71
14	2.99	3.67	2.58[3]	40	4.68	1.85	1.54
15	2.46	2.71	1.81	41	7.43	4.41	2.94
16	1.23	1.48	0.49	42	0.04	0.00	0.01
17	33.83	28.88	23.36	43	6.92	1.76	1.80
18	3.36	1.37	0.73	44	20.30	6.83	6.28
19	1.05	0.41	0.54	45	31.36	5.73	5.83
20	0.13	0.00	0.01	46	20.	6.37	5.99
21	1.39	0.47	0.68	47	3.	4.54	2.26[2]
22	4.03	2.08	2.30	48	2.	7.27	1.81[2]
23	5.54	5.37	4.33[3]	49	0.	0.00	0.01
24	6.78	2.06	3.29	50	13.	13.35	5.90
25	2.73	22.81	2.21[2]	51	30.10	6.36	6.30
26	1.21	19.00	0.98[2]	Total	534	280.89	239.41

[1]Source: (216, part 6).
[2]Maximum regulated flow possible.
[3]Near maximum regulated flow.

Table 3.4. Storage to mean annual flow ratios to make the indicated percent mean annual flow available with 95 percent probability of adequacy.

River basin	Percent gross mean annual flow available										Maximum net flow[1]
	10	20	30	40	50	60	70	80	90	95	
Upper Missouri	0.035	0.075	0.138	0.225	0.349	0.522	0.725	0.988	1.750	-	0.80
Lower Missouri	0.085	0.160	0.235	0.355	0.542	0.822	1.215	1.740	3.250	-	0.78
Upper Ark.-White-Red	0.005	0.130	0.269	0.438	0.676	1.000	1.444	-	-	-	0.48
Lower Ark.-White-Red	0.100	0.190	0.305	0.455	0.590	0.762	1.015	1.475	2.370	-	0.79
Western Gulf	0.100	0.150	0.379	0.589	0.920	1.300	1.900	2.920	-	-	0.50
Upper Rio Grande & Pecos	0.025	0.070	0.115	0.175	0.260	0.400	0.580	0.840	1.500	-	0.74
Colorado	0.030	0.075	0.125	0.200	0.300	0.420	0.571	0.775	1.278	2.680	0.81
Great Basin	0.020	0.050	0.095	0.181	0.312	0.481	0.730	1.152	1.925	3.695	0.70
Pacific N.W.	0.030	0.070	0.115	0.175	0.260	0.374	0.449	0.574	0.900	1.622	0.93
Central Pac.	0.075	0.139	0.205	0.274	0.391	0.562	0.850	1.350	3.050	-	0.88
South Pac.	0.100	0.283	0.545	0.838	1.263	1.820	2.660	-	-	-	0.44

[1]Source: (42). These numbers represent the maximum net flow in percent of the mean annual flow that can be made available for consumption through surface storage. If storage is developed to retain a large percent of the mean annual flow, evaporation will result in a decrease in net flow.

Table 3.5. Irrigation efficiencies of selected crops.[1]

Crop	Efficiency of irrigation
Alfalfa	75
Clover	60
Pasture	70
Grains and silage	70
Cotton	70
Vegetables	65
Rice	65
Sugar beets	65
Citrus and nuts	75
Subtropical fruits and vines	75

[1]Source: (59).

Table 3.6. Present prices paid by farmers for water in the 51 water supply regions.[1]

Region	Dollars per acre foot	Region	Dollars per acre foot
1	2.04	27	8.65
2	4.01	28	2.30
3	2.29	29	5.13
4	2.29	30	2.13
5	2.94	31	2.52
6	2.04	32	10.74
7	2.29	33	3.06
8	2.51	34	2.67
9	2.63	35	8.85
10	2.05	36	6.10
11	1.83	37	3.05
12	2.73	38	3.06
13	1.91	39	6.10
14	5.88	40	6.10
15	30.28	41	4.22
16	57.96	42	4.22
17	8.32	43	11.58
18	3.05	44	4.22
19	2.47	45	11.58
20	2.47	46	6.10
21	4.13	47	2.20
22	3.11	48	8.28
23	1.50	49	8.28
24	2.58	50	8.28
25	0.85	51	8.28
26	3.87		

[1]Prices include an adjustment to convert to cost per acre foot consumed rather than delivered.

Table 3.8. Per capita coefficients and population levels used in the study, 1970 and 2000.

Commodity	Unit	1970[1]	2000
Livestock products			
Beef and veal	lbs. carc. wt.	116.70	157.70
Pork	lbs. carc. wt.	65.00	66.30
Broilers	lbs. ready-to-cook wt.	39.10	40.70
Turkeys	lbs. ready-to-cook wt.	8.30	8.60
Lamb and mutton	lbs. carc. wt.	3.40	3.40
Dairy products	lbs. milk equivalent	595.00	403.20
Eggs	number	302.00	204.00
Crop products			
Corn-sorghum	bushels	1.26[2]	1.25
Barley-oats	bushels	0.84[2]	0.80
Wheat	bushels	2.57[2]	2.58
Cotton	lbs.	18.60[2]	12.00
Sugar beets	tons	0.12[2]	0.11
Other			
Disposable income	1970 dollars	3,420.00	5,400.00[3]
Population B level	million	205.30	325.10
Population C level	million	205.30	299.30
Population D level	million	205.30	279.30

[1]Source: (159).

[2]1969 level. Source: (143).

[3]This is the $4,000 maximum used to calculate the commodity demands expressed in 1970 prices.

Table 3.9. Exports of crop and poultry products in 2000.

Commodity	Unit	Level I[1]	Level II[2]
		(000)	
Corn-sorghum	bushels	710,264	1,299,783
Barley-oats	bushels	51,292	93,864
Wheat	bushels	637,115	1,165,920
Oilmeals	cwt	218,992	481,780
Cotton lint	bales	3,400	3,400
Eggs	dozen	47,000	47,000
Broilers	lbs. ready-to-cook	167,000	167,000
Turkeys	lbs. ready-to-cook	42,000	42,000

[1]Average 1967-69 exports. Used for all policy models except Model D.

[2]Used for Model D.

Table 3.10. Imports of livestock products in 2000.

Commodity	Unit	Imports per capita[1]
		(lbs.)
Beef and veal	carc. wt.	6.96
Lamb and mutton	carc. wt.	0.67
Pork	carc. wt.	1.09
Dairy products	milk equivalent	6.44

[1]Average 1967-69 exports. Used for all policy models in the study.

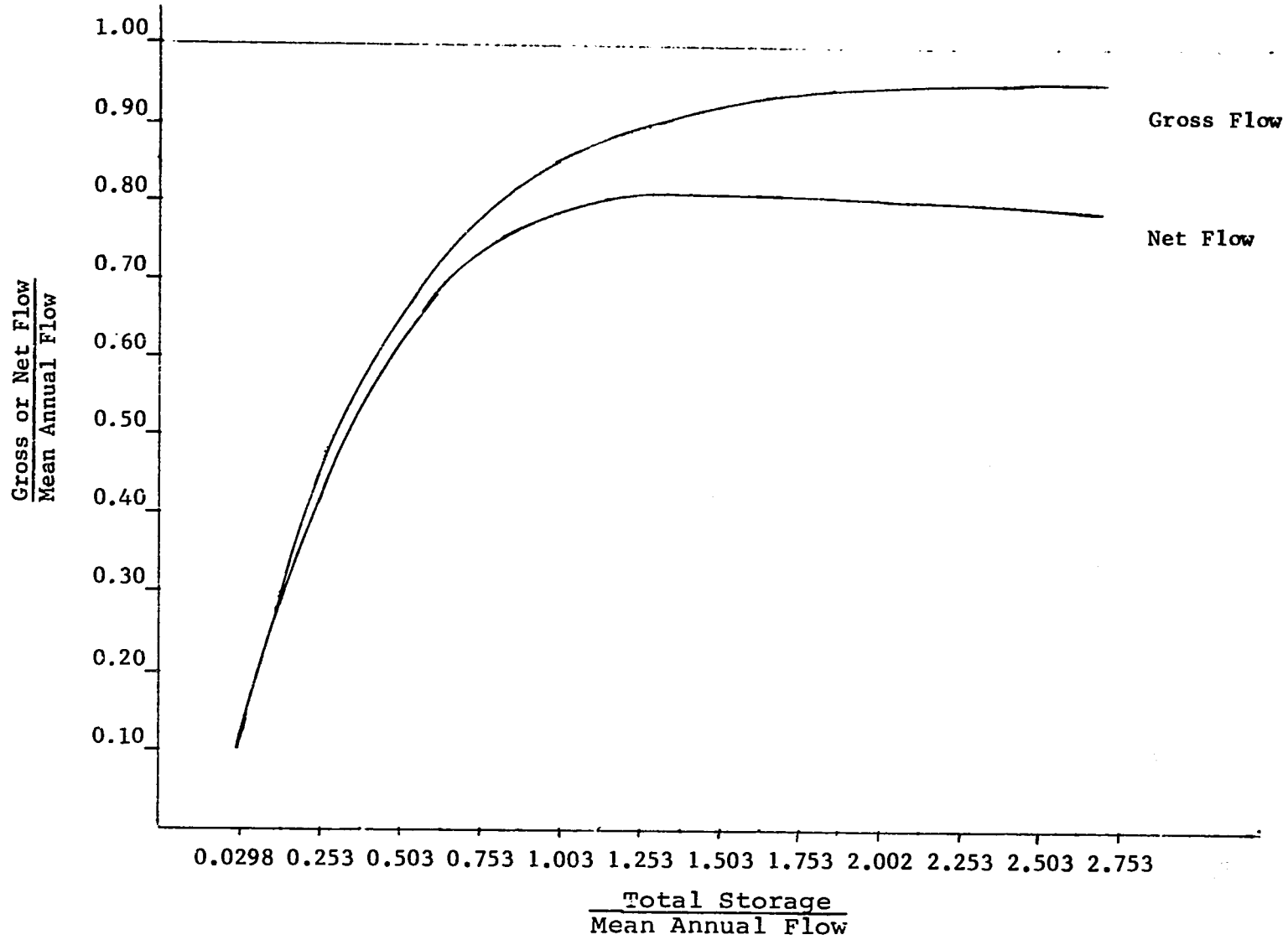

Figure 3.1. Storage and flow in the Colorado River Basin

IV. EMPIRICAL RESULTS

Nine alternative policy models are analyzed in the following sections. The basic issues to be examined are: Given the total of natural resources available to agriculture, land and water, export-import policies adopted by Congress and nonagricultural requirements for water in 2000, can the United States meet future food demands at a reasonable cost of food to consumers? Can diversion of water to nonfarm uses cause food supply capacity to be brought into a better balance with demand? Is supply capacity large enough, considering both land and water resources, to allow restraints on the use of insecticides and fragile lands[1] without large increases in real food prices?

Policy Models Analyzed

Six basic policy models are analyzed in the following sections: Model A, Model B, Model C, Model D, Model E and Model F. Model A and Model B are free-market policy models with population levels of 300 million and 280 million, respectively. Model C, with a population level of 280 million, simulates an annual land retirement program similar to the wheat, feed grain and cotton programs used during the 1961-71 decade. Model D uses an advanced level of technology in 2000, has a population of 325 million and increased levels of exports. Model E incorporates a population of 280 million with elimination of insecticides in corn and cotton production but with no restrictions on land use. Model F also uses a population of 280 million but has fragile lands removed from any type of crop production.[1] These six basic policy models assume present prices for water in 2000.

In addition to the basic policy models, three policy models A1, A2 and A3, were formulated as free-market policy models with population at the 300 million level but each assumes an alternative price for water in the year 2000. Under Model A1, farmers in the 51 water supply regions (Figure 2.2) pay at least $15.00 per acre foot for water (from surface runoff), under Model A2 at least $22.50 per acre foot and under Model A3, at least $30.00 per acre foot. The nine policy models analyzed are summarized in Table 4.1 (p. 113).

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[1]Fragile lands include land Classes V through VIII across the nation and land Class IV in certain areas of the Great Plains where wind erosion has been severe in the past. On the Class IV lands defined as fragile, only pasture production is included in the analysis.

In the following sections, results are presented on the land and water used under the nine altenative policy models. Results are summarized and reported for the 18 river basins shown in Figure 4.1. The New England and Middle Atlantic basins are joined as the North Atlantic, thus, only 17 river basins are shown in Figure 4.1 (p.186). Maps showing the locations of crop production are provided for selected crops and policy models. For the price variation policy models, A, A1, A2 and A3, demand functions for water in the West and land in the East are presented. The substitutions of land in the East for water in the West and dryland production in the West for water (irrigated land) in the West also are analyzed.

Additional sections present results on the level of livestock output and expected farm price levels, an indication of consumer food cost, under the nine alternative policy models. Average crop yields and shadow prices of land and water under the alternative policy models are reported in Appendix H. Tables and figures start on pages 113 and 186, respectively.

Full Comparative Advantage and Simulated Free Market Policy Models with 300 Million Population

Four of the nine policy models analyzed are intended to simulate conditions of full comparative advantage and a free market in American agriculture with 300 million people in 2000. Full comparative advantage is allowed in this manner: Crop production can be allocated and land and water can be used among areas and regions so that the national production pattern is most efficient. Land in the East can be substituted for land in the West or vice versa to attain the economically most efficient national pattern. No policy restraints, such as land retirement, are placed on geographic and land-water substitutions. The four policy models evaluated in this sector differ only with respect to the price of water. These four policy models, then, provide estimates of data needed for an analysis of the trade-offs between alternative futures in the United States. Model A will be used as a benchmark in the analysis.

Model A: Free market, 300 million population, present water prices and trend technology in 2000

Under these conditions--domestic demand for 300 million people and exports at the 1967-69 average levels--a total of 189.5 million acres are used for dryland annual crop production (Table 4.2). Per capita consumption of beef and veal in 2000 is projected to increase 44.0 pounds over 1969. Per capita consumption of pork is projected to remain near the 1969 level while per capita consumption of broilers and turkeys are projected to be higher than actual consumption in 1969 (Table 3.8). Consumption of the remaining livestock and poultry products continues to decline following the trend of the past two decades.

The results of this policy model indicate that, for a 300 million population and the conditions of management, technology and exports projected, the nation will have no problems in meeting its aggregate demands in 2000. With currently retired land allowed to return to production, irrigated acreage and water used in agriculture could be reduced accordingly. Thus, water is available to transfer to other uses. Water and land are allowed to substitute for each other, and surplus capacity in both land and water is projected to prevail for 2000. The total food producing capacity of the nation would still tend to be large relative to demand, and the tendency toward depressed farm prices, in the absence of supply control programs, would still prevail in the year 2000. Even with reduced water use for agriculture and a substitution of land over the nation for water in the West, some land still could go unused for field crops.

Total acreage and distribution of dryland and irrigated crops

Compared with 1964, the dryland acreage of annual crops increases by 13.1 million acreas as supply-control measures are relaxed. Dryland acreages of corn for grain and cotton are significantly lower, but dryland acreages of wheat, grain sorghum and soybeans are significantly higher (Table 4.2). Based on dryland acreage of annual crops, the rank generally is the same as 1964, except that the Texas-Gulf basin increases feed-grain acreage significantly, 6.9 million acres, primarily because of grain sorghum grown in that area (Figure 4.3). The sorghum grown in the Texas-Gulf basin is needed for the large number of cattle to satisfy the beef demand for an increased population in the Houston-Dallas area. With the relative shift of cattle feeding to the Texas area and the general yield increase projected for grain sorghum and other crops by 2000, the national acreage of corn for cotton production is concentrated in the southeastern United States (Figure 4.4).

The dryland acreage of tame hay and silages is projected to increase 41.9 million acreas over that in 1964 (Table 4.3). This large increase in dryland forage production is associated with: (1) the projected increase in cattle feeding and (2) the increased beef cow numbers to provide the feeder cattle. For the United States, the number of beef cows is projected to increase by 49.4 million head (137 percent) over the 1969 level (Table 4.70).

The ranking of the river basins with respect to the dryland acreage of tame hay and silages generally is the same as that in 1964. But the Arkansas-White-Red basin moves into third place as these crops increase by 11.2 million acres over 1964. The Upper Mississippi basin, ranking second behind the Missouri basin in both 1964 and 2000, has an increase of 7.3 million acres of tame hay and silages over levels in 1964. In both the Upper Mississippi and Missouri river basins, the increase in forage production is associated with the great increase in numbers of fed cattle and beef cows. The dryland acreage of wild hay and pasture is essentially the same as that in 1964, except that acreage of improved

pasture is projected to increase by the year 2000. The greater production from wild hay and pasture in 2000 is consumed by the increased number of fed beef and beef cows. The location of the tame hay and wild hay acreage under Model A is shown in Figure 4.5. The dryland acreage of hay is concentrated in the Missouri and Upper Mississippi basins. The irrigated acreage of hay is scattered in the Arkansas-White-Red, Columbia-North Pacific, Texas-Gulf, Missouri and California-South Pacific basins. The location of pasture under Model A is shown in Figure 4.6. They dryland acreage of pasture is concentrated in the 17 Western States. The irrigated acreage of pasture is concentrated in the Columbia-North Pacific, California-South Pacific and Missouri basins.

Large supply capacity through substitution of land for water

The irrigated acreage of annual crops in 2000 is projected to decline by 5.1 million acres from the 1964 level (Table 4.4). The estimated supply of both land and water is large enough to allow this shift while attaining a greater total output. The use of less irrigated land and the return to production of land now idled by supply control programs would allow the nation's over-all agricultural production to be optimized by this pattern and shift. Agriculture could either (a) produce the nation's food needs at a lower total factor cost or (b) produce a given amount at a greater national farm profit by this pattern. The shift to a smaller dependence on irrigated acreage and a greater dependence on dryland acreage, could have inportant interregional effects on the distribution of income.

The Texas-Gulf, Missouri and California-South Pacific basins show the largest decrease (4.6 million acres) of irrigated land. This decrease of irrigated annual crops in 2000, compared with levels in 1964, can be explained by a number of factors.[2] First, in conformity with the objective function of the programming model, it is efficient for dryland production in either the East or West to be substituted for irrigated production. As discussed previously for Model A, the projected dryland acreage of annual crops increases 13.1 million acres, and the projected dryland acreage of tame hay and silages increases by 41.9 million acres over 1964. In this comparison, remember that Model A does not include a land retirement or supply control program of the 1964 type for the year 2000. Model A allows unirrigated land to be brought back into production and substituted for water or irrigated land where (a) municipal and industrial water requirements indicate the need and (b) where the efficiency of production is furthered by the substitution. In other words, land idled under current supply control programs is released for substitution for water and irrigated land for meeting the efficiency objective. Water in some specific areas is not available for irrigation

[2]The amount of these annual crops irrigated in 1969 was not available when this report was written, but the decrease in 2000 would be even greater since actual irrigated acreage continued to increase between 1964 and 1969.

after exogenous water requirements (municipal, industrial, fruits and vegetables, etc.) are satisfied. This outcome explains some of the decrease in irrigated annual crops in the Southwest and the Texas-Gulf basin. Since use of ground water above recharge rates is not allowed in the programming model, certain areas using water for irrigation in 1964 have reduced supplies in 2000. Therefore, some of the decrease in irrigated annual crop production in the Texas-Gulf basin, the Southwest and the Missouri basin may result from the smaller projected water supply. Ground water in the Texas High Plains area is expected to be depleted by 2000 (27). Finally, some water and irrigable land are utilized in forage production for the greater beef production. Under Model A, the irrigated acreage of tame hay and silages increases by 4.0 million acreas over the 1964 level (Table 4.5). The increase in forage production, as already outlined, is used for the increased fed beef and beef cow production in 2000. (See Figures 4.2, 4.3 and 4.4 for the location of irrigated annual crops under Model A in 2000.)

For the 9 western river basins, the largest projected increases (a total of 3.8 million acres) in the irrigated acreage of tame hay and silage are in the Missouri, California-South Pacific and Columbia-North Pacific basins. Both the Missouri and California-South Pacific basins would have significant decreases in the irrigated acreage of annual crops, compared with that in 1964. Most of the land so released would be shifted to irrigated tame hay and silage production. The irrigated acreage of tame hay and silages in the Texas-Gulf basin would decrease slightly due to the shortage of water in that basin in 2000. (See Figure 4.5 for the location of the irrigated acreage of tame hay and wild hay under Model A in 2000.)

Irrigated acreages of wild hay and pasture would differ only slightly from 1964 actual levels. The irrigated acreage of fruits, nuts, rice and vegetables for 2000 in the West is projected to increase 15.0 percent over 1964. Over 90 percent of the increase would be in the California-South Pacific basin.[3] Figure 4.6 shows the location of irrigated pasture and Figure 4.7 shows the location of irrigated fruits, nuts, rice and vegetables in the 9 western river basins in 2000 under Model A.

Interregional shifts of land and water use and surplus capacity

Even with the projected higher food and fiber requirements in 2000, 16.4 million acres of land could remain unused (Table 4.6). The term unused refers to the amount of land not used to meet the domestic and export food demands at the numerical levels estimated for the restraint equations of the programming model. Of course, in a completely free

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[3]See Appendix A for the methods used to estimate land and water requirements for fruits, nuts, rice and vegetables in 2000.

market, we would expect the acreage denoted as unused to be absorbed into nonagricultural or urban uses, or for public purposes such as parks and recreation. The greatest proportion of land designated as not needed for agricultural production (in terms of the specific demand restraints of the programming model) would be in the Appalachian, Smokey and other mountainous areas of the East (Figure 4.8). Also, a large proportion of the unused land would be along the heavily populated area of the Eastern Seaboard, where the demand for recreational lands may be large over the next three decades. Most of the remaining unused land would occur in the 17 Western States either as land is released from irrigation or as supply controls are relaxed from 1964 levels, and more productive soils in the Corn Belt or elsewhere are substituted.

Of the unused cropland and hayland under Model A, 5.3 million acres could be used for additional annual crop or tame hay production and 11.1 million more acres could be, in terms of soil and topographic characteristics, used only for tame hay production. Also, a considerable amount of land currently irrigated would switch to dryland uses in 2000 under Model A. There would be 26.0 million acres of land available for irrigated annual crops and irrigated tame hay production in 2000 (Table 3.2). But only 17.0 million acres of annual crops and tame hay are irrigated under Model A (Table 4.6). Thus, over 7 million acres of land currently irrigated (or with a high probability of being irrigated by 1980) would be used for dryland production in 2000. The Texas-Gulf, Missouri and California-South Pacific basins would contain most of the land switched from irrigated to dryland crop production. In the Texas-Gulf basin and in southern California, water would be used for nonagricultural purposes (Table 4.7) and(or) for irrigation of fruits, nuts, rice and vegetables. In the Missouri basin where a surplus of water is projected (Table 4.8) future additional food and fiber production would come from dryland grain and hay production.

From 1961-70, an average of 56.0 million acres of land was retired in various government land retirement programs. With the increased food consumption, especially beef under Model A, added grain and forage production would leave only 16.4 million acres unused in the nation. But a considerable amount of land, 49.3 million acres either currently in land retirement programs or currently used for annual crop production, would be shifted to tame hay production under Model A (Table 4.6). Over 80 percent of the land shifted would be in the Missouri, Arkansas-White-Red and Upper Mississippi river basins. These are the areas that have large amounts of land in current land retirement programs. But under Model A, a shift to more diversified farming is indicated for these areas to supply forage for the increased beef production.

Consumptive use and supplies of water by river basin

Projected withdrawals and consumptive use of water under Model A are shown in Table 4.7. The net water balance in the 9 western river basins is summarized in Table 4.8. Total comsumptive use of water in the 17 Western States is projected to increase 22.3 million acre feet,

or 30 percent, over the 1965 level. Only the Arkansas-White Red and Rio Grande basins have a projected total water consumption in 2000 that is less than the 1965 level. Projected food and fiber production in the Arkansas-White-Red basin is predominently from dryland acreage. In the Rio Grande basin, only a small amount of the projected available water would be in surplus (Table 4.8). In certain areas of both the Arkansas-White-Red and Rio Grande basins, current use of ground water predominates (Figure 1.4). Since groundwater use above recharge rates is not allowed in Model A, water for consumptive use in 2000 would be less than present supplies. As shown in Table 4.4, projected irrigated acreage of annual crops in the Rio Grande basin declines from the actual 1964 levels.

Of the total increased consumptive use of water under Model A, 10.0 million acre feet, 45 percent, would be in the California-South Pacific basin. The Missouri, Texas-Gulf and Columbia-North Pacific basins also would increase water consumption to much higher levels. The projected increase in water consumption in the California-South Pacific basin is due to population growth and increased fruit, nut, rice and vegetable production. In the Texas-Gulf basin, estimated municipal and industrial water requirements give rise to the major increase. Crops would be the primary water user in both the Missouri and Columbia-North Pacific basins. The increases in water consumption in the Great Basin and Lower Colorado basins would be relatively small and irrigated acreages are less than 1964 levels under Model A (Tables 4.4 and 4.5). Currently, ground water is an important supply source in both these areas (Figure 1.4).

Under Model A, about 40 percent of the estimated total water supply would be consumed in 2000 (Table 4.8). Only the Texas-Gulf basin is projected to have a water deficit. The Rio Grande, Great Basin and Lower Colorado basins would have a relative scarcity, however. All remaining basins, including the Upper Colorado, have adequate water and need no further surface reservoir construction after 1980. The Upper Colorado basin would have a surplus of 0.9 million acre feet per year. In addition, it would release 5.3 million acre feet for consumptive use in the Lower Colorado basin. The Columbia-North Pacific basin would have the largest surplus, 98.9 million acre feet per year.

The projected water supply-demand situation under Model A is shown in Figure 4.9. In general, water supplies would be exhausted in the southwestern United States and in the Great Plains including the states of Kansas, Nebraska, Oklahoma and the High Plains of Texas. These areas currently use large amounts of ground water to satisfy irrigation water demands.

Under the formulation of Model A, only surface runoff would be available for the alternative water uses. Hence, these areas would adjust to the reduced supply of water available for agricultural uses in the year 2000.

Desalting would be required in the Texas-Gulf basin to cover the projected deficit of surface water resulting from the estimated exogenous uses for water. No other river basin would experience a water deficit, however, many would utilize all the water available. This indicates that given the demands projected under Model A, the major concern would be of water distribution rather than water shortage. The use of cropland previously in government programs could provide agrigulture with the productive capacity to meet the demands for food and fiber with little pressure on total water quantities.

Supply potential and policy alternatives

The projections to 2000 under Model A indicate neither a land nor an over-all water shortage for agriculture. The prospect is for continued large supply capacity relative to projected domestic and export demand for U.S. farm products. Farm commodity prices are not likely to rise to high real levels under the projected supply-demand relationships. (See Table 4.71 for a summary of projected farm prices under Model A.) The nation averaged 56.0 million acres retired from production under federal supply control programs over the period 1961-70, and Model A indicates that some cropland still would not be needed for crops in meeting projected demands. The amount of land not used for crops, however, is projected to decline from the 58 million acres out of production in 1969 to 16.4 million in 2000. At the same time, the amount of water used for irrigation and the amount of land irrigated could decline if resources were allocated optimally in terms of Model A. Under Model A, the amount of irrigated acreage would decline from the estimated 38.5 million acres in 1969 to 27.3 million acres in the 17 Western States. Hence, the nation could readily meet its food needs under the assumptions of Model A and some water could be released for other uses accordingly. Even if urban, municipal and manufacturing demand for water proves greater than that projected, more water would be diverted from agriculture where locational aspects of water supply and demand mesh. With even more water withdrawn from agriculture to meet nonfarm demand at particular locations, land elsewhere in the nation would be available to maintain total output.

Hence, even with a somewhat reduced acreage of irrigated land in 2000, the problems of agriculture nationally are more likely to be more nearly those of large production capacity and low prices, than of small supply relative to demand and high real costs of food to consumers. This statement, of course, is based on the projections used--including projections for export demands. If some unexpected circumstances caused urgency for much greater exports or international food aid, the situation would be altered.[4]

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[4]A higher level of both population and exports is evaluated under Model D.

Model A1: Free market, 300 million population, $15 water price and trend technology in 2000

This policy model is the same as Model A except that the price of water is higher and farmers in the 17 Western States pay at least $15.00 per acre foot for water (from surface runoff) used for crop irrigation or livestock production. The higher price on water affects its allocation in terms of the programming model's objective function.

Total acreage and distribution of dryland and irrigated crops

Compared with those in Model A, dryland acreages of the annual crops, hays and pastures would increase by 4.6 million, while irrigated acreages of these same crops would decrease by 4.6 million. The dryland acreage of annual crops, however, would be 1.0 million acres smaller that that under Model A (Table 4.9). Under Model A1, the dryland acreage of annual crops would increase 0.2 million acres in the South Atlantic-Gulf basin and decrease 0.6 million acres in the Arkansas-White-Red basin, 0.4 million acres in the Lower Mississippi basin, 0.2 million acres in the Upper Mississippi basin, 0.1 million acres in the Missouri basin and 0.1 million acres in the Great Lakes basin. The dryland acreage of wheat would decline 2.1 million acres, and dryland acreages of corn for grain, grain sorghum, soybeans and cotton would increase slightly. Compared with that in Model A, the irrigated acreage of annual crops would increase by 0.3 million acres under Model A1 including 0.5 million acres more irrigated wheat in the Columbia-North Pacific basin (Table 4.11).

Under Model A1, the dryland acreage of tame hay and silages would be 5.5 million acres higher than that under Model A (Table 4.10). The following river basins show most of the projected increase (and amounts): Missouri (1.4 million acres), Columbia-North Pacific (1.4 million acres), and Arkansas-White-Red (0.8 million acres). The irrigated acreage of tame hay and silages would decrease by 3.5 million from Model A. The following river basins show most of the projected decrease (and amounts): Upper Colorado (0.4 million acres), Columbia-North Pacific (1.8 million acres), Missouri (0.9 million acres) and Great Basin (0.4 million acres).

Dryland acreages of wild hay and pasture would be nearly the same as those under Model A. However, the projected irrigated acreage of wild hay and pasture is 1.3 million acres fewer than that under Model A (Table 4.12). Most of the decrease would be in the following river basins (and amounts): Upper Colorado (0.4 million acres), Columbia-North Pacific (0.3 million acres), California-South Pacific (0.2 million acres), Missouri (0.2 million acres) and Rio Grande (0.2 million acres).

In summary, the price of water is assumed to increase to $15.00 under Model A1 and in conformance with the national objective function, the projected mix of crops within the annual crop category changes and the proportion of annual crops and hay and pasture changes. For example, compared with that in Model A, the total dryland acreage of all crops

would be 4.6 million acres higher and the total irrigated acreage would be 4.6 million acres lower under Model A1. Under A1, compared with that in Model A, projected dryland production of all crops in both the West and the East is substituted for irrigated production in the West.

Unused cropland and hayland projected under Model A1 are reported in Table 4.13. Total unused land would be 1.3 million acres fewer than that under Model A. In addition, 3.3 million acres more irrigable land would be switched to dryland production compared with that in Model A, and 0.5 million acres more cropland would be shifted to tame hay production (Table 4.13). These changes are a result of the projected 5.5 million acres increase in dryland tame hay and silages under Model A1.

Consumptive use and supplies of water by river basin

Projected total water consumed under Model A1 is 12.0 percent below that of Model A. Compared with Model A, all river basins show a decrease in consumption, although the Arkansas-White-Red and Lower Colorado basins would have only slight decreases (Table 4.14). Water consumption would be reduced by 4.1 million acre feet per year in the Columbia-North Pacific basin, 2.4 million acre feet in the Missouri basin, 1.6 million acre feet in the Upper Colorado basin, 1.0 million acre feet in the Rio Grande basin, 1.0 million acre feet in the California-South Pacific basin, 0.9 million acre feet in the Great Basin basin and by 0.4 million acre feet in the Texas-Gulf basin.

No river basin would have a water deficit (Table 4.15) with a water price of $15.00. The Texas-Gulf basin still would use water desalting, however, because enough surface runoff water would not be available in water supply region 51. Thus, with the higher water price, the basin as a whole would have a small surplus, but water supply region 51 in the basin would have a deficit. The Great Basin and Lower Colorado basins would have a relative scarcity of water. As is true under Model A, the Columbia-North Pacific basin has the largest projected water suplus, followed by the Arkansas-White-Red and Missouri basins.

Under Model A1, 36.0 percent of the projected total water supply would be required for consumptive uses in 2000. For publicly developed projects, the cost of most farm supplies of irrigation water currently is in the form of a fixed cost based on water rights and amortized repayment schedules. In construction of Model A1, a marginal cost is added to the water charge to make the cost of surface runoff water at least $15.00 per acre foot in every water supply region. This higher price would reduce the quantity of water demanded within the national optimization of the programming model's objective function and release 11.4 million acre feet for other uses. In other words, the quantity of water demanded could be changed by an appropriate scheduling of water costs for farm users, allowing a substitution of nonirrigated land for water in attaining a given production level.

Model A2: Free market, 300 million population, $22.50 water price and trend technology in 2000

This policy model is the same as Model A1 except that the water price is even higher than under that in Model A1. Farmers in the 17 Western States would pay at least $22.50 per acre foot for surface run-off used for irrigation or livestock production.

Total acreage and distribution of dryland and irrigated crops

The dryland acreage of annual crops would be 0.6 million acres more under Model A2 than that under Model A (Table 4.16). The dryland acreage of wheat would decrease under Model A2. Dryland acreages of all other crops would increase as compared with those in Model A. The dryland acreage of annual crops in the following river basins would not change from that in Model A: Upper Colorado, Lower Colorado and Rio Grande. Compared with that in Model A, the following river basins would show a decrease in the dryland acreage of annual crops: Middle Atlantic, Great Lakes, Upper Mississippi, Missouri and Lower Mississippi (which would have the largest decrease, 1.1 million acres). All other river basins would show an increase compared with Model A. In the East, the largest projected increases in the dryland acreage of annual crops are in the South Atlantic-Gulf (0.7 million acres) and the Souris-Red-Rainy (0.8 million acres) basins. In the West, the California-South Pacific basin would have the largest increase, 1.3 million acres.

River basins with the largest increases in the projected dryland acreage of tame hay and silages include most of those with decreases in the dryland acreage of annual crops: South Atlantic-Gulf, Great Lakes, Upper Mississippi, Lower Mississippi, Missouri, Arkansas-White-Red and Columbia-North Pacific. The largest projected increase is 2.6 million acres in the Missouri basin (compare Table 4.3 with Table 4.17). Compared with that in Model A, only the Souris-Red Rainy basin would show a decrease while the Tennessee and Rio Grande basins would show no change in the dryland acreage of annual crops shown in Table 4.16. The dryland acreage of tame hay and silages under Model A2 would exceed that of Model A by 10.3 million acres and that of Model A1 by 4.8 million acres. The dryland acreage of wild hay and pasture under Model A2 would change very little from that of Model A (Table 4.17). Under Model A2, the effect of the increase in water price on the substitution of dryland production for irrigated production would be evident.

Compared with that in Model A, the irrigated acreage of annual crops would be 1.1 million acres fewer under Model A2, since at the higher water price land would be substituted for water (Table 4.18). This decrease would be shared by all annual crops except soybeans and all river basins except the California-South Pacific basin. Compared with that of Model A, dryland production would be substituted for irrigated production. Also the projected crop mix would change, with dryland and irrigated acreages of wheat and dryland acreage of tame hay and

silages declining relatively (Table 4.19). A reduction of 6.4 million acres of tame hay and silages is projected under Model A2, compared with that in Model A. Including wild hay and pasture, irrigated forage acreage would decline by 9.0 million acres under Model A2. In other words, when the price of water is raised from the implied level of Model A to $22.50 per acre foot under Model A2, projected acreage of irrigated land in the 17 Western States would decrease by 10.1 million acres. Over 90 percent of this total decrease would take place in the irrigated acreage of forage crops. Considering all irrigated forage crops, the following river basins (acres in parentheses) would show the largest decreases: Missouri (2.5 million), California-South Pacific (1.9 million), and Upper Colorado (1.0 million). The irrigated acreage of fruits, nuts, rice and vegetables under Model A2 would be the same as under Model A. The amount of cropland available for annual crops but shifted to tame hay production under Model A2 would be about the same as that under Model A (Table 4.20). Irrigated land would decrease by 10.1 million acres. Again, with the national objective function of Model A2, land without irrigation would be substituted for water and irrigated land as the water price is increased to $22.50 per acre foot. With the projected decline in yield on formerly irrigated land, as compared with that in Model A, a larger national acreage of crops is required to meet the restraints of the regional food demand equations. Consequently, the unused land category would be smaller under Model A2 than under either Model A1 or Model A.

Consumptive use and supplies of water by river basin

Under Model A2, total consumptive use of water would decline by 25.5 million acre feet per year as compared with that in Model A and would be 3.2 million acre feet less than the 1965 actual level (Table 4.21). The following river basins (and amounts in acre feet) have the largest reductions in projected water consumption: California-South Pacific (7.2 million), Columbia-North Pacific (5.9 million), Missouri (5.7 million) and Upper Colorado (2.4 million). Since only 30.0 percent of the estimated water supply would be used under Model A2, 167.5 million acre feet is surplus (Table 4.22). No river basin would have a water deficit, but both the Lower Colorado and Texas-Gulf basins would have relative water scarcities. Of the 3.7 million acre feet surplus projected for the Upper Colorado, much could be used in the Lower Colorado via the Colorado River. Desalting still would be used, under Model A2, in water supply region 51 of the Texas-Gulf basin to satisfy projected nonagricultural water demands. A surplus is projected, however, for the basin as a whole. Under Model A2, even the Great Basin would have a surplus of 1.0 million acre feet. As noted for the previous policy models, the Columbia-North Pacific basin has the largest projected surplus, 104.8 million acre feet per year.

The insertion of a $15.00 water price into the analysis (Model A1) would cause land devoted to crops without irrigation to be substituted for irrigation water and would release 11.4 million acre feet of water per year for other uses. An increase in the water price by 50.0 percent to a

minimum of $22.50 (Model A2) would cause an even greater release of water. The 50 percent increase in water price under Model A2 would increase the water released from agriculture to 25.5 million acre feet per year, or 24.0 percent more than that under Model A1. In other words, the same level of national food production would be attained under the several water prices, but as water price increases, demand for water would decrease and demand for unirrigated land would be augmented. An accentuated regional shift in crop production into states east of the Missouri River and away from the 17 Western States is projected as the substitution of land for water is extended under the $22.50 water price.

Model A3: Free market, 300 million population, $30.00 water price and trend technology in 2000

Model A3 with a water price of $30.00 represents the final water price variation of Model A. Model A3 and the three previous policy models provide points on a demand curve for agricultural water in the West. Also, the projected substitution rates between water in the West and land employed for rainfed crops in the East and the West can be evaluated.

Total acreage and distribution of dryland and irrigated crops

Compared with that in Model A, the dryland acreage of wheat would decline 6.5 million acres under Model A3. Projected dryland acreage is the same for sugar beets and decreases 1.4 million acres for grain sorghum. Dryland acreages of all other crops would be higher (Table 4.23) than those projected under Model A. A substitution of dryland production for irrigated production again would occur. Compared with that in Model A, the following river basins would have a larger dryland acreage of annual crops under Model A3: New England, South Atlantic-Gulf, Ohio, Tennessee, Souris-Red-Rainy, Arkansas-White-Red, Great Basin, Columbia-North Pacific and the California-South Pacific. The Rio Grande, Upper Colorado and Lower Colorado river basins show no projected change. The following river basins would have decreases: Middle Atlantic, Great Lakes, Upper Mississippi, Lower Mississippi and Texas-Gulf. The California-South Pacific basin has the largest projected increase in dryland acreage of annual crops, 1.8 million acres, and the Texas-Gulf basin has the largest projected decrease, 4.3 million acres.

Projected locations of annual crops under Model A3 are shown in Figures 4.10, 4.11 and 4.12. In general, the locations of both dryland and irrigated wheat would be the same as those under Model A, except that irrigated acreage would be less (Figure 4.10). The change between Model A3 and Model A is more apparent for feed grains and soybeans. Not only is the projected irrigated acreage of feed grains and soybeans less, but the projected dryland acreage is even more concentrated in the East, especially in the U-shaped belt running through the Corn Belt and Great Lakes and in Texas. Also, the dryland acreage of annual crops would increase significantly over a broad area stretching from the Corn Belt to Texas (Figure 4.11). Projected locations of dryland and irrigated acreages of cotton and sugar

beets are nearly identical with those of Model A (Figure 4.12). As for the previous policy models, the optimal solution under Model A3 indicates a shift of cotton acreage from the Southwest to the Southeast. With a water price of $30.00 per acre foot, the shift would be augmented as compared with the water price levels of Models A, A1 and A2. As noted for Model A, however, an optimal land and water use pattern at the national level in the year 2000 under assumptions of a free market also would specify a shift of cotton acreage from the Southwest to the Southeast. This shift conforms with a projected reduced use of irrigation for cotton production as it would move back into the Southeast. This pattern would be the most efficient national use of land and water under the assumptions of Model A3, which specify attainment of the nation's food and fiber needs at minimum factor cost (or, from a national standpoint, the most profitable production pattern in meeting a specific set of demands).

The solution is most evident for dryland acreage of tame hay and silages, which would increase by 16.4 million acres over that in Model A (Table 4.24). Both the Souris-Red-Rainy and Arkansas-White-Red basins would have a reduced dryland acreage of tame hay and silages under Model A3, but both of these basins would have a higher dryland acreage of annual crops under Model A3 (Table 4.23). The Rio Grande and Lower Colorado basins would show no change from Model A. All remaining river basins would have larger dryland acreages of tame hay and silages under Model A3. The river basins with major increases in projected dryland acreages of tame hay and silages (and amounts in acres) are: Texas-Gulf (4.4 million), Missouri (3.9 million), Columbia-North Pacific (2.5 million), Middle Atlantic (1.0 million) and the Great Lakes (1.0 million). The projected locations of dryland and irrigated hay production under Model A3 are shown in Figure 4.13. Compared with that in Model A, there would be significant shift of hay acreage from the states west of the Northern Plains to the Northern Plains and western Corn Belt states. Irrigated acreage of hay would be significantly lower under the higher water price of Model A3.

Irrigated land projected under Model A3 is shown in Table 4.25 for annual crops and in Table 4.26 for tame hay and silages. As compared with that in Model A, the irrigated acreage of annual crops would decline by 2.1 million acres and the irrigation acreage of tame hay and silages would decline by 8.6 million acres under Model A3. (See Figures 4.10, 4.11, 4.12 and 4.13 for the locations of irrigated crops under Model A3.) Irrigated acreages of wild hay and pasture would decline by 4.2 million acres under Model A3 (Table 4.26). The projected location of irrigated pasture under Model A3 (Figure 4.14) is mainly in California, Idaho, Utah, Nebraska and Kansas, essentially the same as that under Model A. The projected irrigated acreage of fruits, nuts, rice and vegetables is the same as for Model A (Table 4.5). The largest reductions in acreages of irrigated annual crops would occur in the Missouri, Arkansas-White-Red and Columbia-North Pacific river basins. For all irrigated hays, silages and pasture, the largest projected acreage reductions are in the following river basins (amounts in acres): Coulumbia-North Pacific (3.9 million), Missouri (3.8 million) and California-South Pacific (2.4 million).

With an assumed water price of $30.00 per acre foot under Model A3, total irrigated land in the West would decline by 14.9 million acres and the national dryland acreage of all crops would increase by 14.9 million acres, compared with those in Model A. Considering only the crops that use cropland and hayland (excluding wild hay and pasture), 14.6 million acres of dryland crops would substitute for 10.7 million acres of irrigated land and 26.8 million acre feet of water as compared to those in Model A.

Unused cropland and hayland under Model A3 are reported in Table 4.27. Total unused land would decline by 3.9 million acres between Model A and Model A3 because a further substitution of land for water would occur over the nation. Under Model A, over 7 million acres of irrigable cropland and irrigable hayland would switch to dryland production. Also, 49.3 million acres of cropland either currently in land retirement programs or currently used for annual crops production would be shifted to tame hay production. Under Model A3, compared with those in Model A, an additional 9.7 million acres of irrigable land would be switched to dryland production, and an additional 2.9 million acres of cropland would be shifted to tame hay production. The Middle Atlantic and South Atlantic-Gulf basins would account for more than three-fourths of increased dryland acreage of all crops. The Missouri basin has almost a third of the projected decrease in irrigated land (4.2 million acres) under Model A3. The projected location of unused land under Model A3 is shown in Figure 4.15. Compared with that in Model A, unused land would be more dispersed throughout the southwestern United States.

Consumptive use and supplies of water by river basin

Compared with Model A, total water consumption would decline by 36.2 million acre feet per year (Table 4.28). Also, as a result of a higher water price, water consumed under Model A3 would be 13.9 million acre feet less per year than the actual 1965 use. The largest projected decreases in agricultural water consumption are in the following river basins (and amounts in acre feet): Columbia-North Pacific (9.6 million), California-South Pacific (9.6 million) and Missouri (8.4 million). Only 25.5 percent of the total estimated water supply in the 17 Western States would be consumed under Model A3. In other words, as the price of water is increased to $30.00 per acre foot (for surface runoff), 36.2 million acre feet per year would be released from irrigation and livestock production and would be available for other uses.

As shown in Table 4.29, 178.3 million acre feet of water would be surplus under Model A3. None of the river basins would have a water deficit. However, in water supply region 51 of the Texas-Gulf basin, water for municipal and industrial consumptive uses would require water desalting to satisfy total requirements. Even the Lower Colorado basin would have a water surplus of 1.0 million acre feet per year. The Columbia-North Pacific basin again has the largest projected surplus, over 60 percent of the total surplus in the 17 Western States. The projected water supply-demand situation under Model A3 is shown in Figure 4.16. As indicated by Figure 4.9,

under Model A, the water supply would be exhausted in 22 water supply regions. Under Model A3 with the higher water price, the water supply would be exhausted in only 12 water supply regions. Under both Model A and Model A3, the water supply would be completely exhausted in all water supply regions in the Great Basin river basin. Thus, ample water exists for projected nonfarm uses and the nation could readily meet its food demands in 2000 through the substitution of land for water.

Demand summary

Figures 4.17 and 4.18 and Tables 4.30 and 4.31 summarize projected land and water use for agricultural purposes under the four policy models of the preceding sections (Model A, Model A1, Model A2 and Model A3). The results from Model A and the three price variation policy models provide information on (1) the projected demand curve for water in the 17 Western States and (2) the possible substitutions between land used for rainfed crops in the East for water (irrigated production) in the West and rainfed production in the West for irrigated production in the West. A third possible substitution, irrigated production in the East for irrigated production in the West, is not evaluated in the present study.

The projected demand curve for water in the 17 Western States is shown in Figure 4.17.[5] Given the points on the curve and the formulation of the programming model which underlie them, the arc price elasticities of demand

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[5]The curve in Figure 4.17 is drawn as a smooth curve although there are only four points shown on this curve. It is not entirely valid to join point A with the other three points because the assumptions behind Model A are not entirely consistent with the three price variation policy models. Recall that under the price variation policy models, farmers must pay at least a certain amount for surface runoff water (i.e., $15.00, $22.50 and $30.00). Under Model A, present prices for water in 2000 are assumed. To make Model A completely consistent with the price variation policy models, and make the demand curve more correct, farmers should have been required to pay at least $7.50 per acre foot for water in every water supply region. Additional points below point A could then have been derived by assuming farmers pay at least $2.50 or $1.50, etc.

for water can be calculated and are shown in Table 4.32.[6]

Table 4.32. Arc elasticity of demand for water for the demand curve in Figure 4.17.

Segment	Arc elasticity
$A_3 - A_2$	-1.683
$A_2 - A_1$	-1.012
$A_1 - A$	-0.329

These elasticities have the following interpretation: On the lower portion of the demand curve (A_1 - A) in Figure 4.17, a 1.0 percent increase in the water price is associated with a decrease of 0.329 percent in the quantity of water used in agriculture. On the higher portion of the demand curve (above A_1), a 1.0 percent increase in the water price results in a decrease of more than 1.0 percent in the quantity of water purchased or used. The segment of the curve below point A1 (Figure 4.17) is inelastic and the portion above is elastic. The curve in Figure 4.17 is a normative demand function expressing the response of agriculture to an increase in the price of water used for irrigation and livestock production. For a water scarce area, a similar curve could be derived to suggest the level of water price required to release water for higher priority uses. In the optimizing sense of the programming model employed, the curve suggests the rate of appropriate water pricing policies in potential reallocations of water use in the 17 Western States and the reallocation of land use both within these States and between them and the rest of the nation.

As the water price is increased (i.e., Model A1, Model A2 and Model A3), land and its production in the East would be substituted for water and its

[6]The demand curve in Figure 4.17 expresses the projected relationship between water price and water used in the West for livestock, annual crops, tame hay and silages, wild hay and pasture. Water for fruits, nuts, rice and vegetables and nonagricultural water requirements are not reported in Figure 4.17 as water used, since the amount for these purposes does not vary between the policy models under consideration.

production in the West. Also, the same type of land-water substitution in the West would occur. These two types of substitutions are shown clearly in Figure 4.18 and Tables 4.30 and 4.31. Movement from right to left along the demand curve in Figure 4.17, (i.e., points A, A1, A2 and A3) conforms with movement between the points on the different demand curves in Figure 4.18 (i.e., points D_1, D_2, D_3 and D_4). In other words, as the water price in the West rises, the demand curve for land used in annual crop and tame hay production in the East shifts to the right.[7] Nationally, dryland production in the East would be substituted for irrigated production in the West as the water price rises. The second projected substitution, dryland production in the West for irrigated production in the West, is shown in Tables 4.30 and 4.31. As the price of water rises, total dryland acreage of annual crops and tame hay and silages in the West would increase by 10.5 million acres. Total irrigated acreage of annual crops, tame hay and silages, wild hay and pasture would decrease by 14.9 million acres. Excluding wild hay and pasture, total irrigated acreage would decrease by 10.7 million acres in the West.

In summary, when the price of water increases to $30.00 per acre foot, total irrigated land in the West would decrease 14.9 million acres; total irrigated acreage of annual crops and tame hay and silages would decrease by 10.7 million acres. At the same time, total dryland acreage of annual crops and tame hay would increase by 4.0 million acres in the East and by 10.5 million acres in the West. When one acre is removed from irrigated production in the West, on the average, one acre dryland production would replace it. The replacement acre would be composed of about one-third of an acre in the East and two-thirds of an acre in the West. This projected one-to-one substitution is possible because (1) the mix of annual crops would change (e.g., wheat would decrease relative to corn for grain) and (2) the relative mix of hays to grain would change.

Alternative Policy Models with 280 Million Population

Four alternative policy models, all using 280 million population are analyzed in this section. The first policy model analyzed, Model B, is the same as Model A except that a lower level of population is used. The second policy model, Model E, incorporates the lower population and full comparative advantages of free market condition with the elimination of insecticides in corn and cotton production. The third policy model, Model F, assumes that all fragile lands would be removed from crop production, and the final policy model, Model C, simulates an annual land retirement program similar to the wheat, feed grain and cotton programs used during the period 1961-71.

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[7]Only points D_1, D_2, D_3 and D_4 in Figure 4.18 are generated from the programming model. Smooth curves have been drawn through each point for illustrative purposes only. In actuality the demand curves may be more inelastic than those shown, but given time and resources available, additional points on these curves were not estimated.

Model B: Free market, 280 million population, present water prices and trend technology in 2000

This is the fifth full comparative advantage and free market policy model analyzed using a given set of technologies. It is the same as Model A except a lower population of 280 million people (D level) is used.

Total acreage and distribution of dryland and irrigated crops

With a lower population in 2000 (280 million as compared to 300 million under Model A and its variants), the projected dryland acreage of annual crops would decrease by 12.2 million acres or by 6.4 percent (Table 4.33). The dryland acreage of wheat, however, would increase 4.9 million acres and the dryland acreage of oats would decrease by 9.0 million acres. The dryland acreage of corn for grain would decrease by 3.6 million acres, soybeans by 3.1 million acres and grain sorghum by 1.7 million acres, as compared with Model A. More wheat would be used for livestock feed under Model B than under Model A. Thus the dryland acreage of wheat would increase and dryland acreages of other grains would decrease. The following river basins have the largest projected decrease in dryland acreage of annual crops: Missouri, Upper Mississippi, Middle Atlantic, South Atlantic-Gulf, Ohio and Arkansas-White-Red. The Souris-Red-Rainy basin has a projected increase in the dryland acreage of annual crops. The New England, Lower Mississippi, Rio Grande, Upper Colorado, Lower Colorado, Columbia-North Pacific, Great Basin, Tennessee, Great Lakes and California-South Pacific basins would have little or no change compared with Model A.

Figures 4.19, 4.20 and 4.21 show the projected locations of annual crops production for Model B in 2000. Under Model B compared with Model A the acreage of wheat would increase in North Dakota and Minnesota (Figure 4.19) and the acreage of feed grains would decrease in these same areas (Figure 4.20). Under Model B, as under Model A, there would be a shift of cotton acreage to the Southeast (Figure 4.21).

Under Model B, projected dryland acreage of tame hay and silages is 22.5 million acres or 20.8 percent below that projected in Model A (Table 4.34). The Missouri basin would have a decrease of 13.3 million acres, the Ohio basin a decrease of 3.1 million acres, the Arkansas-White-Red would have a decrease of 1.8 million acres and the Great Lakes a decrease of 1.6 million acres. The South Atlantic-Gulf, the Souris-Red-Rainy and Arkansas-White-Red basins each would have a decrease of 1.1 million acres, and the Texas-Gulf basin would have a decrease of 0.6 million acres, compared with Model A. The Upper Mississippi basin would have an increase of 1.0 million acres. The remaining river basins would show little or no change from Model A. The projected location of the tame hay and wild hay acreage under Model B is shown in Figure 4.22. Compared with Model A, there would be much less hay production in the Missouri river basin.

The projected irrigated acreage of annual crops under Model B would be nearly the same as under Model A (Table 4.35). This projected constancy in irrigated acreage is possible because of the lower population used in Model B

and a conforming reduction in water needed for municipal and industrial uses. At the same time that more water would be available for agricultural uses, the relative availability of land under rainfed production would be increased in both the East and the West. Projected irrigated acreages of annual crops are shown in Figures 4.19, 4.20 and 4.21.

The projected irrigated acreage of tame hay and silages would be 1.1 million acres lower (Table 4.36) and the decrease would be spread uniformly over the 9 western river basins. Irrigated acreages of wild hay and pasture would be nearly the same as under Model A. Projected irrigated acreages of tame and wild hay and pasture are shown in Figures 4.22 and 4.23, respectively. The irrigated acreage of fruits, nuts, rice and vegetables would decline slightly because of the smaller population (Table 4.36). The large projected decrease in cropland and hayland requirements (and thus a large increase in unused land), under Model B, indicates the sensitivity of farm output to livestock feed requirements and total food needs as related to population. Under Model B, the projected number of beef cows is 5.6 million less than under Model A (Table 4.70). Production of other livestock also would be lower, as would food and industry requirements generally. In total, 34.6 million fewer acres of cropland and hayland would be utilized for the smaller population projected under Model B.

Fifty-one million acres of cropland and hayland would be unused with the 280 million population of Model B (Table 4.37). Of the total projected unused land, 25.6 million acres would be available for annual crop or tame hay production and an additional 25.3 million acres would be available for tame hay production only. The greatest projected change is in the Missouri basin where 17.1 million acres of cropland and hayland would be unused under Model B compared with 0.4 million acres unused under Model A. Compared with Model A, 0.3 million acres more of irrigable land would be switched to dryland production but 6.5 million acres less land either currently used for annual crop production would be shifted to tame hay production.

The projected location of unused crop and hayland under Model B is shown in Figure 4.24. Compared with Model A, much more unused land would be located along the Eastern Seaboard and in the southwestern United States. In addition, there would be a concentration of unused land in a belt extending from Texas to North Dakota and South Dakota as the acreage of unused cropland and hayland would increase to 51.0 million acres under the smaller projected food and fiber requirements of Model B.

With a population of only 280 million in the year 2000, the projected surplus capacity of agriculture promises to approach that of the 1961-70 period, when an annual average of 56.0 million acres of cropland were idle under federal supply control programs. While a reduced population growth rate is posed by some as a necessary future means to retain environmental quality, the projected lower food demand would pose a long-run continuation of price and income problems for the agricultural sector. With the projected 51.0 million acres of landnot used to meet food demand for the 280 million population in 2000, capacity would exist to alter land and water use for agriculture so that this sector would not add to environmental deterioration even under a population considerably greater than at the present.

Consumptive use and supplies of water by river basin

Projected withdrawals and consumptive use of water under Model B are shown in Table 4.38. Compared with Model A, total water consumed would be 5.3 million acre feet fewer per year or 5.4 percent less. Only 38.4 percent of the total estimated water supply would be consumed. And none of the river basins would be water deficit (Table 4.39). The Texas-Gulf basin, a water deficit area under Model A, would have a surplus of 0.9 million acre feet per year under Model B. The projected water supply-demand situation under Model B is shown in Figure 4.25. Under Model B, water supplies would be exhausted in 17 water supply regions compared with 22 water supply regions under Model A. Water supplies would be exhausted in the Great Basin and Lower Colorado river basins, southern California, Nebraska, northern Kansas and in the High Plains areas of Oklahoma and Texas.

Supply potential and policy alternatives

The projections to 2000 under Model B indicate an even larger land and water surplus than under Model A. As we outline in a later section, farm commodity prices are projected to be low under Model B, with 51.0 million acres of unused cropland and hayland. Thus, even with the presently low prices paid by farmers for water in the West, the nation could readily meet its food and fiber demands and release some water for higher priority uses if or as the need arises.

But even with the higher population of 300 million in 2000 (Model A, Model A1, Model A2 and Model A3), domestic food and fiber and export requirements at the levels projected would not cause demand to press against available land and water resources. As summarized in our discussion of land supplies used in this study, other researchers have estimated that from 40 to 150 million acres of new land could be brought into production if needed. And as indicated by the price variation policy models, an additional 11.4 million acre feet per year of water could be made available for other uses with a water price of $15.00 per acre foot, an additional 25.5 million acre feet with a water price of $22.50, and an additional 36.2 million acre feet with a water price of $30.00. Hence, even with higher population and exports than used in this study, land and water still might be in surplus in 2000. The situation could change with much greater population and export requirements than projected. With present concerns about population and environmental balances, however, the population in 2000 could be lower than 300 million. Hence, with the prospect of continued large or surplus food-producing capacity in the future and the potential prospect for continued "low" prices in agriculture, in the following sections we project and evaluate the effects of insecticide limitations, the removal of fragile lands and an annual land retirement program on land and water use under the 280 million population in 2000.

Model E: Free market, insecticide limitation, 280 million population, present water prices and trend technology in 2000

Model E is the same as Model B except that insecticides are eliminated in corn grain, corn silage and cotton production. Using available data on application rates and costs of insecticides, acreages treated with insecticides and crop damage in the absence of insecticides, new cost and yield coefficients were developed and used in the programming model.[8] Thus, Model E measures the projected impact on land and water use and farm prices should insecticides be eliminated in corn and cotton production in attempts to improve the quality of the environment.

Total acreage and distribution of dryland and irrigated crops

Nationally, compared with Model B, the dryland acreage of annual crops would increase 2.2 million acres under Model E (Table 4.40). The dryland acreage of corn would increase 1.0 million acres and the dryland acreage of oats would increase 0.6 million acres, in response to the insecticide limitation. The dryland acreage of soybeans would decrease 0.9 million acres, the dryland acreage of grain sorghum would decrease 0.7 million acres and the dryland acreages of cotton and sugar beets would decrease only slightly compared with Model B. Regionally, under Model E, the dryland acreage of annual crops would increase 1.3 million acres in the Upper Mississippi and 0.4 milllion acres in the Missouri river basins. The projected dryland acreage of annual crops in remaining river basins shows only relatively small changes compared with Model B.

The projected locations of dryland and irrigated corn acreages (grain and silage) are shown in Figure 4.26 for Model E and in Figure 4.27 for Model B. Compared with Model B, there would be an increase in the acreages of corn grain and silage in Iowa, Illinois, Indiana and Ohio (Corn Belt states) in response to the insecticide limitation. Even with projected lower yields due to increased crop damage from insects, the Corn Belt still would be the primary source of U.S. corn production.

The projected locations of dryland and irrigated cotton acreages are shown in Figure 4.28 under Model E and in Figure 4.29 under Model B. Under Model E, there would be a small increase in the irrigated acreage of cotton in the West. The largest part of the projected U.S. cotton acreage, however, still would be in the Southeast even with the insecticide limitation.

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[8]See Part III, "Yield and cost adjustments for the insecticide limitation policy model," for an explanation of the methods used to adjust corn and cotton yields and production costs.

Nationally, under Model E, the dryland acreage of tame hay and silages would be only slightly higher than that of Model B (Table 4.41). Regionally the largest projected increase in the dryland acreage of tame hay and silage would be in the Missouri river basin, 1.4 million acres. With Model E, the largest decrease in the dryland acreage of tame hay and silages would be in the Upper Mississippi river basin, 1.3 million acres, which also would have an increase in the dryland acreage of annual crops of 1.3 million acres. The projected dryland acreage of tame hay and silages in the remaining river basins show little or no change compared with Model B. The dryland acreages of wild hay and pasture under Model E would be slightly higher than under Model B (Table 4.41).

With insecticides eliminated in corn and cotton production, the irrigated acreage of annual crops would increase 0.4 million acres (Table 4.42). Compared with Model B, the irrigated acreages of wheat, grain sorghum and cotton would be higher under Model E. The projected irrigated acreage of corn grain would be lower. Regionally, under Model E, the projected irrigated acreage of annual crops would increase slightly in the following river basins: Missouri, Arkansas-White-Red and Great Basin. The irrigated acreage of cotton would be higher in the Texas-Gulf and California-South Pacific river basins under Model E.

The projected irrigated acreages of tame hay and silages, wild hay and pasture under Model E show little or no change compared with Model B (Table 4.43). Under Model E, the irrigated acreage of tame hay and silages would be 0.2 million acres higher in the California-South Pacific river basin and 0.1 million acres lower in the Great Basin river basin.

When insecticides are eliminated in corn and cotton production, the projected acreage of annual crops increases. Thus, under Model E, unused cropland and hayland would be 2.9 million acres less than under Model B (Table 4.44). Regionally, the largest change in unused land would occur in the Missouri river basin which would have 2.0 million acres less unused cropland and hayland.

The projected location of unused cropland and hayland under Model E is shown in Figure 4.30. Even with the insecticide ban, there still would be large amounts of unused cropland and hayland along the Eastern Seaboard and in the northern part of the Northern Plains.

Compared with Model B, the amount of land switched from irrigated to dryland production would be 0.2 million acres fewer under Model E. And land shifted (i.e., land either currently in land retirement programs or currently used for annual crop production) would be 0.4 million acres fewer under Model E.

Consumptive use and supplies of water

Projected withdrawals and consumptive use of water under Model E are reported in Table 4.45. Compared with Model B, total consumptive use of water would increase 1.3 million acre feet annually. Regionally, the

largest increase in consumptive use of water would be in the California-South Pacific river basin, 1.1 million acre feet per year. Under Model E, water for consumptive use also would be higher in the Missouri and the Rio Grande river basins but lower in the Lower Colorado river basin.

The projected net water balance under Model E is reported in Table 4.46 and Figure 4.31. Compared with Model B, there would be relatively few differences. In addition to the water scarce regions under Model B, water supply region 40 would use all available water for consumptive use under Model E. Other water scarce regions would be the traditionally lower rainfall regions of the nation.

Supply potential and policy alternatives

As expected, there is a smaller projected land and water surplus under Model E than under Model B. When insecticides are eliminated in corn and cotton production, more land would be cropped to maintain the previous levels of output, due to lower yields from locational shifts and the increased insect damage. Also, the total amount of water consumed would increase and farm prices would be higher under Model E than under Model B. In general, the projected price differences are in the expected direction but insignificant (Table 4.71). Resulting food costs also would be only slightly higher. Therefore, the costs in terms of additional resource use and higher food prices from insecticide limitations would not be significant. Farm prices would be only slightly higher. These conclusions follow from the results of Model E with a population of 280 million and with exports of farm products at 1967-69 levels. Should either the population or exports or both be higher than these levels, the results would be different. Land and water surplus would be smaller than indicated for Model E and farm prices and food costs would be higher. Under Model E, however, considerable slack still would exist in the farming sector to absorb further controls in attempts to "clean up" the environment. We next evaluate a farm policy that would remove fragile lands from potential crop uses.

Model F: Free market, fragile lands removed, 280 million population, present water prices and trend technology in 2000

Model F is the same as Model B except that fragile lands (i.e., blow lands, wash lands and wetlands) or lands that would have detrimental effects on the environment (quality of water and air, vegetative cover, wildlife, etc.) if subjected to agricultural uses are removed from the potential land base.[9] In total, over 656 million acres of land are removed from the "normal" land base under Model F (Tables 3.1 and 3.2). Nearly 97 percent of this land currently is used for dryland pasture production. Generally, this land is low yielding. Since projected aggregate demand for farm products is the same under Model F and Model B, adjustments would take place in both the crop mix and location of production to maintain output.

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[9]See Part III, "Land restraints for the fragile lands policy model" and "Yield adjustments for the fragile lands policy model" for an explanation of the methods used to adjust the land base and crop yields for Model F.

Total acreage and distribution of dryland and irrigated crops

Compared with Model B, the dryland acreage of annual crops would be 6.8 million acres fewer under Model F (Table 4.47). The largest projected change is in the dryland acreage of wheat which would be 13.6 million acres less under Model F. The dryland acreage of grain sorghum would be 2.5 million acres less, the dryland acreage of barley would be 1.6 million acres less and the dryland acreages of cotton and sugar beets would be only slightly lower under Model F. The dryland acreages of oats, corn grain and soybeans under Model F would increase by 7.8 million acres, 2.6 million acres and 0.7 million acres, respectively.

Regionally, the largest projected decreases in dryland acreages (and amounts) of annual crops under Model F would be in the following river basins: Missouri (2.6 million acres), Texas-Gulf (2.4 million acres), Arkansas-White-Red (1.4 million acres) and Souris-Red-Rainy (1.3 million acres). Compared with Model B, the dryland acreages of annual crops would be higher in the Middle Atlantic, Ohio and South Atlantic-Gulf river basins.

The irrigated and dryland acreages of wheat, feed grains and soybeans and cotton and sugar beets projected under Model F are shown in Figures 4.32, 4.33 and 4.34, respectively. The most notable change in the projected location of the acreage of annual crops between Model F and Model B is the large decrease in wheat acreage and corresponding increase in feed grain acreage (oats and corn grain) in western North Dakota and northern Minnesota (Figures 4.32 and 4.33). Under Model F, the U.S. cotton acreage still would be concentrated in the Southeast but there would be a shift in the acreage of sugar beets to Nevada and Idaho from Michigan (Figure 4.34).

With the removal from production of a large amount of pasture lands, the dryland acreage of tame hay and silages would increase by 18.2 million acres (primarily tame hay; Table 4.48). Under Model F, the dryland acreage of wild hay would be 0.4 million acres less and the dryland acreage of pasture would be 580.2 million acres fewer than under Model B (Table 4.48).

Regionally, under Model F, the largest projected increase in the dryland acreage of tame hay and silages would be in the Missouri river basin (8.5 million acres). No river basin would have a decrease in the dryland acreage of tame hay and silages under Model F. As shown in Figure 4.35, there would be substantial increases in the acreages of hay in the Missouri, Ohio and Texas-Gulf river basins under Model F. All river basins would have a decrease in the acreage of pasture under Model F (Figure 4.36).

With the removal of fragile lands from crop production (primarily forage), there are small projected increases in the irrigated acreages of annual crops (Table 4.49) and tame hay and silages (Table 4.50). The irrigated acreages of wild hay and pasture would be less than under Model B. Thus, there would be no net change in the total irrigated acreage of annual crops, hay and pasture under Model F.

The amounts and location of projected unused cropland and hayland under Model F are reported in Table 4.51 and Figure 4.38. Compared with Model B, unused cropland and hayland would be 30.9 million acres fewer. The amount of land switched from irrigated to dryland production would be nearly the same as under Model B. But an additional 7.3 million acres of land would be shifted from annual crops production to tame hay prodution under Model F in response to the large amount of fragile lands removed from pasture production. (Of the more than 656 million acres removed from crop production, nearly 97 percent currently would be used for pasture.)

The location of land considered as fragile lands under Model F is shown in Figure 4.37. In areas with large amounts of fragile lands, there would be a corresponding decrease in the amount of unused cropland and hayland under Model F. Thus, under Model F, there would be less unused cropland and hayland in the northern part of the Northern Plains (i.e., North Dakota and South Dakota), the Great Basin river basin, the Texas-Gulf river basin, the western part of the Arkansas-White-Red river basin, the southern part of the Upper Mississippi river basin, the western part of the Ohio river basin, the South Atlantic-Gulf river basin and the Eastern Seaboard (Compare Figure 4.24 with Figure 4.38). These are the same areas with large amounts of fragile lands (Figure 4.37).

Consumptive use and supplies of water by river basin

Although the total irrigated acreage of crops would be unchanged from Model B, total water consumed is 1.8 million acre feet per year higher under Model F (Table 4.52). Regionally, the largest projected increase in water for consumptive use is in the California-South Pacific river basin which would have an increase of 1.0 million acre feet annually. Under Model F, an additional 0.3 million acres of tame hay would be irrigated in this basin and, thus, water consumption would be higher. Compared with Model B, there would be a small decrease in the amount of water consumed in the Upper Colorado river basin. Remaining river basins show little or no change compared with Model B.

The projected net water balance under Model F is reported in Table 4.53 and Figure 4.39. Under Model F, the available water supply would be fully depleted in 20 water supply regions, compared with 17 water supply regions under Model B. The three additional water supply regions that would be water scarce under Model F are numbers 15, 31 and 40. As a result of the removal of fragile lands, the level of water consumption would be higher than under either Model B or Model E.

Supply potential and policy alternatives

Even with the removal of a large quantity of fragile land from crop production, a large supply capacity still could exist in the year 2000. Since most of the fragile lands in the nation currently are used for extensive type crops such as pasture and since this land generally is lower yielding, the aggregate level of output could be maintained with a much smaller

increased use of higher quality cropland and hayland. The increase in consumption of water also would be quite small.

In general, farm prices would be about 12 percent higher if fragile lands were removed from crop production (Table 4.71). Correspondingly, food costs would be higher than those under either Model B or Model E. With fragile lands idled from crop production, wind and water erosion could be reduced considerably. However, since most of the fragile land already is used for extensive type crops such as pasture, the improved effect on the quality of the envionment would be less than if the fragile lands currently were used for row type crops. Improved vegetative cover could be established, and the number of wildlife increased with removal of fragile lands from agricultural uses. Supply capacity would be reduced below the levels of Model B or Model E, farm prices and incomes would be higher and food costs would be higher.

Much of the fragile lands which could be removed from production under Model F currently is owned by the government (Bureau of Land Management permit and lease lands and Forest Service lands). Thus, only a low level of government payments would be required to induce farmers to idle additional fragile lands not owned by the government. If even higher prices and incomes than achieved under Model F are the goal, additional land could be taken out of production on a whole-farm or whole-region basis (see, for example, 21b, 44, 46). Over the past decade, however, a partial-farm land retirement program has been the main tool of price and income support in agriculture. Hence, with the prospect of continued large or surplus food-producing capacity and the potential for "low" prices in agriculture even until the year 2000, we next evaluate an annual land retirement program similar to the wheat, feed grains and cotton program actually used during the 1961-71 decade.

Model C: 45 million acre annual land retirement program, 280 million population, present water prices and trend technology in 2000

This is the fourth and final policy model analyzed with 280 million population. It assumes that 45 million acres are retired in 2000 on a partial-farm basis with most areas of the nation sharing in supply control. The program simulated is like the annual wheat, feed grain and cotton programs used during the 1961-71 decade and does not allow land uses and crop production to be fully allocated among regions on a comparative advantage basis. The policy model forces some land retirement in all regions of the nation, but aside from this restraint, crop production can be allocated interregionally on a comparative advantage basis.

A land retirement program that controls supply effectively is a means of substituting water in the 17 Western States for land in states east of the Missouri River (but with some substitution also of water in the West for land used under rainfed conditions in the West). Previous policy models allow land, especially in the East, to be substituted for water in the West in meeting food demands in the sense of a national economic optimal pattern. Model B, with the lower population, indicates considerable

surplus food capacity and a surplus of 147.4 million acre feet of water for other uses. As compared to current water and land use programs and patterns, it allows land in the East to be substituted for water in the West. Model C forces the substitution of water in the West for rainfed production in the East (and also for some dryland production in the West) in meeting projected food needs for the 280 million population. Of course, this is the outcome of the agricultural and water policies of the 1960's: they reduce the supply of land for crops by payments which divert it from the food-producing framework and use public investments to increase the supply of water for food production.

The pattern of crop production under this policy model would be substantially different than that under any previous policy model. With the lower population, aggregate food demand is less than under Model A but is the same as under Model B. Under Model C, however, farmers are limited in the amount or acreage of certain crops they can harvest. In this specific policy model, crop acreages are tied to their 1964 base for wheat, feed grains and cotton. Thus the pattern of production should compare favorably with 1964 and the spatial distribution of unused or retired land should parallel that of the 1961-71 decade.

The primary purpose of a land-retirement program of the type simulated is price support through supply control. In a later section we analyze the expected farm prices under each of the nine policy models included in this study. But our general conclusion thus far has been that the outlook in 2000 is for continued large or even surplus capacity of American agriculture and continued "low" prices, especially under Model B (Table 4.71). With a land retirement program of the type simululated, farm prices could be raised substantially and commodity stocks could be effectively controlled. We wish to analyze how a program of this type might affect the agricultural demand for water in the year 2000 and the manner and extent it would alter the supply of water available for municipal and industrial uses.

Total acreage and distribution of dryland and irrigated crops

Compared with Model B, the dryland acreage of annual crops would decline by 10.7 million acres (Table 4.54). The dryland acreage of both wheat and barley would decline substantially, 21.6 million and 4.0 million, respectively. On the other hand, dryland acreages of grain sorghum and soybeans would increase substantially, by 10.5 million acres and 13.1 million acres, respectively. Compared with Model B, the dryland acreage of annual crops would increase 12.5 million acres in the Missouri river basin, 3.9 million acres in the Arkansas-White-Red river basin and 2.3 million acres in the Upper Mississippi river basin. Dryland acreages of grain sorghum and soybeans would increase substantially in the Missouri and Arkansas-White-Red river basins. The acreage of soybeans also would increase in the Upper Mississippi river basin, and the acreage of grain sorghum would increase in the South Atlantic-Gulf river basin. Under Model C, farmers would feed less wheat, more of the other grains, more oilmeal and less forage than under either Model A or Model B. In tying crop production to a historic crop and

geographic base by supply control through land retirement, dispersed spatially over many regions and farms, a substantial change in the crop mix would result. Projected locations of acreages of annual crops under Model C are shown in Figures 4.40, 4.41 and 4.42. The production of each type of annual crop would be much more dispersed than that under any of the free-market policy models discussed previously.

The dryland acreage of tame hay and silages would be 7.7 million acres fewer than under Model B (Table 4.55). Compared with Model B, large decreases in the dryland acreage of tame hay and sialges would occur in the Missouri, Arkansas-White-Red and Upper Mississippi river basins. Under Model C, large increases in the dryland acreage of tame hay and silages would occur in the Middle Atlantic, South Atlantic-Gulf and Ohio river basins.

With an annual land retirement program, the irrigated acreage of annual crops would be 2.8 million acres higher than that projected under Model B (Table 4.56). Only the irrigated acreage of barley would be less than under Model B. Both the Missouri and California-South Pacific river basins would have increases of over a million acres in the irrigated acreage of annual crops compared with Model B. The irrigated acreage of annual crops in the Arkansas-White-Red basin would decrease by 0.4 million acres. (See Figures 4.40, 4.41 and 4.42 for the locations of the irrigated acreages of annual crops under Model C.)

Projected irrigated acreages of tame hay and silages, wild hay and pasture under Model C are reported in Table 4.57. Under Model C, irrigated acreages of tame hay and silages, wild hay and pasture would be nearly the same as under Model B.

In summary, under Model C, the dryland acreage of annual crops would be less than under Model A, but 10.7 million acres more than under Model B. The dryland acreage of wheat would decline substantially under Model C and dryland acreages of grain sorghum and soybeans would increase substantially as farmers (1) switch from feeding as much wheat and (2) are required to plant within their historic base. The dryland acreage of tame hay and silages would decrease by 9.9 percent from Model B. Under Model C, the irrigated acreages of hays, silages and pasture would increase only slightly but the irrigated acreage of annual crops would increase by 2.8 million acres, compared with Model B. The projected location of dryland and irrigated acreages of annual crops under Model C compares favorably with 1964.

As is expected, under Model C, all areas of the nation would have unused cropland (Table 4.58). Since farmers would be required to "set aside" part of their historic base under the supply control programs simulated, areas with large acreages of annual crops in the past would have the largest amounts of unused or idle land (primarily cropland). Since the irrigated acreage of annual crops would be higher under Model C than under any other policy model included in this study, 4.4 million acres less irrigable cropland and hayland would be switched to dryland production as compared with Model B. Also, under Model C, only 2.1 million acres of land available for annual crops would be shifted to tame hay production compared with 42.8 million acres under Model B.

The projected location of unused land under Model C is shown in Figure 4.43 and is widely dispersed over the nation compared with the comparative advantage and free market policy models in the previous sections (e.g., compare Figure 4.24 with Figure 4.43).

Consumptive use and supplies of water by river basin

Since the irrigated acreage of all crops under Model C would be more than under Model B, the amount of water consumed for irrigation would be higher (Table 4.59). Over 40 percent of the total estimated water supply would be consumed under Model C. Relatively speaking, under Model C, the projected pattern of water consumed by crops parallels the 1965 actual pattern. The total water consumed would differ from 1965, however, because of the larger municipal and industrial requirements projected for the Texas-Gulf and California-South Pacific river basins in 2000.

The projected supply-demand situation under Model C is reported in Table 4.60 and Figure 4.44. Total water consumed would be greater than under Model B and more water supply regions would be water-scarce (Figure 4.44). Also, the pattern of water consumption would be slightly different under Model C than Model B. Under Model C, but not Model B, water supply regions 15, 31, and 40 would be water scarce. Under Model B, but not Model C, water supply regions 36 and 41 would be water scarce. These projected differences are due to the acreage restrictions placed on farmers under Model C and, hence, a shift in the projected location of irrigated acreage. But the net projected effect of the farm program evaluated under Model C is a substitution of water (4.6 million acre feet annually) in the 17 Western States for previously dryland acreages in both the West and the East (Model B).

Supply potential and policy alternatives

Under Model B, a free market with 280 million population, farm prices generally would be lower than 1969 (Table 4.71). Thus, policy makers might consider a farm program, like the one evaluated with Model C, to raise farm prices. Under Model C, farm prices generally would be one-third higher than 1969 and 50 percent higher than Model B. With the annual land retirement program simulated, commodity stocks could be controlled to enhance farm incomes. Food costs, however, would be substantially higher than under Model B and more water would be used in agriculture. At the same time, large government payments would be required to induce farmer participation in the price and income support program. In recent years, programs of the type simulated under Model C have required treasury payments of about $5 billion, including administrative costs (2). With a population of 280 million and exports of farm products near recent year levels in 2000, farm prices could be lower than the present, unless some type of supply control program were implemented.

A Free Market Policy Model with 325 Million Population and Advanced Technology

Model D: Free market, 325 million population, present water prices and advanced technology in 2000

Model D is the ninth and final policy model included in this study.

It differs from Model A in three respects. First, the population in 2000 is assumed to 325 million (B level) rather than the 300 million (C level) used for Model A. Second, advanced technology is assumed for crops and livestock in the Southeast and for livestock across the entire nation. In general, agriculture in the Southeast is assumed to "catch up" to agriculture in the Corn Belt by 2000. For livestock in the nation, average feed conversion rates are assumed to approach levels now attained under research conditions and the calving rate is assumed to increase considerably.[10] Third, under Model D, the level of exports of farm products is assumed to be nearly twice as high as the 1967-69 average level incorporated into Model A. Compared with Model A, exports of feed grains and wheat would be 83.0 percent higher and exports of oilmeals 120.0 percent higher.[11] Thus, the combination of a higher population and higher exports under Model D would increase total demand for agricultural products to a maximum foreseeable level.

Total acreage and distribution of dryland and irrigated crops

The large increase in demand under Model D would result in sharply higher farm prices compared with Model A. In general, Model D prices of crop commodities would be about 50 percent higher and livestock prices about 12 percent higher (Table 4.71). With the higher projected demands, especially the export demand, the dryland acreage of annual crops would increase 29.7 million acres or 25.2 percent more than under Model A (Table 4.61). The dryland acreage of soybeans would increase by 22.2 million acres, corn for grain would increase 12.8 million acres, and grain sorghum would increase 1.4 million acres. Dryland acreage of barley would decrease 4.2 million acres, oats 1.1 million acres and wheat 0.9 million acres. The river basins (and amounts in acres) with large projected increases in the dryland acreage of annual crops would be: Missouri (17.7 million), Upper Mississippi (5.1 million), Arkansas-White-Red (4.8 million), Souris-Red-Rainy (3.3 million), and South Atlantic-Gulf (2.6 million). The largest projected decrease in total dryland acreage of annual crops would be in the Texas-Gulf river basin, 5.1 million acres.

With the higher calving rate assumed under Model D, the number of beef cows would be 12.0 million head (39.0 percent) less than under Model A. Although the numbers of dairy cows and fed beef would increase due to the higher domestic demands, the total demand for forages would decrease somewhat. As a result, the dryland acreage of tame hay and silages would be 18.9 million acres or 19.1 percent less than under Model A (Table 4.62). (The dryland acreage of tame hay decreases 20.1 million acres.) Compared with

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[10] See the section on "technological advance" in Part III for a more complete description of the differences between trend technology of Model A and advanced technology of Model D.

[11] See the section on "international trade" in Part III for the actual levels of exports assumed under Model D.

Model A, the following river basins (and amounts in acres) show large projected increases in dryland acreage of tame hay and silages: Texas-Gulf (5.4 million), Middle Atlantic (4.4 million), and South Atlantic-Gulf (1.8 million). The following river basins (and amounts in acres) show large projected decreases: Missouri (18.2 million), Arkansas-White-Red (5.9 million), Upper Mississippi (5.1 million), and Souris-Red-Rainy (3.2 million). Remaining river basins show relatively small changes from Model A. The dryland acreages of wild hay and pasture would be nearly the same as under Model A (Table 4.62). In summary, under Model D, the dryland acreage of annual crops would increase substantially and the dryland acreage of tame hay and silage would decrease substantially. The increased food and fiber demands and advanced technology in the Southeast would result in an increase of over 5 million acres of dryland annual crops and tame hay and silage in the Southeast (South Atlantic-Gulf and Tennessee river basins).

The irrigated acreage of annual crops under Model D would be 2.0 million acres higher than under Model A (Table 4.63). The irrigated acreages of grain sorghum, oats and corn grain would decline while the irrigated acreages of all other annual crops would increase over Model A. The largest increases would be for irrigated wheat (0.9 million acres) and irrigated cotton (0.8 million acres). All river basins except the Texas-Gulf and Lower Colorado basins would have a larger irrigated acreage of annual crops under Model D. The largest increase in irrigated acreage of annual crops would be in the Great Basin river basin (1.8 million acres).

The irrigated acreage of tame hay and silages under Model D would decline only slightly from Model A (0.8 million acres; Table 4.64). The irrigated acreage of tame hay and silages would increase the most in the Missouri river basin (0.3 million acres) and decrease the most in the Columbia-North Pacific river basin (0.7 million acres). The irrigated acreages of wild hay and pasture under Model D would be nearly the same as under Model A (Table 4.64).

Under Model D, only 4.5 million acres of cropland and hayland would remain unused (Table 4.65). Nearly 50 percent of the total unused land would be in the Great Lakes river basin and northeastern United States (Figure 4.45). Thus, nearly 12 million acres more would be used for annual crops and tame hay under Model D compared with Model A. Also, under Model D, 28.3 million acres less of cropland would be shifted to tame hay production. And 0.5 million acres less of irrigable land would be switched to dryland production under Model D. Thus, the increased domestic and export demands under Model D would leave only a small amount of unused land.

Consumptive use and supplies of water

Compared with Model A, total water consumed would increase by 3.6 million acre feet per year (3.7 percent). Water consumed by nonagricultural intake uses (municipal and industrial) would increase 1.9 million acre feet per year (Table 4.66). Forty-two percent of the total water supply would be consumed under Model D.

With the higher projected water consumption under Model D, there would be a water scarcity in the Rio Grande, Upper Colorado, Lower Colorado and Great Basin river basins (Table 4.67). The Upper Colorado river basin, however, would release 5.3 million acre feet of water into the Lower Colorado river basin. The Texas-Gulf river basin still would be water deficit due to the large nonagricultural water demand in water supply region 51.

Under Model D, 24 water supply regions would be water scarce compared with 22 regions under Model A (Figure 4.46). Water supply regions that would be water scarce under Model D but not Model A include regions 31, 47 and 48. Water supply region 37 would be water scarce under Model A but not Model D. Thus, under Model D, the entire southwestern United States would be water scarce. And regions presently using large amounts of ground water, i.e., Texas, Oklahoma, Kansas and Nebraska, would face water problems in 2000 with only projected surface water supplies available and the higher food and fiber demands of Model D.

Supply potential and policy alternatives

The projections to 2000 under Model D indicate a much smaller water and land surplus than under Model A. Farm commodity prices would rise substantially with only 4.5 million acres of unused land. As summarized in Part III, other researchers have estimated that from 50 to 150 million acres of new land could be brought into production if necessary. The farm price levels under Model D would encourage reclamation and development of these new lands.

Even with the large food and fiber demands under Model D, the total irrigated acreage of 28.6 million acres would be less than the estimated 1969 level of 38.5 million acres. Only 42.0 percent of the total water supply would be consumed, although four river basins would be relatively water scarce and one river basin, the Texas-Gulf basin, would be water-deficit. Thus, additional water demands could be satisfied in many of the river basins.

Model D incorporates domestic and foreign demands at a maximum foreseeable level. It also incorporates an accelerated rate of technological advance for crops and livestock in the Southeast and for livestock across the entire nation. Although nearly all the land presently cropped would be used, a considerable amount of water still would be in surplus. But current population trends and concern over the environment as well as the "green revolution" tend to negate these assumptions and make a lower population and much lower level of exports of farm products much more realistic.

Table 4.1. Summary of the policy models included in the study.

Model	Farm policy	Population	Water price	Exports[4]	Technology
Model A	free market	300 million[1]	present	1967-69 average	trend
Model A1	free market	300 million	$15.00	1967-69 average	trend
Model A2	free market	300 million	$22.50	1967-69 average	trend
Model A3	free market	300 million	$30.00	1967-69 average	trend
Model B	free market	280 million[2]	present	1967-69 average	trend
Model C	annual land retirement	280 million	present	1967-69 average	trend
Model D	free market	325 million[3]	present	higher	advanced
Model E	insecticide limitation	280 million	present	1967-69 average	trend
Model F	fragile lands removed	280 million	present	1967-69 average	trend

[1]This is the C population level of the Department of Commerce.

[2]This is the D population level of the Department of Commerce.

[3]This is the B population level of the Department of Commerce.

[4]Imports of beef and veal, pork, lamb and mutton and dairy products are assumed to equal average 1967-69 per capita levels in 2000. Higher exports under Model D are twice the 1967-69 average levels.

Table 4.2. Dryland acreages of annual crops in the 18 river basins with C population level, present water prices, trend technology and a free market in 2000 (Model A).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
United States	176,379	189,521	53,143	33,575	24,082	20,550	7,013	45,784	4,298	1,076
New England	37	83	0	0	0	83	0	0	0	0
M. Atlantic	3,671	5,865	3,191	0	0	0	2,314	360	0	0
S. Atlantic-Gulf	10,084	10,855	618	0	957	0	1,958	7,322	0	0
Great Lakes	10,513	12,357	1,366	3,335	0	1,903	202	3,975	0	1,076
Ohio	16,020	19,311	2,623	9,235	0	1,076	0	6,377	0	0
Tennessee	1,215	1,340	0	0	0	0	0	250	1,090	0
U. Mississippi	37,849	39,255	3,761	16,458	2,738	3,386	0	12,912	0	0
L. Mississippi	11,154	14,253	5,402	0	0	0	0	5,643	3,208	0
S.-Red-Rainy	9,317	9,190	1,399	1,172	0	6,619	0	0	0	0
Missouri	43,416	36,802	14,750	1,112	6,816	4,567	1,252	8,305	0	0
Ark.-White-Red	18,929	15,295	11,088	1,745	789	646	387	640	0	0
Texas-Gulf	8,512	15,422	3,221	18	10,840	1,064	279	0	0	0
Rio Grande	374	1,014	0	0	1,014	0	0	0	0	0
U. Colorado	167	0	0	0	0	0	0	0	0	0
L. Colorado	21	0	0	0	0	0	0	0	0	0
Great Basin	320	441	175	0	0	23	243	0	0	0
Col.-N. Pacific	4,686	6,065	5,369	0	0	696	0	0	0	0
Cal.-S. Pacific	94	1,973	180	0	928	487	378	0	0	0

[1]Source: (186).

Table 4.3. Dryland acreages of silages, hay and pasture in the 18 river basins with C population level, present water prices, trend technology and a free market in 2000 (Model A).

River basin	Silages		Tame hay		Wild hay		Pasture	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[2]	2000[3]
				(000 acres)				
United States	10,572	13,717	46,675	85,417	9,005	8,907	621,192	929,614
New England	138	0	1,031	0	0	0	1,551	1,475
M. Atlantic	1,041	0	4,289	0	0	0	8,234	9,756
S. Atlantic-Gulf	370	796	1,675	1,612	0	0	30,314	43,745
Great Lakes	1,402	832	5,356	7,366	35	28	7,256	9,831
Ohio	639	429	5,603	5,436	0	0	21,570	23,828
Tennessee	102	0	1,025	819	0	0	5,658	6,012
U. Mississippi	2,786	4,133	8,785	14,728	357	351	21,150	19,589
L. Mississippi	121	0	957	1,265	43	42	12,137	24,806
S.-Red-Rainy	425	1,148	1,282	3,864	771	771	4,224	4,110
Missouri	2,716	3,869	10,548	33,142	6,234	6,234	169,015	198,279
Ark.-White-Red	546	1,617	2,819	12,966	1,201	1,160	79,262	100,234
Texas-Gulf	108	401	1,387	1,504	141	106	71,139	87,260
Rio Grande	7	0	32	289	5	2	52,276	76,764
U. Colorado	9	0	68	888	10	8	15,449	46,078
L. Colorado	2	0	2	0	1	0	44,995	77,851
Great Basin	34	401	127	71	31	30	16,371	69,687
Col.-N. Pacific	122	91	1,373	1,393	139	139	35,555	87,125
Cal.-S. Pacific	4	0	316	74	37	36	25,036	43,784

[1]Source: (186).
[2]Source: (186). Public grazing lands not included.
[3]Includes 291 million acres of public grazing lands.

Table 4.4. Irrigated acreages of annual crops in the 9 western river basins with C population level, present water prices, trend technology and a free market in 2000 (Model A).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
Western Basins	11,242	6,163	1,497	913	2,536	415	339	8	385	70
Missouri	2,021	788	114	363	53	258	0	0	0	0
Ark.-White-Red	1,568	1,645	0	295	1,283	16	0	8	43	0
Texas-Gulf	2,764	918	0	52	797	30	0	0	39	0
Rio Grande	755	269	0	0	180	33	0	0	56	0
U. Colorado	86	48	0	28	0	20	0	0	0	0
L. Colorado	661	315	0	0	0	0	315	0	0	0
Great Basin	222	61	37	0	0	0	24	0	0	0
Col.-N. Pacific	918	1,135	382	109	0	44	0	0	0	0
Cal.-S. Pacific	2,247	984	364	66	223	14	0	0	247	70

[1]Source: (186).

Table 4.5. Irrigated acreages of silages, hay, pasture and fruits, nuts, rice and vegetables in the 9 western river basins with C population level, present water prices, trend technology and a free market in 2000 (Model A).

River basin	Silages		Tame hay		Wild hay		Pasture		Fruits, nuts, etc.	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000
	(000 acres)									
Western Basins	745	1,069	6,150	9,804	1,361	1,249	5,093	4,302	4,096	4,697
Missouri	301	487	1,345	2,967	459	419	984	882	34	43
Ark.-White-Red	86	260	226	491	16	8	145	129	22	36
Texas-Gulf	35	7	72	62	0	0	237	127	534	501
Rio Grande	29	95	286	245	58	57	268	232	227	118
U. Colorado	15	22	532	316	174	174	580	580	66	5
L. Colorado	36	0	229	193	4	0	101	40	141	126
Great Basin	5	0	547	537	293	287	499	188	33	72
Col.-N. Pacific	93	103	1,596	2,675	291	290	1,147	1,249	621	832
Cal.-S. Pacific	145	95	1,317	2,318	66	14	1,132	875	2,418	2,964

[1]Source: (186).

Table 4.6. Unused land and land shifted from annual crops to tame hay production in the 18 river basins with C population level, present water prices, trend technology and a free market in 2000 (Model A).

River basin	Unused dryland cropland	Unused irrigable cropland	Total unused cropland	Unused dryland hayland	Unused irrigable hayland	Total unused hayland	Total unused land	Land shifted[1]
			(000 acres)					
United States	4,806	543	5,349	9,924	1,136	11,060	16,409	49,274
New England	150	-	150	1,176	-	1,176	1,326	0
M. Atlantic	77	-	77	4,607	-	4,607	4,684	0
S. Atlantic-Gulf	3,259	-	3,259	1,407	-	1,407	4,666	604
Great Lakes	0	-	0	0	-	0	0	1,770
Ohio	160	-	160	935	-	935	1,095	414
Tennessee	317	-	317	633	-	633	950	250
U. Mississippi	0	-	0	0	-	0	0	5,496
L. Mississippi	0	-	0	0	-	0	0	187
S.-Red-Rainy	0	-	0	32	-	32	32	2,568
Missouri	0	0	0	227	146	373	373	24,257
Ark.-White-Red	101	0	101	147	45	192	293	10,261
Texas-Gulf	0	0	0	68	15	83	83	67
Rio Grande	384	151	535	21	8	29	564	159
U. Colorado	55	0	55	10	0	10	65	533
L. Colorado	171	392	563	34	140	174	737	72
Great Basin	6	0	6	35	191	226	232	67
Col.-N. Pacific	0	0	0	240	0	240	240	1,114
Cal.-S. Pacific	126	0	126	352	591	943	1,069	1,455

[1]Cropland presently in land retirement programs or used for annual crop production but used for tame hay production in 2000.

Table 4.7. Withdrawals and consumptive use of water in the 9 western river basins with C population level, present water prices, trend technology and a free market in 2000 (Model A).

River basin	Total 1965[1]	Projected 2000: All crops	Livestock	Municipal & industrial[2]	Onsite	Other[3]	Total 2000
	(thousand acre feet per year)						
Withdrawals							
Western Basins	151,733	93,205	1,725	53,605	4,797	2,632	155,964
Missouri	21,668	15,808	657	6,562	1,086	1,132	25,245
Ark.-White-Red	10,541	6,361	408	8,515	0	0	15,284
Texas-Gulf	18,382	5,539	232	16,834	227	0	22,832
Rio Grande	8,165	3,843	143	1,356	0	0	5,342
U. Colorado	4,500	3,388	60	1,104	198	0	4,750
L. Colorado	7,774	3,482	50	1,414	585	1,500	7,031
Great Basin	5,730	2,880	2	1,109	1,276	0	5,267
Col.-N. Pacific	33,191	20,633	55	7,155	0	0	27,843
Cal.-S. Pacific	41,782	31,271	118	9,556	1,425	0	42,370
Consumptive use							
Western Basins	75,050	66,354	1,725	22,623	3,981	2,632	97,315
Missouri	11,822	10,736	657	1,305	1,086	1,132	14,916
Ark.-White-Red	6,580	4,309	408	1,429	0	0	6,146
Texas-Gulf	8,165	4,114	232	7,723	227	0	12,296
Rio Grande	4,632	2,685	143	616	0	0	3,444
U. Colorado	2,220	2,575	60	507	144	0	3,286
L. Colorado	3,862	2,400	50	659	351	1,500	4,960
Great Basin	2,524	2,146	2	474	908	0	3,530
Col.-N. Pacific	11,785	13,549	55	1,670	0	0	15,274
Cal.-S. Pacific	23,460	23,840	118	8,240	1,265	0	33,463

[1]Source: (216, Tables 7-3-4 and 7-3-5).

[2]Includes rural domestic, municipal, self supplied industrial, recreation, mining and thermal electric power.

[3]Includes water export to Mexico, depletion of the Upper Milk River by Canada and transfer of water from the Missouri river basin into the S.-Red-Rainy basin.

Table 4.8. Total water supply, total consumptive use and the net water balance in the 9 western river basins with C population level, present water prices, trend technology and a free market in 2000 (Model A).

River basin	Water from natural runoff[1]	Water from inter-basin natural stream flows	Water from inter-basin transfers	Total water supply	Total consumptive use[2]	Surplus or deficit	Water from desalting
	(thousand acre feet per year)						
	Consumptive use						
Western Basins	239,410	0	0	239,410	97,315	142,095	355
Missouri	28,600	0	337	28,937	14,916	14,021	0
Ark.-White-Red	24,390	0	-51	24,339	6,146	18,193	0
Texas-Gulf	12,210	0	51	12,261	12,296	-35	355
Rio Grande	4,070	0	0	4,070	3,444	626	0
U. Colorado	9,830	-5,277	-337	4,216	3,286	930	0
L. Colorado	2,890	5,277	-3,207	4,960	4,960	0	0
Great Basin	3,530	0	0	3,530	3,530	0	0
Col.-N.Pacific	114,190	0	0	114,190	15,274	98,916	0
Cal.-S.Pacific	39,700	0	3,207	42,907	33,463	9,444	0

[1]See Table 3.3.

[2]See Table 4.7.

Table 4.9. Dryland acreages of annual crops in the 18 river basins with C population level, $15.00 water prices, trend technology and a free market in 2000 (Model A1).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
United States	176,379	188,540	51,086	33,824	24,462	20,533	6,865	46,335	4,357	1,078
New England	37	83	0	0	0	83	0	0	0	0
M. Atlantic	3,571	5,866	3,191	0	0	0	2,161	514	0	0
S. Atlantic-Gulf	10,084	11,103	789	0	957	0	2,035	7,322	0	0
Great Lakes	10,513	12,211	1,366	3,835	0	1,903	201	3,828	0	1,078
Ohio	16,020	19,292	2,508	9,955	0	1,116	115	5,598	0	0
Tennessee	1,215	1,340	0	0	0	0	0	250	1,090	0
U. Mississippi	37,349	39,028	3,761	15,661	2,738	3,154	0	13,714	0	0
L. Mississippi	11,154	13,878	4,708	268	0	51	0	5,584	3,267	0
S.-Red-Rainy	9,317	9,190	1,399	1,172	0	6,619	0	0	0	0
Missouri	43,416	36,698	14,333	1,172	6,815	4,321	1,252	8,305	0	0
Ark.-White-Red	18,929	14,727	9,919	1,745	791	665	387	1,220	0	0
Texas-Gulf	8,512	15,473	3,303	16	11,219	935	0	0	0	0
Rio Grande	374	1,014	0	0	1,014	0	0	0	0	0
U. Colorado	167	0	0	0	0	0	0	0	0	0
L. Colorado	21	0	0	0	0	0	0	0	0	0
Great Basin	320	529	304	0	0	0	225	0	0	0
Col.-N. Pacific	4,686	6,096	5,325	0	0	771	0	0	0	0
Cal.-S. Pacific	94	2,012	180	0	928	415	489	0	0	0

[1]Source: (186).

Table 4.10. Dryland acreages of silages, hay and pasture in the 18 river basins with C population level, $15.00 water prices, trend technology and a free market in 2000 (Model A1).

River basin	Silages		Tame hay		Wild hay		Pasture	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[2]	2000[3]
				(000 acres)				
United States	10,572	13,881	46,675	90,787	9,005	8,963	621,192	929,614
New England	138	0	1,031	0	0	0	1,551	1,475
M. Atlantic	1,041	0	4,289	42	0	0	8,234	9,156
S. Atlantic-Gulf	370	849	1,675	1,914	0	0	30,314	43,745
Great Lakes	1,402	832	5,356	7,513	35	31	7,256	9,831
Chic	639	448	5,603	5,436	0	0	21,570	23,828
Tennessee	102	0	1,025	819	0	0	5,658	6,012
U. Mississippi	2,786	4,043	8,785	15,046	357	351	21,150	19,589
L. Mississippi	121	12	957	1,629	43	42	12,137	24,806
S.-Red-Rainy	425	1,148	1,282	3,897	771	771	4,224	4,110
Missouri	2,716	3,989	10,548	34,446	6,234	6,234	169,015	198,279
Ark.-White-Red	546	1,661	2,819	13,683	1,201	1,199	79,262	100,234
Texas-Gulf	108	409	1,387	1,527	141	120	71,139	87,260
Rio Grande	7	0	32	289	5	2	52,276	76,764
U. Colorado	9	0	68	940	10	8	15,449	46,078
L. Colorado	2	0	2	0	1	0	44,995	77,851
Great Basin	34	296	127	328	31	30	16,371	69,687
Col.-N. Pacific	122	194	1,373	2,656	139	139	35,555	87,125
Cal.-S. Pacific	4	0	316	622	37	36	25,036	43,784

[1]Source: (186).
[2]Source: (186). Public grazing lands not included.
[3]Includes 291 million acres of public grazing lands.

Table 4.11. Irrigated acreages of annual crops in the 9 western river basins with C population level, $15.00 water prices, trend technology and a free market in 2000 (Model A1).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
Western Basins	11,242	6,413	1,944	861	2,288	409	507	8	327	69
Missouri	2,021	749	0	425	53	271	0	0	0	0
Ark.-White-Red	1,568	1,580	0	295	1,225	16	0	8	36	0
Texas-Gulf	2,764	858	0	0	819	0	0	0	39	0
Rio Grande	755	217	0	0	180	33	0	0	4	0
U. Colorado	86	10	0	6	0	4	0	0	0	0
L. Colorado	661	261	0	0	0	0	261	0	0	0
Great Basin	222	78	37	0	0	0	41	0	0	0
Col.-N. Pacific	918	1,609	1,543	66	0	0	0	0	0	0
Cal.-S. Pacific	2,247	1,051	364	69	11	85	205	0	248	69

[1]Source: (186).

Table 4.12. Irrigated acreages of silages, hay, pasture and fruits, nuts, rice and vegetables in the 9 western river basins with C population level, $15.00 water prices, trend technology and a free market in 2000 (Model A1).

	Silages		Tame hay		Wild hay		Pasture		Fruits, nuts, etc.	
River basin	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000
					(000 acres)					
Western Basins	745	977	6,150	6,370	1,361	799	5,093	3,424	4,096	4,697
Missouri	301	510	1,345	2,037	459	239	984	882	34	43
Ark.-White-Red	86	259	226	509	16	8	145	129	22	36
Texas-Gulf	35	7	72	33	0	0	237	69	534	501
Rio Grande	29	95	286	143	58	0	268	72	227	118
U. Colorado	15	7	532	139	174	173	580	185	66	5
L. Colorado	36	0	229	223	4	0	101	40	141	126
Great Basin	5	0	547	123	293	287	499	188	33	72
Col.-N. Pacific	93	0	1,596	969	291	92	1,147	1,138	621	832
Cal.-S. Pacific	145	99	1,317	2,194	66	0	1,132	721	2,418	2,964

[1]Source: (186).

Table 4.13. Unused land and land shifted from annual crops to tame hay production in the 18 river basins with C population level, $15.00 water prices, trend technology and a free market in 2000 (Model A1).

River basin	Unused dryland cropland	Unused irrigable cropland	Total unused cropland	Unused dryland hayland	Unused irrigable hayland	Total unused hayland	Total unused land	Land shifted[1]
			(000 acres)					
United States	4,441	687	5,128	8,856	1,150	10,006	15,134	49,778
New England	150	-	150	1,176	-	1,176	1,326	0
M. Atlantic	77	-	77	4,565	-	4,565	4,642	0
S. Atlantic-Gulf	2,928	-	2,928	1,135	-	1,135	4,063	634
Great Lakes	0	-	0	0	-	0	0	1,918
Ohio	160	-	160	935	-	935	1,095	414
Tennessee	317	-	317	633	-	633	950	250
U. Mississippi	0	-	0	0	-	0	0	5,814
L. Mississippi	0	-	0	0	-	0	0	551
S.-Red-Rainy	0	-	0	0	-	0	0	2,568
Missouri	0	0	0	0	0	0	0	23,986
Ark.-White-Red	101	0	101	16	31	47	148	10,874
Texas-Gulf	0	0	0	67	22	89	89	45
Rio Grande	384	203	587	21	109	130	717	159
U. Colorado	55	20	75	10	157	167	242	565
L. Colorado	171	434	605	34	123	157	762	84
Great Basin	6	30	36	21	331	352	388	0
Col.-N. Pacific	0	0	0	92	87	179	179	532
Cal.-S. Pacific	92	0	92	151	290	441	533	1,384

[1] Cropland presently in land retirement programs or used for annual crop production but used for tame hay production in 2000.

Table 4.14. Withdrawals and consumptive use of water in the 9 western river basins with C population level, $15.00 water prices, trend technology and a free market in 2000 (Model A1).

River basin	Total 1965[1]	Projected 2000: All crops	Livestock	Municipal & industrial[2]	Onsite	Other[3]	Total 2000
	(thousand acre feet per year)						
				Withdrawals			
Western Basins	151,733	76,546	1,720	53,605	4,797	2,632	139,300
Missouri	21,568	12,126	655	6,562	1,086	1,132	21,561
Ark.-White-Red	10,541	6,226	421	8,515	0	0	15,162
Texas-Gulf	18,382	4,947	232	16,834	227	0	22,240
Rio Grande	8,165	2,536	140	1,356	0	0	4,032
U. Colorado	4,500	1,354	47	1,104	198	0	2,703
L. Colorado	7,774	3,461	53	1,414	585	1,500	7,013
Great Basin	5,730	1,722	2	1,109	1,276	0	4,109
Col.-N. Pacific	33,191	14,311	56	7,155	0	0	21,522
Cal.-S. Pacific	41,782	29,863	114	9,556	1,425	0	40,958
				Consumptive use			
Western Basins	75,050	54,984	1,720	22,623	3,981	2,632	85,940
Missouri	11,822	8,327	655	1,305	1,086	1,132	12,505
Ark.-White-Red	6,580	4,227	421	1,429	0	0	6,077
Texas-Gulf	8,165	3,731	232	7,723	227	0	11,913
Rio Grande	4,632	1,742	140	616	0	0	2,498
U. Colorado	2,220	1,030	47	507	144	0	1,728
L. Colorado	3,862	2,392	53	659	351	1,500	4,955
Great Basin	2,524	1,248	2	474	908	0	2,632
Col.-N. Pacific	11,785	9,428	56	1,670	0	0	11,154
Cal.-S. Pacific	23,460	22,859	114	8,240	1,265	0	32,478

[1]Source: (216, Tables 7-3-4 and 7-3-5).

[2]Includes rural domestic, municipal, self supplied industrial, recreation, mining and thermal electric power.

[3]Includes water export to Mexico, depletion of the Upper Milk River by Canada and transfer of water from the Missouri river basin into the S.-Red-Rainy basin.

Table 4.15. Total water supply, total consumptive use and the net water balance in the 9 western river basins with C population level, $15.00 water prices, trend technology and a free market in 2000 (Model A1).

River basin	Water from natural runoff[1]	Water from inter-basin natural stream flows	Water from inter-basin transfers	Total water supply	Total consumptive use[2]	Surplus or deficit	Water from desalting
	(thousand acre feet per year)						
	Consumptive use						
Western Basins	239,410	0	0	239,410	85,940	153,470	355
Missouri	28,600	0	337	28,937	12,505	16,432	0
Ark.-White-Red	24,390	0	-51	24,339	6,077	18,262	0
Texas-Gulf	12,210	0	51	12,261	11,913	348	355
Rio Grande	4,070	0	0	4,070	2,498	1,572	0
U. Colorado	9,830	-5,277	-337	4,216	1,728	2,488	0
L. Colorado	2,890	5,277	-3,212	4,955	4,955	0	0
Great Basin	3,530	0	0	3,530	2,632	898	0
Col.-N.Pacific	114,190	0	0	114,190	11,154	103,036	0
Cal.-S.Pacific	39,700	0	3,212	42,912	32,478	10,434	0

[1]See Table 3.3.

[2]See Table 4.14.

Table 4.16. Dryland acreages of annual crops in the 18 river basins with C population level, $22.50 water prices, trend technology and a free market in 2000 (Model A2).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
United States	176,379	190,105	47,229	34,983	25,502	20,872	7,646	48,450	4,323	1,100
New England	37	89	0	0	0	89	0	0	0	0
M. Atlantic	3,671	5,834	3,033	246	0	8	2,033	514	0	0
S. Atlantic-Gulf	10,084	11,542	732	0	2,017	0	1,471	7,322	0	0
Great Lakes	10,513	11,517	1,366	3,853	0	1,952	178	3,068	0	1,100
Ohio	16,020	19,335	2,508	10,246	0	1,132	166	5,283	0	0
Tennessee	1,215	1,499	0	0	0	0	0	409	1,090	0
U. Mississippi	37,849	38,143	3,761	14,706	2,738	2,831	0	14,107	0	0
L. Mississippi	11,154	13,188	3,097	1,070	0	204	0	5,584	3,233	0
S.-Red-Rainy	9,317	10,003	1,399	1,172	0	7,432	0	0	0	0
Missouri	43,416	36,570	14,237	1,945	5,683	5,148	1,252	8,305	0	0
Ark.-White-Red	18,929	15,313	7,443	1,745	998	882	387	3,858	0	0
Texas-Gulf	8,512	15,427	3,303	0	12,124	0	0	0	0	0
Rio Grande	374	1,014	0	0	1,014	0	0	0	0	0
U. Colorado	167	0	0	0	0	0	0	0	0	0
L. Colorado	21	0	0	0	0	0	0	0	0	0
Great Basin	320	636	287	0	0	0	349	0	0	0
Col.-N. Pacific	4,686	6,675	5,896	0	0	779	0	0	0	0
Cal.-S. Pacific	94	3,320	167	0	928	415	1,810	0	0	0

[1]Source: (186).

Table 4.17. Dryland acreages of silages, hay and pasture in the 18 river basins with C population level, $22.50 water prices, trend technology and a free market in 2000 (Model A2).

River basin	Silages		Tame hay		Wild hay		Pasture	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[2]	2000[3]
				(000 acres)				
United States	10,572	15,371	46,675	94,088	9,005	8,981	621,192	929,843
New England	138	4	1,031	0	0	0	1,551	1,475
M. Atlantic	1,041	32	4,289	846	0	0	8,234	9,156
S. Atlantic-Gulf	370	1,769	1,675	1,964	0	0	30,314	43,745
Great Lakes	1,402	868	5,356	8,171	35	31	7,256	9,831
Ohio	639	456	5,603	5,436	0	0	21,570	23,828
Tennessee	102	0	1,025	819	0	0	5,658	6,012
U. Mississippi	2,786	3,915	8,785	16,059	357	351	21,150	19,589
L. Mississippi	121	81	957	2,248	43	42	12,137	24,806
S.-Red-Rainy	425	1,311	1,282	2,921	771	771	4,224	4,339
Missouri	2,716	3,938	10,548	35,611	6,234	6,234	169,015	198,279
Ark.-White-Red	546	2,039	2,819	13,258	1,201	1,199	79,262	100,234
Texas-Gulf	108	454	1,387	1,536	141	138	71,139	87,260
Rio Grande	7	0	32	289	5	2	52,276	76,764
U. Colorado	9	0	68	1,079	10	8	15,449	46,078
L. Colorado	2	0	2	0	1	0	44,995	77,851
Great Basin	34	230	127	328	31	30	16,371	69,687
Col.-N. Pacific	122	224	1,373	2,861	139	139	35,555	87,125
Cal.-S. Pacific	4	0	316	663	37	36	25,036	43,784

[1]Source: (186).
[2]Source: (186). Public grazing lands not included.
[3]Includes 291 million acres of public grazing lands.

Table 4.18. Irrigated acreages of annual crops in the 9 western river basins with C population level, $22.50 water prices, trend technology and a free market in 2000 (Model A2).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
Western Basins	11,242	5,111	1,365	406	2,419	220	295	8	342	56
Missouri	2,021	671	0	263	324	84	0	0	0	0
Ark.-White-Red	1,568	1,217	0	61	1,096	16	0	8	36	0
Texas-Gulf	2,764	858	0	0	819	0	0	0	39	0
Rio Grande	755	217	0	0	180	33	0	0	4	0
U. Colorado	86	10	0	6	0	4	0	0	0	0
L. Colorado	661	0	0	0	0	0	0	0	0	0
Great Basin	222	37	37	0	0	0	0	0	0	0
Col.-N. Pacific	918	987	951	36	0	0	0	0	0	0
Cal.-S. Pacific	2,247	1,114	377	40	0	83	295	0	263	56

[1]Source: (186).

Table 4.19. Irrigated acreages of silages, hay, pasture and fruits, nuts, rice and vegetables in the 9 western river basins with C population level, $22.50 water prices, trend technology and a free market in 2000 (Model A2).

	Silages		Tame hay		Wild hay		Pasture		Fruits, nuts, etc.	
River basin	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964	2000	1964[1]	2000
					(000 acres)					
Western Basins	745	760	6,150	3,736	1,361	502	5,093	2,410	4,096	4,697
Missouri	301	443	1,345	1,147	459	209	984	467	34	43
Ark.-White-Red	86	144	226	411	16	0	145	84	22	36
Texas-Gulf	35	7	72	23	0	0	237	0	534	501
Rio Grande	29	95	286	96	58	0	268	45	227	118
U. Colorado	15	7	532	0	174	31	580	41	66	5
L. Colorado	36	0	229	387	4	0	101	5	141	126
Great Basin	5	0	547	125	293	224	499	188	33	72
Col.-N. Pacific	93	0	1,596	957	291	38	1,147	859	621	832
Cal.-S. Pacific	145	64	1,317	590	66	0	1,132	721	2,418	2,964

[1]Source: (186).

Table 4.20. Unused land and land shifted from annual crops to tame hay production in the 18 river basins with C population level, $22.50 water prices, trend technology and a free market in 2000 (Model A2).

River basin	Unused dryland cropland	Unused irrigable cropland	Total unused cropland	Unused dryland hayland	Unused irrigable hayland	Total unused hayland	Total unused land	Land shifted[1]
			(000 acres)					
United States	2,944	886	3,830	7,851	1,247	9,098	12,928	49,426
New England	140	-	140	1,176	-	1,176	1,316	0
M. Atlantic	77	-	77	3,761	-	3,761	3,838	0
S. Atlantic-Gulf	1,651	-	1,651	1,002	-	1,002	2,653	550
Great Lakes	0	-	0	0	-	0	0	2,575
Ohio	109	-	109	935	-	935	1,044	414
Tennessee	158	-	158	633	-	633	791	250
U. Mississippi	0	-	0	0	-	0	0	6,827
L. Mississippi	0	-	0	0	-	0	0	1,170
S.-Red-Rainy	0	-	0	0	-	0	0	1,591
Missouri	0	0	0	0	0	0	0	24,205
Ark.-White-Red	101	0	101	40	44	84	185	10,364
Texas-Gulf	0	0	0	67	22	89	89	38
Rio Grande	384	240	624	21	120	141	765	123
U. Colorado	55	20	75	10	157	167	242	565
L. Colorado	171	596	767	34	57	91	858	182
Great Basin	6	30	36	21	328	349	385	0
Col.-N. Pacific	0	0	0	0	0	0	0	537
Cal.-S. Pacific	92	0	92	151	519	670	762	35

[1]Cropland presently in land retirement programs or used for annual crop production but used for tame hay production in 2000.

Table 4.21. Withdrawals and consumptive use of water in the 9 western river basins with C population level, $22.50 water prices, trend technology and a free market in 2000 (Model A2).

River basin	Total 1965[1]	Projected 2000: All crops	Livestock	Municipal & industrial[2]	Onsite	Other[3]	Total 2000
	(thousand acre feet per year)						
Withdrawals							
Western Basins	151,733	57,636	1,684	53,605	4,797	2,632	120,354
Missouri	21,668	7,303	657	6,562	1,086	1,132	16,740
Ark.-White-Red	10,541	4,356	415	8,515	0	0	13,286
Texas-Gulf	18,382	4,549	232	16,834	227	0	21,842
Rio Grande	8,165	2,152	146	1,356	0	0	3,654
U. Colorado	4,500	240	42	1,104	198	0	1,584
L. Colorado	7,774	3,303	49	1,414	585	1,500	6,851
Great Basin	5,730	1,556	2	1,109	1,276	0	3,943
Col.-N. Pacific	33,191	11,618	63	7,155	0	0	18,836
Cal.-S. Pacific	41,782	22,559	78	9,556	1,425	0	33,618
Consumptive use							
Western Basins	75,050	40,946	1,684	22,623	3,981	2,632	71,866
Missouri	11,822	5,053	657	1,305	1,086	1,132	9,233
Ark.-White-Red	6,580	2,966	415	1,429	0	0	4,810
Texas-Gulf	8,165	3,464	232	7,723	227	0	11,646
Rio Grande	4,632	1,473	146	616	0	0	2,235
U. Colorado	2,220	182	42	507	144	0	875
L. Colorado	3,862	2,304	49	659	351	1,500	4,863
Great Basin	2,524	1,123	2	474	908	0	2,507
Col.-N. Pacific	11,785	7,664	63	1,670	0	0	9,397
Cal.-S. Pacific	23,460	16,717	78	8,240	1,265	0	26,300

[1]Source: (216, Tables 7-3-4 and 7-3-5).

[2]Includes rural domestic, municipal, self supplied industrial, recreation, mining and thermal electric power.

[3]Includes water export to Mexico, depletion of the Upper Milk River by Canada and transfer of water from the Missouri river basin into the S.-Red-Rainy basin.

Table 4.22. Total water supply, total consumptive use and the net water balance in the 9 western river basins with C population level, $22.50 water prices, trend technology and a free market in 2000 (Model A2).

River basin	Water from natural runoff[1]	Water from inter-basin natural stream flows	Water from inter-basin transfers	Total water supply	Total consumptive use[2]	Surplus or deficit	Water from desalting
	(thousand acre feet per year)						
	Consumptive use						
Western Basins	239,410	0	0	239,410	71,866	167,544	355
Missouri	28,600	0	10	23,610	9,233	19,377	0
Ark.-White-Red	24,390	0	-51	24,339	4,810	19,529	0
Texas-Gulf	12,210	0	51	12,261	11,646	615	355
Rio Grande	4,070	0	0	4,070	2,235	1,835	0
U. Colorado	9,830	-5,277	-10	4,543	875	3,669	0
L. Colorado	2,890	5,277	-3,304	4,863	4,863	0	0
Great Basin	3,530	0	0	3,530	2,507	1,023	0
Col.-N.Pacific	114,190	0	0	114,190	9,397	104,793	0
Cal.-S.Pacific	39,700	0	3,304	43,004	26,300	16,704	0

[1]See Table 3.3.

[2]See Table 4.21.

Table 4.23. Dryland acreages of annual crops in the 18 river basins with C population level, $30.00 water prices, trend technology and a free market in 2000 (Model A3).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
United States	176,379	187,741	46,653	35,562	22,681	21,785	7,458	47,918	4,608	1,076
New England	37	89	0	0	0	89	0	0	0	0
M. Atlantic	3,671	5,825	2,954	315	0	10	1,921	625	0	0
S. Atlantic-Gulf	10,084	11,628	781	0	1,594	0	1,471	7,734	48	0
Great Lakes	10,513	11,340	1,366	3,853	0	1,952	202	2,891	0	1,076
Ohio	16,020	19,326	2,623	10,587	0	1,150	51	4,915	0	0
Tennessee	1,215	1,702	0	0	0	0	0	409	1,293	0
U. Mississippi	37,849	38,217	3,761	14,761	2,738	2,850	0	14,107	0	0
L. Mississippi	11,154	13,222	3,109	1,060	0	202	0	5,584	3,267	0
S.-Red-Rainy	9,317	9,964	1,399	1,172	0	7,393	0	0	0	0
Missouri	43,416	36,315	13,350	2,069	5,668	5,671	1,252	8,305	0	0
Ark.-White-Red	18,929	16,699	7,444	1,745	2,890	885	387	3,348	0	0
Texas-Gulf	8,512	11,152	3,303	0	7,849	0	0	0	0	0
Rio Grande	374	1,014	0	0	1,014	0	0	0	0	0
U. Colorado	167	0	0	0	0	0	0	0	0	0
L. Colorado	21	0	0	0	0	0	0	0	0	0
Great Basin	320	636	287	0	0	0	349	0	0	0
Col.-N. Pacific	4,686	6,889	6,109	0	0	780	0	0	0	0
Cal.-S. Pacific	94	3,723	167	0	928	803	1,825	0	0	0

[1]Source: (186).

Table 4.24. Dryland acreages of silages, hay and pasture in the 18 river basins with C population level, $30.00 water prices, trend technology and a free market in 2000 (Model A3).

River basin	Silages		Tame hay		Wild hay		Pasture	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[2]	2000[3]
	(000 acres)							
United States	10,572	15,871	46,675	99,638	9,005	8,983	621,192	929,843
New England	138	4	1,031	0	0	0	1,551	1,475
M. Atlantic	1,041	40	4,289	994	0	0	8,234	9,156
S. Atlantic-Gulf	370	1,683	1,675	1,964	0	0	30,314	43,745
Great Lakes	1,402	868	5,356	8,348	35	33	7,256	9,831
Ohio	639	465	5,603	5,436	0	0	21,570	23,828
Tennessee	102	0	1,025	1,409	0	0	5,658	6,012
U. Mississippi	2,786	3,922	8,785	15,977	357	351	21,150	19,589
L. Mississippi	121	47	957	2,248	43	42	12,137	24,806
S.-Red-Rainy	425	1,304	1,282	2,967	771	771	4,224	4,339
Missouri	2,716	4,233	10,548	36,694	6,234	6,234	169,015	198,279
Ark.-White-Red	546	2,446	2,819	11,469	1,201	1,199	79,262	100,234
Texas-Gulf	108	403	1,387	5,886	141	138	71,139	87,260
Rio Grande	7	0	32	289	5	2	52,276	76,764
U. Colorado	9	0	68	1,079	10	8	15,449	46,078
L. Colorado	2	0	2	0	1	0	44,995	77,851
Great Basin	34	230	127	328	31	30	16,371	69,687
Col.-N. Pacific	122	226	1,373	3,804	139	139	35,555	87,125
Cal.-S. Pacific	4	0	316	746	37	36	25,036	43,784

[1]Source: (186).
[2]Source: (186). Public grazing lands not included.
[3]Includes 291 million acres of public grazing lands.

Table 4.25. Irrigated acreages of annual crops in the 9 western river basins with C population level, $30.00 water prices, trend technology and a free market in 2000 (Model A3).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
Western Basins	11,242	4,072	1,161	348	2,125	136	0	8	224	70
Missouri	2,021	392	0	255	53	84	0	0	0	0
Ark.-White-Red	1,568	1,214	0	61	1,107	16	0	8	22	0
Texas-Gulf	2,764	858	0	0	819	0	0	0	39	0
Rio Grande	755	183	0	0	146	33	0	0	4	0
U. Colorado	86	0	0	0	0	0	0	0	0	0
L. Colorado	661	0	0	0	0	0	0	0	0	0
Great Basin	222	0	0	0	0	0	0	0	0	0
Col.-N. Pacific	918	784	784	0	0	0	0	0	0	0
Cal.-S. Pacific	2,247	641	377	32	0	3	0	0	159	70

[1]Source: (186).

Table 4.26. Irrigated acreages of silages, hay, pasture and fruits, nuts, rice and vegetables in the 9 western river basins with C population level, $30.00 water prices, trend technology and a free market in 2000 (Model A3).

River basin	Silages		Tame hay		Wild hay		Pasture		Fruits, nuts, etc.	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000
	(000 acres)									
Western Basins	745	687	6,150	1,604	1,361	276	5,093	1,038	4,096	4,697
Missouri	301	399	1,345	395	459	4	984	116	34	43
Ark.-White-Red	86	144	226	411	16	0	145	80	22	36
Texas-Gulf	35	7	72	0	0	0	237	0	534	501
Rio Grande	29	91	286	96	58	0	268	26	227	118
U. Colorado	15	0	532	0	174	20	580	0	66	5
L. Colorado	36	0	229	140	4	0	101	0	141	126
Great Basin	5	0	547	55	293	217	499	131	33	72
Col.-N. Pacific	93	0	1,596	0	291	35	1,147	373	621	832
Cal.-S. Pacific	145	46	1,317	507	66	0	1,132	312	2,418	2,964

[1]Source: (186).

Table 4.27. Unused land and land shifted from annual crops to tame hay production in the 18 river basins with C population level, $30.00 water prices, trend technology and a free market in 2000 (Model A3).

River basin	Unused dryland cropland	Unused irrigable cropland	Total unused cropland	Unused dryland hayland	Unused irrigable hayland	Total unused hayland	Total unused land	Land shifted[1]
			(000 acres)					
United States	2,786	1,165	3,951	7,082	1,454	8,536	12,487	52,128
New England	140	-	140	1,176	-	1,176	1,316	0
M. Atlantic	77	-	77	3,613	-	3,613	3,690	0
S. Atlantic-Gulf	1,651	-	1,651	1,002	-	1,002	2,653	550
Great Lakes	0	-	0	0	-	0	0	2,752
Ohio	109	-	109	935	-	935	1,044	414
Tennessee	0	-	0	0	-	0	0	207
U. Mississippi	0	-	0	0	-	0	0	6,745
L. Mississippi	0	-	0	0	-	0	0	1,170
S.-Red-Rainy	0	-	0	0	-	0	0	1,638
Missouri	0	0	0	0	0	0	0	24,532
Ark.-White-Red	101	0	101	40	44	84	185	8,575
Texas-Gulf	0	0	0	67	22	89	89	4,352
Rio Grande	384	278	662	21	120	141	803	123
U. Colorado	55	37	92	10	157	167	259	565
L. Colorado	171	708	879	34	193	227	1,106	71
Great Basin	6	67	73	21	399	420	493	0
Col.-N. Pacific	0	0	0	0	0	0	0	399
Cal.-S. Pacific	92	75	167	163	519	682	849	35

[1] Cropland presently in land retirement programs or used for annual crop production but used for tame hay production in 2000.

Table 4.28. Withdrawals and consumptive use of water in the 9 western river basins with C population level, $30.00 water prices, trend technology and a free market in 2000 (Model A3).

River basin	Total 1965[1]	Projected 2000 All crops	Livestock	Municipal & industrial[2]	Onsite	Other[3]	Total 2000
	(thousand acre feet per year)						
				Withdrawals			
Western Basins	151,733	42,304	1,684	53,605	4,797	2,632	105,022
Missouri	21,668	3,394	651	6,562	1,086	1,132	12,825
Ark.-White-Red	10,541	4,328	419	8,515	0	0	13,262
Texas-Gulf	18,382	4,465	232	16,834	227	0	21,758
Rio Grande	8,165	1,938	170	1,356	0	0	3,464
U. Colorado	4,500	50	38	1,104	198	0	1,390
L. Colorado	7,774	1,614	46	1,414	585	1,500	5,159
Great Basin	5,730	1,022	2	1,109	1,276	0	3,409
Col.-N. Pacific	33,191	6,159	59	7,155	0	0	13,373
Cal.-S. Pacific	41,782	19,334	67	9,556	1,425	0	30,382
				Consumptive use			
Western Basins	75,050	30,195	1,684	22,623	3,981	2,632	61,115
Missouri	11,822	2,322	651	1,305	1,086	1,132	6,496
Ark.-White-Red	6,580	2,948	419	1,429	0	0	4,796
Texas-Gulf	8,165	3,410	232	7,723	227	0	11,592
Rio Grande	4,632	1,330	170	616	0	0	2,116
U. Colorado	2,220	37	38	507	144	0	726
L. Colorado	3,862	1,107	46	659	351	1,500	3,663
Great Basin	2,524	740	2	474	908	0	2,124
Col.-N. Pacific	11,785	3,971	59	1,670	0	0	5,700
Cal.-S. Pacific	23,460	14,330	67	8,240	1,265	0	23,902

[1]Source: (216, Tables 7-3-4 and 7-3-5).

[2]Includes rural domestic, municipal, self supplied industrial, recreation, mining and thermal electric power.

[3]Includes water export to Mexico, depletion of the Upper Milk River by Canada and transfer of water from the Missouri river basin into the S.-Red-Rainy basin.

Table 4.29. Total water supply, total consumptive use and the net water balance in the 9 western river basins with C population level, $30.00 water prices, trend technology and a free market in 2000 (Model A3).

River basin	Water from natural runoff[1]	Water from inter-basin natural stream flows	Water from inter-basin transfers	Total water supply	Total consumptive use[2]	Surplus or deficit	Water from desalting
	(thousand acre feet per year)						
	Consumptive use						
Western Basins	239,410	0	0	239,410	61,115	178,295	355
Missouri	28,600	0	0	28,600	6,496	22,104	0
Ark.-White-Red	24,390	0	-51	24,339	4,796	19,543	0
Texas-Gulf	12,210	0	51	12,261	11,592	669	355
Rio Grande	4,070	0	0	4,070	2,116	1,954	0
U. Colorado	9,830	-5,277	0	4,553	726	3,827	0
L. Colorado	2,890	5,277	-3,486	4,681	3,663	1,018	0
Great Basin	3,530	0	0	3,530	2,124	1,406	0
Col.-N.Pacific	114,190	0	0	114,190	5,700	108,490	0
Cal.-S.Pacific	39,700	0	3,486	43,186	23,902	19,284	0

[1]See Table 3.3.

[2]See Table 4.28.

Table 4.30. Dryland acreage of crops in the 9 western river basins under alternative prices paid for water by farmers in 2000.[1]

River basin	Water price: Present (Model A)	$15.00 (Model A1)	$22.50 (Model A2)	$30.00 (Model A3)	Change Model A to Model A3
	(thousand acres)				
Western Basins	133,719	137,591	141,517	144,263	10,544
Missouri	73,814	75,134	76,169	77,244	3,430
Ark.-White-Red	29,878	30,071	30,610	30,613	735
Texas-Gulf	17,327	17,409	17,418	17,442	115
Rio Grande	1,303	1,303	1,303	1,303	0
U. Colorado	888	940	1,079	1,079	191
L. Colorado	0	0	0	0	0
Great Basin	913	1,153	1,194	1,194	281
Col.-N. Pacific	7,549	8,946	9,760	10,918	3,369
Cal.-S. Pacific	2,047	2,635	3,984	4,470	2,423

[1]Includes wheat, corn grain, grain sorghum, corn and sorghum silage, oats, barley, soybeans, cotton, sugar beets and tame hay. Since acreages of dryland wild hay and dryland pastures change only slightly from Model A to Model A3, they are not included in this table.

Table 4.31. Irrigated acreage of crops in the 9 western river basins under alternative prices paid for water by farmers in 2000.[1]

River basin	Water price: Present (Model A)	$15.00 (Model A1)	$22.50 (Model A2)	$30.00 (Model A3)	Change Model A to Model A3
	(thousand acres)				
Western Basins	22,587	17,985	12,519	7,680	-14,907
Missouri	5,543	4,417	2,936	1,306	-4,237
Ark.-White-Red	2,533	2,485	1,855	1,848	-685
Texas-Gulf	1,114	967	888	865	-249
Rio Grande	899	528	454	396	-503
U. Colorado	1,139	515	90	20	-1,119
L. Colorado	548	524	392	144	-404
Great Basin	1,073	676	574	403	-670
Col.-N. Pacific	5,452	3,808	2,841	1,192	-4,260
Cal.-S. Pacific	4,286	4,065	2,489	1,506	-2,780

[1]Includes wheat, corn grain, grain sorghum, corn and sorghum silage, oats, barley, soybeans, cotton, sugar beets, tame hay, wild hay and pasture.

Table 4.33. Dryland acreages of annual crops in the 18 river basins with D population level, present water prices, trend technology and a free market in 2000 (Model B).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
United States	176,379	177,363	58,052	29,941	22,348	11,515	7,636	42,697	4,054	1,120
New England	37	83	0	0	0	83	0	0	0	0
M. Atlantic	3,671	4,231	2,717	0	0	0	1,514	0	0	0
S. Atlantic-Gulf	10,084	9,302	104	0	876	0	2,010	6,312	0	0
Great Lakes	10,513	12,076	1,533	3,654	0	1,693	547	3,529	0	1,120
Ohio	16,020	18,158	2,636	8,333	0	847	0	6,342	0	0
Tennessee	1,215	1,090	0	0	0	0	0	0	1,090	0
U. Mississippi	37,849	37,053	3,761	15,181	2,738	2,958	0	12,415	0	0
L. Mississippi	11,154	14,252	5,402	0	0	0	0	5,886	2,964	0
S.-Red-Rainy	9,317	10,295	10,147	22	0	126	0	0	0	0
Missouri	43,416	33,194	12,339	1,006	6,729	4,295	1,252	7,573	0	0
Ark.-White-Red	18,929	14,444	10,247	1,745	781	644	387	640	0	0
Texas-Gulf	8,512	13,956	3,296	0	9,282	0	1,378	0	0	0
Rio Grande	374	1,014	0	0	1,014	0	0	0	0	0
U. Colorado	167	0	0	0	0	0	0	0	0	0
L. Colorado	21	0	0	0	0	0	0	0	0	0
Great Basin	320	529	310	0	0	0	219	0	0	0
Col.-N. Pacific	4,686	6,065	5,380	0	0	685	0	0	0	0
Cal.-S. Pacific	94	1,621	180	0	928	184	329	0	0	0

[1]Source: (186).

Table 4.34. Dryland acreages of silages, hay and pasture in the 18 river basins with D population level, present water prices, trend technology and a free market in 2000 (Model B).

River basin	Silages		Tame hay		Wild hay		Pasture	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[2]	2000[3]
				(000 acres)				
United States	10,572	11,641	46,675	66,217	9,005	7,709	621,192	929,117
New England	138	0	1,031	0	0	0	1,551	1,475
M. Atlantic	1,041	0	4,289	0	0	0	8,234	9,156
S. Atlantic-Gulf	370	639	1,675	620	0	0	30,314	43,745
Great Lakes	1,402	714	5,356	5,912	35	28	7,256	9,831
Ohio	639	348	5,603	2,393	0	0	21,570	23,828
Tennessee	102	0	1,025	594	0	0	5,658	6,012
U. Mississippi	2,786	3,915	8,785	16,086	357	178	21,150	19,589
L. Mississippi	121	0	957	995	43	0	12,137	24,806
S.-Red-Rainy	425	22	1,282	3,864	771	769	4,224	4,110
Missouri	2,716	3,691	10,548	20,329	6,234	5,891	169,015	198,279
Ark.-White-Red	546	1,612	2,819	11,778	1,201	577	79,262	100,234
Texas-Gulf	108	317	1,387	997	141	51	71,139	87,260
Rio Grande	7	0	32	258	5	2	52,276	76,764
U. Colorado	9	0	68	813	10	8	15,449	45,877
L. Colorado	2	0	2	0	1	0	44,995	77,851
Great Basin	34	292	127	0	31	30	16,371	69,687
Col.-N. Pacific	122	91	1,373	1,578	139	139	35,555	87,125
Cal.-S. Pacific	4	0	316	0	37	36	25,036	43,488

[1]Source: (186).
[2]Source: (186). Public grazing lands not included.
[3]Includes 291 million acres of public grazing lands.

Table 4.35. Irrigated acreages of annual crops in the 9 western river basins with D population level, present water prices, trend technology and a free market in 2000 (Model B).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
Western Basins	11,242	6,113	1,420	856	2,406	454	601	0	376	0
Missouri	2,021	674	0	363	53	258	0	0	0	0
Ark.-White-Red	1,568	1,659	0	295	1,297	16	0	0	51	0
Texas-Gulf	2,764	857	0	0	818	0	0	0	39	0
Rio Grande	755	217	0	0	180	33	0	0	4	0
U. Colorado	86	134	0	28	0	20	86	0	0	0
L. Colorado	661	331	28	0	0	0	303	0	0	0
Great Basin	222	78	37	0	0	0	41	0	0	0
Col.-N. Pacific	918	1,140	991	107	0	42	0	0	0	0
Cal.-S. Pacific	2,247	1,023	364	63	58	85	171	0	282	0

[1]Source: (186).

Table 4.36. Irrigated acreages of silages, hay, pasture and fruits, nuts, rice and vegetables in the 9 western river basins with D population level, present water prices, trend technology and a free market in 2000 (Model B).

	Silages		Tame hay		Wild hay		Pasture		Fruits, nuts, etc.	
River basin	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000
					(000 acres)					
Western Basins	745	1,062	6,150	8,734	1,361	1,247	5,093	4,444	4,096	4,385
Missouri	301	487	1,345	2,905	459	417	984	882	34	40
Ark.-White-Red	86	260	226	472	16	8	145	129	22	34
Texas-Gulf	35	7	72	55	0	0	237	88	534	468
Rio Grande	29	95	286	96	58	57	268	232	227	110
U. Colorado	15	22	532	161	174	174	580	580	66	5
L. Colorado	36	0	229	173	4	0	101	64	141	118
Great Basin	5	0	547	551	293	287	499	188	33	67
Col.-N. Pacific	93	99	1,596	2,303	291	290	1,147	1,249	621	777
Cal.-S. Pacific	145	92	1,317	2,018	66	14	1,132	1,032	2,418	2,766

[1]Source: (186).

Table 4.37. Unused land and land shifted from annual crops to tame hay production in the 18 river basins with D population level, present water prices, trend technology and a free market in 2000 (Model B).

River basin	Unused dryland cropland	Unused irrigable cropland	Total unused cropland	Unused dryland hayland	Unused irrigable hayland	Total unused hayland	Total unused land	Land shifted[1]
			(000 acres)					
United States	24,934	704	25,638	23,480	1,839	25,319	50,957	42,823
New England	150	-	150	1,176	-	1,176	1,326	0
M. Atlantic	1,711	-	1,711	4,607	-	4,607	6,318	0
S. Atlantic-Gulf	5,066	-	5,066	2,301	-	2,301	7,367	507
Great Lakes	370	-	370	1,481	-	1,481	1,851	1,798
Ohio	1,479	-	1,479	3,894	-	3,894	5,373	330
Tennessee	414	-	414	1,012	-	1,012	1,426	404
U. Mississippi	-	-	0	1,062	-	1,062	1,062	7,916
L. Mississippi	26	-	26	243	-	243	269	161
S.-Red-Rainy	21	-	21	32	-	32	53	2,568
Missouri	12,401	0	12,401	4,605	141	4,746	17,147	15,340
Ark.-White-Red	943	0	943	1,211	188	1,399	2,342	10,261
Texas-Gulf	1,282	0	1,282	876	49	925	2,207	396
Rio Grande	384	240	624	40	132	172	796	123
U. Colorado	100	16	116	15	76	91	207	385
L. Colorado	171	363	534	34	172	206	740	84
Great Basin	10	0	10	57	224	281	291	115
Col.-N. Pacific	0	0	0	390	37	427	427	1,051
Cal.-S. Pacific	406	85	491	444	820	1,264	1,755	1,384

[1] Cropland presently in land retirement programs or used for annual crop production but used for tame hay production in 2000.

Table 4.38. Withdrawals and consumptive use of water in the 9 western river basins with D population level, present water prices, trend technology and a free market in 2000 (Model B).

River basin	Total 1965[1]	Projected 2000: All crops	Livestock	Municipal & industrial[2]	Onsite	Other[3]	Total 2000
	(thousand acre feet per year)						
				Withdrawals			
Western Basins	151,733	88,012	1,637	50,029	4,797	2,632	147,107
Missouri	21,668	15,370	627	6,124	1,086	1,132	24,339
Ark.-White-Red	10,541	6,289	350	7,947	0	0	14,586
Texas-Gulf	18,382	4,873	250	15,711	227	0	21,061
Rio Grande	8,165	2,997	138	1,265	0	0	4,400
U. Colorado	4,500	3,023	57	1,030	198	0	4,308
L. Colorado	7,774	3,469	47	1,320	585	1,500	6,921
Great Basin	5,730	2,924	2	1,035	1,276	0	5,237
Col.-N. Pacific	33,191	19,049	53	6,678	0	0	25,780
Cal.-S. Pacific	41,782	30,018	113	8,919	1,425	0	40,475
				Consumptive use			
Western Basins	75,050	62,672	1,637	21,116	3,981	2,632	92,038
Missouri	11,822	10,454	627	1,218	1,086	1,132	14,517
Ark.-White-Red	6,580	4,270	350	1,333	0	0	5,953
Texas-Gulf	8,165	3,663	250	7,209	227	0	11,349
Rio Grande	4,632	2,077	138	575	0	0	2,790
U. Colorado	2,220	2,290	57	473	144	0	2,964
L. Colorado	3,862	2,405	47	615	351	1,500	4,918
Great Basin	2,524	2,177	2	443	908	0	3,530
Col.-N. Pacific	11,785	12,579	53	1,559	0	0	14,191
Cal.-S. Pacific	23,460	22,757	113	7,691	1,265	0	31,826

[1]Source: (216, Tables 7-3-4 and 7-3-5).

[2]Includes rural domestic, municipal, self supplied industrial, recreation, mining and thermal electric power.

[3]Includes water export to Mexico, depletion of the Upper Milk River by Canada and transfer of water from the Missouri river basin into the S.-Red-Rainy basin.

Table 4.39. Total water supply, total consumptive use and the net water balance in the 9 western river basins with D population level, present water prices, trend technology and a free market in 2000 (Model B).

River basin	Water from natural runoff[1]	Water from inter-basin natural stream flows	Water from inter-basin transfers	Total water supply	Total consumptive use[2]	Surplus or deficit
	(thousand acre feet per year)					
	Consumptive use					
Western Basins	239,410	0	0	239,410	92,038	147,372
Missouri	28,600	0	337	28,937	14,517	14,420
Ark.-White-Red	24,390	0	-51	24,339	5,953	18,386
Texas-Gulf	12,210	0	51	12,261	11,349	912
Rio Grande	4,070	0	0	4,070	2,790	1,280
U. Colorado	9,830	-5,277	-337	4,216	2,964	1,252
L. Colorado	2,890	5,277	-3,249	4,918	4,918	0
Great Basin	3,530	0	0	3,530	3,530	0
Col.-N. Pacific	114,190	0	0	114,190	14,191	999,999
Cal.-S. Pacific	39,700	0	3,249	42,949	31,826	11,123

[1]See Table 3.3.

[2]See Table 4.38.

Table 4.40. Dryland acreages of annual crops in the 18 river basins with D population level, present water prices, trend technology and a free market with insecticide limitation in 2000 (Model E).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
United States	176,379	179,567	60,465	30,935	21,632	12,068	7,716	41,835	4,018	898
New England	37	83	0	0	0	83	0	0	0	0
M. Atlantic	3,671	4,109	2,717	0	0	0	1,392	0	0	0
S. Atlantic-Gulf	10,084	9,299	102	0	885	0	2,116	6,196	0	0
Great Lakes	10,513	12,279	2,512	3,654	0	1,693	504	3,916	0	0
Chic	16,020	18,251	969	8,795	0	1,152	0	7,335	0	0
Tennessee	1,215	1,292	339	0	0	0	0	202	751	0
U. Mississippi	37,849	38,396	5,007	16,723	2,738	3,373	0	9,657	0	898
L. Mississippi	11,154	14,253	5,402	0	0	0	0	5,584	3,267	0
S.-Red-Rainy	9,317	10,299	10,180	18	0	101	0	0	0	0
Missouri	43,416	33,632	14,031	0	5,888	4,156	1,252	8,305	0	0
Ark.-White-Red	18,929	14,444	10,247	1,745	781	644	387	640	0	0
Texas-Gulf	8,512	14,001	3,086	0	9,398	0	1,517	0	0	0
Rio Grande	374	1,014	0	0	1,014	0	0	0	0	0
U. Colorado	167	0	0	0	0	0	0	0	0	0
L. Colorado	21	0	0	0	0	0	0	0	0	0
Great Basin	320	529	310	0	0	0	219	0	0	0
Col.-N. Pacific	4,686	6,065	5,383	0	0	682	0	0	0	0
Cal.-S. Pacific	94	1,621	180	0	928	184	329	0	0	0

[1]Source: (186).

Table 4.41. Dryland acreages of silages, hay and pasture in the 18 river basins with D population level, present water prices, trend technology and a free market with insecticide limitation in 2000 (Model E).

River basin	Silages		Tame hay		Wild hay		Pasture	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[2]	2000[3]
				(000 acres)				
United States	10,572	11,458	46,675	66,568	9,005	8,004	621,192	929,117
New England	138	0	1,031	0	0	0	1,551	1,475
M. Atlantic	1,041	0	4,289	0	0	0	8,234	9,156
S. Atlantic-Gulf	370	642	1,675	684	0	0	30,314	43,745
Great Lakes	1,402	714	5,356	5,894	35	28	7,256	9,831
Ohio	639	454	5,603	2,393	0	0	21,570	23,828
Tennessee	102	0	1,025	392	0	0	5,658	6,012
U. Mississippi	2,786	3,983	8,785	14,675	357	351	21,150	19,589
L. Mississippi	121	0	957	1,178	43	0	12,137	24,806
S.-Red-Rainy	425	18	1,282	3,864	771	769	4,224	4,110
Missouri	2,716	3,514	10,548	21,904	6,234	5,904	169,015	198,279
Ark.-White-Red	546	1,611	2,819	11,918	1,201	686	79,262	100,234
Texas-Gulf	108	318	1,387	997	141	51	71,139	87,260
Rio Grande	7	0	32	258	5	2	52,276	76,764
U. Colorado	9	0	68	811	10	8	15,449	45,877
L. Colorado	2	0	2	0	1	0	44,995	77,851
Great Basin	34	113	127	22	31	30	16,371	69,687
Col.-N. Pacific	122	91	1,373	1,578	139	139	35,555	87,125
Cal.-S. Pacific	4	0	316	0	37	36	25,036	43,488

[1]Source: (186).
[2]Source: (186). Public grazing lands not included.
[3]Includes 291 million acres of public grazing lands.

Table 4.42. Irrigated acreages of annual crops in the 9 western river basins with D population level, present water prices, trend technology and a free market with insecticide limitation in 2000 (Model E).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
Western Basins	11,242	6,512	1,594	629	2,564	456	537	0	695	37
Missouri	2,021	788	114	363	53	258	0	0	0	0
Ark.-White-Red	1,568	1,771	0	61	1,643	16	0	0	51	0
Texas-Gulf	2,764	812	0	0	563	0	0	0	249	0
Rio Grande	755	269	0	0	180	33	0	0	56	0
U. Colorado	86	134	0	23	0	20	86	0	0	0
L. Colorado	661	330	0	0	0	0	316	0	14	0
Great Basin	222	214	136	0	0	0	41	0	0	37
Col.-N. Pacific	918	1,134	980	110	0	44	0	0	0	0
Cal.-S. Pacific	2,247	1,060	364	67	125	85	94	0	325	0

[1]Source: (186).

Table 4.43. Irrigated acreages of silages, hay, pasture and fruits, nuts, rice and vegetables in the 9 western river basins with D population level, present water prices, trend technology and a free market with insecticide limitation in 2000 (Model E).

River basin	Silages		Tame hay		Wild hay		Pasture		Fruits, nuts, etc.	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000
					(000 acres)					
Western Basins	745	959	6,150	8,928	1,361	1,247	5,093	4,420	4,096	4,385
Missouri	301	487	1,345	2,905	459	417	984	882	34	40
Ark.-White-Red	86	150	226	556	16	8	145	129	22	34
Texas-Gulf	35	5	72	55	0	0	237	88	534	468
Rio Grande	29	94	286	123	58	57	268	232	227	110
U. Colorado	15	22	532	163	174	174	580	580	66	5
L. Colorado	36	0	229	129	4	0	101	40	141	118
Great Basin	5	0	547	447	293	287	499	188	33	67
Col.-N. Pacific	93	104	1,596	2,303	291	290	1,147	1,249	621	777
Cal.-S. Pacific	145	97	1,317	2,247	66	14	1,132	1,032	2,418	2,766

[1]Source: (186).

Table 4.44. Unused land and land shifted from annual crops to tame hay production in the 18 river basins with D population level, present water prices, trend technology and a free market with insecticide limitation in 2000 (Model E).

River basin	Unused dryland cropland	Unused irrigable cropland	Total unused cropland	Unused dryland hayland	Unused irrigable hayland	Total unused hayland	Total unused land	Land shifted[1]
			(000 acres)					
United States	23,085	636	23,721	22,775	1,604	24,379	48,100	42,418
New England	150	0	150	1,176	0	1,176	1,326	0
M. Atlantic	1,834	0	1,834	4,607	0	4,607	6,441	0
S. Atlantic-Gulf	5,045	0	5,045	2,258	0	2,258	7,303	526
Great Lakes	370	0	370	1,296	0	1,296	1,666	1,594
Ohio	1,278	0	1,278	3,894	0	3,894	5,172	330
Tennessee	414	0	414	1,012	0	1,012	1,426	202
U. Mississippi	0	0	0	1,062	0	1,062	1,062	6,506
L. Mississippi	19	0	19	66	0	66	85	167
S.-Red-Rainy	21	0	21	32	0	32	53	2,568
Missouri	10,596	0	10,596	4,462	141	4,603	15,199	16,771
Ark.-White-Red	943	0	943	1,072	104	1,176	2,119	10,261
Texas-Gulf	1,282	0	1,282	876	49	925	2,207	396
Rio Grande	384	187	571	40	106	146	717	124
U. Colorado	100	16	116	15	76	91	207	385
L. Colorado	171	389	560	34	193	227	787	60
Great Basin	72	0	72	39	307	346	418	93
Col.-N. Pacific	0	0	0	390	37	427	427	1,051
Cal.-S. Pacific	406	44	450	444	591	1,035	1,485	1,384

[1]Cropland presently in land retirement programs or used for annual crop production but used for tame hay production in 2000.

Table 4.45. Withdrawals and consumptive use of water in the 9 western river basins with D population level, present water prices, trend technology and a free market with insecticide limitation in 2000 (Model E).

River basin	Total 1965[1]	Projected 2000: All crops	Livestock	Municipal & industrial[2]	Onsite	Other[3]	Total 2000
	(thousand acre feet per year)						
				Withdrawals			
Western Basins	151,733	89,833	1,644	50,029	4,797	2,632	148,935
Missouri	21,668	15,588	628	6,124	1,086	1,132	24,558
Ark.-White-Red	10,541	6,426	353	7,947	0	0	14,726
Texas-Gulf	18,382	4,874	252	15,711	227	0	21,064
Rio Grande	8,165	3,367	142	1,265	0	0	4,774
U. Colorado	4,500	3,029	52	1,030	198	0	4,309
L. Colorado	7,774	3,130	46	1,320	585	1,500	6,581
Great Basin	5,730	2,935	2	1,035	1,276	0	5,248
Col.-N. Pacific	33,191	19,053	53	6,678	0	0	25,784
Cal.-S. Pacific	41,782	31,431	116	8,919	1,425	0	41,891
				Consumptive use			
Western Basins	75,050	63,980	1,644	21,116	3,981	2,632	93,353
Missouri	11,822	10,594	628	1,218	1,086	1,132	14,658
Ark.-White-Red	6,580	4,337	353	1,333	0	0	6,023
Texas-Gulf	8,165	3,663	252	7,209	227	0	11,351
Rio Grande	4,632	2,334	142	575	0	0	3,051
U. Colorado	2,220	2,294	52	473	144	0	2,963
L. Colorado	3,862	2,143	46	615	351	1,500	4,655
Great Basin	2,524	2,177	2	443	908	0	3,530
Col.-N. Pacific	11,785	12,582	53	1,559	0	0	14,194
Cal.-S. Pacific	23,460	23,856	116	7,691	1,265	0	32,928

[1]Source: (216, Tables 7-3-4 and 7-3-5).

[2]Includes rural domestic, municipal, self supplied industrial, recreation, mining and thermal electric power.

[3]Includes water export to Mexico, depletion of the Upper Milk River by Canada and transfer of water from the Missouri river basin into the S.-Red-Rainy basin.

Table 4.46. Total water supply, total consumptive use and the net water balance in the 9 western river basins with D population level, present water prices, trend technology and a free market with insecticide limitation in 2000 (Model E).

River basin	Water from natural runoff[1]	Water from inter-basin natural stream flows	Water from inter-basin transfers	Total water supply	Total consumptive use[2]	Surplus or deficit
	(thousand acre feet per year)					
	Consumptive use					
Western Basins	239,410	0	0	239,410	93,353	146,057
Missouri	28,600	0	337	28,937	14,658	14,279
Ark.-White-Red	24,390	0	-51	24,339	6,023	18,316
Rio Grande	4,070	0	0	4,070	3,051	1,019
U. Colorado	9,830	-5,277	-337	4,216	2,963	1,253
L. Colorado	2,890	5,277	3,512	4,655	4,655	0
Great Basin	3,530	0	0	3,530	3,530	0
Col.-N. Pacific	114,190	0	0	114,190	14,194	99,996
Cal.-S. Pacific	39,700	0	3,512	43,212	32,928	10,284

[1]See Table 3.3.

[2]See Table 4.45.

Table 4.47. Dryland acreages of annual crops in the 18 river basins with D population level, present water prices, trend technology and a free market with fragile lands removed in 2000 (Model F).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
United States	176,379	170,490	44,485	32,537	19,797	19,318	6,075	43,427	3,925	926
New England	37	83	0	0	0	83	0	0	0	0
M. Atlantic	3,671	4,963	2,838	0	0	0	2,125	0	0	0
S. Atlantic-Gulf	10,084	9,703	197	0	903	0	1,444	7,159	0	0
Great Lakes	10,513	11,921	2,444	3,794	0	1,875	121	3,650	0	37
Ohio	16,020	18,886	2,432	9,940	0	1,102	0	5,412	0	0
Tennessee	1,215	1,067	0	0	0	0	0	0	1,067	0
U. Mississippi	37,849	36,899	3,696	15,106	2,695	2,644	0	12,758	0	0
L. Mississippi	11,154	14,017	5,324	0	0	0	0	5,835	2,858	0
S.-Red-Rainy	9,317	9,028	1,353	1,158	0	6,517	0	0	0	0
Missouri	43,416	30,641	9,741	1,129	6,003	4,586	1,179	8,003	0	0
Ark.-White-Red	18,929	13,030	9,464	1,390	711	477	378	610	0	0
Texas-Gulf	8,512	11,529	2,234	20	7,590	1,184	501	0	0	0
Rio Grande	374	970	0	0	970	0	0	0	0	0
U. Colorado	167	46	46	0	0	0	0	0	0	0
L. Colorado	21	0	0	0	0	0	0	0	0	0
Great Basin	320	391	303	0	0	41	47	0	0	0
Col.-N. Pacific	4,686	5,824	4,254	0	0	681	0	0	0	889
Cal.-S. Pacific	94	1,492	159	0	925	128	280	0	0	0

[1]Source: (186).

Table 4.48. Dryland acreages of silages, hay and pasture in the 18 river basins with D population level, present water prices, trend technology and a free market with fragile lands removed in 2000 (Model F).

River basin	Silages		Tame hay		Wild hay		Pasture	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[2]	2000[3]
				(000 acres)				
United States	10,572	12,649	46,675	83,408	9,005	7,300	621,192	348,948
New England	138	0	1,031	0	0	0	1,551	722
M. Atlantic	1,041	0	4,289	0	0	0	8,234	5,569
S. Atlantic-Gulf	370	794	1,675	1,498	0	0	30,314	31,214
Great Lakes	1,402	818	5,356	7,330	35	26	7,256	7,777
Ohio	639	444	5,603	5,077	0	0	21,570	12,629
Tennessee	102	0	1,025	1,586	0	0	5,658	2,606
U. Mississippi	2,786	3,773	8,785	16,362	357	308	21,150	14,533
L. Mississippi	121	0	957	1,209	43	40	12,137	15,923
S.-Red-Rainy	425	1,134	1,282	3,733	771	647	4,224	2,648
Missouri	2,716	3,877	10,548	28,610	6,234	4,983	169,015	71,598
Ark.-White-Red	546	1,232	2,819	12,070	1,201	1,002	79,262	43,564
Texas-Gulf	108	231	1,387	3,275	141	96	71,139	50,290
Rio Grande	7	0	32	289	5	2	52,276	10,900
U. Colorado	9	0	68	806	10	7	15,449	3,402
L. Colorado	2	0	2	0	1	0	44,995	38,000
Great Basin	34	261	127	133	31	26	16,371	6,249
Col.-N. Pacific	122	85	1,373	1,430	139	128	35,555	18,897
Cal.-S. Pacific	4	0	316	0	37	35	25,036	12,427

[1]Source: (186).
[2]Source: (186). Public grazing lands not included.
[3]Includes 291 million acres of public grazing lands.

Table 4.49. Irrigated acreages of annual crops in the 9 western river basins with D population level, present water prices, trend technology and a free market with fragile lands removed in 2000 (Model F).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
Western Basins	11,242	6,529	1,523	946	2,585	416	533	8	416	102
Missouri	2,021	799	113	398	31	257	0	0	0	0
Ark.-White-Red	1,568	1,895	0	289	1,545	15	0	8	38	0
Texas-Gulf	2,764	855	0	52	735	30	0	0	38	0
Rio Grande	755	240	0	0	179	10	0	0	51	0
U. Colorado	86	104	0	48	0	56	0	0	0	0
L. Colorado	661	312	0	0	0	0	312	0	0	0
Great Basin	222	195	67	0	0	0	91	0	0	37
Col.-N. Pacific	918	1,114	979	99	0	36	0	0	0	0
Cal.-S. Pacific	2,247	1,015	364	60	95	12	130	0	289	65

[1]Source: (186).

Table 4.50. Irrigated acreages of silages, hay, pasture and fruits, nuts, rice and vegetables in the 9 western river basins with D population level, present water prices, trend technology and a free market with fragile lands removed in 2000 (Model F).

	Silages		Tame hay		Wild hay		Pasture		Fruits, nuts, etc.	
River basin	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000
					(000 acres)					
Western Basins	745	1,041	6,150	9,294	1,361	928	5,093	4,285	4,096	4,385
Missouri	301	461	1,345	2,994	459	307	984	818	34	40
Ark.-White-Red	86	260	226	363	16	11	145	125	22	34
Texas-Gulf	35	43	72	36	0	0	237	168	534	468
Rio Grande	29	48	286	210	58	53	268	204	227	110
U. Colorado	15	55	532	203	174	122	580	459	66	5
L. Colorado	36	0	229	179	4	0	101	54	141	118
Great Basin	5	0	547	391	293	265	499	260	33	67
Col.-N. Pacific	93	85	1,596	2,586	291	163	1,147	1,175	621	777
Cal.-S. Pacific	145	89	1,317	2,332	66	7	1,132	1,022	2,418	2,766

[1]Source: (186).

Table 4.51. Unused land and land shifted from annual crops to tame hay production in the 18 river basins with D population level, present water prices, trend technology and a free market with fragile lands removed in 2000 (Model F).

River basin	Unused dryland cropland	Unused irrigable cropland	Total unused cropland	Unused dryland hayland	Unused irrigable hayland	Total unused hayland	Total unused land	Land shifted[1]
			(000 acres)					
United States	8,492	548	9,040	10,015	1,008	11,023	20,063	50,059
New England	146	0	146	1,097	0	1,097	1,243	0
M. Atlantic	703	0	703	4,272	0	4,272	4,975	0
S. Atlantic-Gulf	4,068	0	4,068	1,329	0	1,329	5,397	544
Great Lakes	0	0	0	88	0	88	88	2,023
Ohio	264	0	264	843	0	843	1,107	383
Tennessee	0	0	0	0	0	0	0	746
U. Mississippi	0	0	0	0	0	0	0	7,568
L. Mississippi	0	0	0	0	0	0	0	180
S.-Red-Rainy	21	0	21	31	0	31	52	2,492
Missouri	2,511	14	2,525	1,411	0	1,411	3,936	21,585
Ark.-White-Red	56	0	56	134	9	143	199	9,448
Texas-Gulf	0	0	0	187	1	188	188	1,974
Rio Grande	219	138	357	30	8	38	395	133
U. Colorado	54	0	54	15	0	15	69	344
L. Colorado	116	386	502	34	156	190	692	74
Great Basin	4	10	14	32	247	279	293	0
Col.-N. Pacific	0	0	0	177	0	177	177	1,096
Cal.-S. Pacific	330	0	330	335	587	922	1,252	1,469

[1]Cropland presently in land retirement programs or used for annual crop production but used for tame hay production in 2000.

Table 4.52. Withdrawals and consumptive use of water in the 9 western river basins with D population level, present water prices, trend technology and a free market with fragile lands removed in 2000 (Model F).

River basin	Total 1965[1]	Projected 2000: All crops	Livestock	Municipal & industrial[2]	Onsite	Other[3]	Total 2000
	(thousand acre feet per year)						
Withdrawals							
Western Basins	151,733	90,656	1,597	50,029	4,797	2,632	149,711
Missouri	21,668	15,610	622	6,124	1,086	1,132	24,574
Ark.-White-Red	10,541	6,432	337	7,947	0	0	14,716
Texas-Gulf	18,382	5,389	256	15,711	227	0	21,583
Rio Grande	8,165	3,342	132	1,265	0	0	4,739
U. Colorado	4,500	2,794	44	1,030	198	0	4,066
L. Colorado	7,774	3,410	49	1,320	585	1,500	6,864
Great Basin	5,730	2,930	2	1,035	1,276	0	5,243
Col.-N. Pacific	33,191	19,464	48	6,678	0	0	26,190
Cal.-S. Pacific	41,782	31,285	107	8,919	1,425	0	41,736
Consumptive use							
Western Basins	75,050	64,527	1,597	21,116	3,981	2,632	93,853
Missouri	11,822	10,621	622	1,218	1,086	1,132	14,679
Ark.-White-Red	6,580	4,342	337	1,333	0	0	6,012
Texas-Gulf	8,165	3,995	256	7,209	227	0	11,687
Rio Grande	4,632	2,322	132	575	0	0	3,029
U. Colorado	2,220	2,122	44	473	144	0	2,783
L. Colorado	3,862	2,360	49	615	351	1,500	4,875
Great Basin	2,524	2,177	2	443	908	0	3,530
Col.-N. Pacific	11,785	12,792	48	1,559	0	0	14,399
Cal.-S. Pacific	23,460	23,796	107	7,691	1,265	0	32,859

[1]Source: (216, Tables 7-3-4 and 7-3-5).

[2]Includes rural domestic, municipal, self supplied industrial, recreation, mining and thermal electric power.

[3]Includes water export to Mexico, depletion of the Upper Milk River by Canada and transfer of water from the Missouri river basin into the S.-Red-Rainy basin.

Table 4.53. Total water supply, total consumptive use and the net water balance in the 9 western river basins with D population level, present water prices, trend technology and a free market with fragile lands removed in 2000 (Model F).

River basin	Water from natural runoff[1]	Water from inter-basin natural stream flows	Water from inter-basin transfers	Total water supply	Total consumptive use[2]	Surplus or deficit
	(thousand acre feet per year) Consumptive use					
Western Basins	239,410	0	0	239,410	93,853	145,557
Missouri	28,600	0	337	28,937	14,679	14,258
Ark.-White-Red	24,390	0	-51	24,339	6,012	18,327
Texas-Gulf	12,210	0	51	12,261	11,687	574
Rio Grande	4,070	0	0	4,070	3,029	1,041
U. Colorado	9,830	-5,277	-337	4,216	2,783	1,433
L. Colorado	2,890	5,277	3,292	4,875	4,875	0
Great Basin	3,530	0	0	3,530	3,530	0
Col.-N. Pacific	114,190	0	0	114,190	14,399	99,791
Cal.-S. Pacific	39,700	0	3,292	42,992	32,859	10,133

[1]See Table 3.3.

[2]See Table 4.52.

Table 4.54. Dryland acreages of annual crops in the 18 river basins with D population level, present water prices, trend technology and a 45 million acre land retirement program in 2000 (Model C).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
United States	176,379	188,061	36,494	32,479	32,846	22,094	3,663	55,793	4,283	409
New England	37	46	0	1	0	45	0	0	0	0
M. Atlantic	3,671	4,991	2,137	594	0	117	1,399	744	0	0
S. Atlantic-Gulf	10,084	9,362	372	20	2,376	0	475	5,798	321	0
Great Lakes	10,513	11,907	1,639	3,568	0	2,003	0	4,536	0	161
Ohio	16,020	16,998	1,246	7,456	485	914	70	6,823	2	2
Tennessee	1,215	1,144	483	0	47	0	0	250	364	0
U. Mississippi	37,849	39,399	1,555	15,597	1,628	4,198	0	16,363	0	58
L. Mississippi	11,154	11,553	451	1,595	426	304	0	5,673	3,104	0
S.-Red-Rainy	9,317	9,890	3,789	573	0	4,976	0	374	0	178
Missouri	43,416	45,683	11,901	1,594	12,122	6,828	1,082	12,156	0	0
Ark.-White-Red	18,929	18,371	7,068	1,461	4,834	1,580	263	3,076	89	0
Texas-Gulf	8,512	12,116	2,021	13	9,679	0	0	0	403	0
Rio Grande	374	893	0	0	893	0	0	0	0	0
U. Colorado	167	118	93	0	0	0	25	0	0	0
L. Colorado	21	10	3	7	0	0	0	0	0	0
Great Basin	320	81	0	0	0	81	0	0	0	0
Col.-N. Pacific	4,686	4,246	3,606	0	0	630	0	0	0	10
Cal.-S. Pacific	94	1,253	130	0	356	418	349	0	0	0

[1]Source: (186).

Table 4.55. Dryland acreages of silages, hay and pasture in the 18 river basins with D population level, present water prices, trend technology and a 45 million acre land retirement program in 2000 (Model C).

River basin	Silages		Tame hay		Wild hay		Pasture	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[2]	2000[3]
				(000 acres)				
United States	10,572	21,184	46,675	48,997	9,005	8,990	621,192	929,843
New England	138	70	1,031	693	0	0	1,551	1,475
M. Atlantic	1,041	176	4,289	4,607	0	0	8,234	9,156
S. Atlantic-Gulf	370	3,122	1,675	2,415	0	0	30,314	43,745
Great Lakes	1,402	942	5,356	5,595	35	33	7,256	9,831
Ohio	639	508	5,603	5,957	0	0	21,570	23,828
Tennessee	102	224	1,025	1,202	0	0	5,658	6,012
U. Mississippi	2,786	3,750	8,785	9,231	357	356	21,150	19,589
L. Mississippi	121	1,835	957	1,078	43	42	12,137	24,806
S.-Red-Rainy	425	909	1,282	1,329	771	771	4,224	4,339
Missouri	2,716	5,405	10,548	10,310	6,234	6,234	169,015	198,279
Ark.-White-Red	546	3,062	2,819	3,212	1,201	1,199	79,262	100,234
Texas-Gulf	108	417	1,387	1,550	141	140	71,139	87,260
Rio Grande	7	0	32	171	5	2	52,276	76,764
U. Colorado	9	0	68	324	10	8	15,449	46,078
L. Colorado	2	0	2	0	1	0	44,995	77,851
Great Basin	34	480	127	51	31	30	16,371	69,687
Col.-N. Pacific	122	284	1,373	1,088	139	139	35,555	87,125
Cal.-S. Pacific	4	0	316	184	37	36	25,036	43,784

[1]Source: (186).
[2]Source: (186). Public grazing lands not included.
[3]Includes 291 million acres of public grazing lands.

Table 4.56. Irrigated acreages of annual crops in the 9 western river basins with D population level, present water prices, trend technology and a 45 million acre land retirement program in 2000 (Model C).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
Western Basins	11,242	8,874	1,844	1,330	2,802	628	265	458	877	670
Missouri	2,021	2,150	114	484	787	298	0	444	0	23
Ark.-White-Red	1,568	1,084	0	295	666	16	0	14	85	8
Texas-Gulf	2,764	868	0	43	472	25	0	0	328	0
Rio Grande	755	458	97	21	180	48	0	0	112	0
U. Colorado	86	144	17	54	0	57	1	0	0	15
L. Colorado	661	489	20	6	0	0	264	0	199	0
Great Basin	222	55	32	0	0	0	0	0	3	20
Col.-N. Pacific	918	1,552	1,183	90	0	101	0	0	0	178
Cal.-S. Pacific	2,247	2,074	381	337	697	83	0	0	150	426

[1]Source: (186).

Table 4.57. Irrigated acreages of silages, hay, pasture and fruits, nuts, rice and vegetables in the 9 western river basins with D population level, present water prices, trend technology and a 45 million acre land retirement program in 2000 (Model C).

River basin	Silages		Tame hay		Wild hay		Pasture		Fruits, nuts, etc.	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000
					(000 acres)					
Western Basins	745	2,047	6,150	8,010	1,361	1,304	5,093	4,534	4,096	4,385
Missouri	301	604	1,345	2,572	459	420	984	882	34	40
Ark.-White-Red	86	699	226	211	16	16	145	138	22	34
Texas-Gulf	35	4	72	73	0	0	237	141	534	468
Rio Grande	29	115	286	226	58	57	268	268	227	110
U. Colorado	15	56	532	349	174	174	580	580	66	5
L. Colorado	36	0	229	230	4	1	101	29	141	118
Great Basin	5	0	547	561	293	283	499	188	33	67
Col.-N. Pacific	93	181	1,596	2,316	291	290	1,147	1,249	621	777
Cal.-S. Pacific	145	388	1,317	1,472	66	63	1,132	1,059	2,418	2,766

[1]Source: (186).

Table 4.58. Unused land and land shifted from annual crops to tame hay production in the 18 river basins with D population level, present water prices, trend technology and a 45 million acre land retirement program in 2000 (Model C).

River basin	Unused dryland cropland	Unused irrigable cropland	Total unused cropland	Unused dryland hayland	Unused irrigable hayland	Total unused hayland	Total unused land	Land shifted[1]
			(000 acres)					
United States	38,011	3,808	41,819	2,649	456	3,105	44,924	2,108
New England	117	-	117	484	-	484	601	0
M. Atlantic	775	-	775	0	-	0	775	0
S. Atlantic-Gulf	3,030	-	3,030	0	-	0	3,030	0
Great Lakes	2,111	-	2,111	0	-	0	2,111	0
Ohio	2,809	-	2,809	0	-	0	2,809	0
Tennessee	540	-	540	0	-	0	540	0
U. Mississippi	5,736	-	5,736	0	-	0	5,736	0
L. Mississippi	1,051	-	1,051	0	-	0	1,051	0
S.-Red-Rainy	2,106	-	2,106	0	-	0	2,106	0
Missouri	9,983	677	10,660	1,043	0	1,043	11,703	1,043
Ark.-White-Red	5,132	739	5,871	58	0	58	5,929	58
Texas-Gulf	1,923	1,392	3,315	53	0	53	3,368	53
Rio Grande	421	176	597	16	0	16	613	9
U. Colorado	182	122	304	43	0	43	347	36
L. Colorado	162	263	425	34	57	91	516	26
Great Basin	64	148	212	114	188	302	514	110
Col.-N. Pacific	1,510	59	1,569	465	0	465	2,034	465
Cal.-S. Pacific	359	232	591	339	211	550	1,141	308

[1] Cropland presently in land retirement programs or used for annual crop production but used for tame hay production in 2000.

Table 4.59. Withdrawals and consumptive use of water in the 9 western river basins with D population level, present water prices, trend technology and a 45 million acre land retirement program in 2000 (Model C).

River basin	Total 1965[1]	Projected 2000: All crops	Livestock	Municipal & industrial[2]	Onsite	Other[3]	Total 2000
	(thousand acre feet per year)						
Withdrawals							
Western Basins	151,733	95,585	1,529	50,029	4,797	2,632	154,572
Missouri	21,668	17,039	550	6,124	1,086	1,132	25,931
Ark.-White-Red	10,541	5,238	327	7,947	0	0	13,512
Texas-Gulf	18,382	5,485	224	15,711	227	0	21,647
Rio Grande	8,165	4,777	158	1,265	0	0	6,200
U. Colorado	4,500	3,860	61	1,030	198	0	5,149
L. Colorado	7,774	5,293	43	1,320	585	1,500	8,741
Great Basin	5,730	2,920	2	1,035	1,276	0	5,233
Col.-N. Pacific	33,191	20,991	57	6,678	0	0	27,726
Cal.-S. Pacific	41,782	29,982	107	8,919	1,425	0	40,433
Consumptive use							
Western Basins	75,050	67,358	1,529	21,116	3,981	2,632	96,616
Missouri	11,822	11,496	550	1,218	1,086	1,132	15,482
Ark.-White-Red	6,580	3,525	327	1,333	0	0	5,185
Texas-Gulf	8,165	4,059	224	7,209	227	0	11,719
Rio Grande	4,632	3,297	158	575	0	0	4,030
U. Colorado	2,220	2,922	61	473	144	0	3,600
L. Colorado	3,862	3,645	43	615	351	1,500	6,154
Great Basin	2,524	2,177	2	443	908	0	3,530
Col.-N. Pacific	11,785	13,736	57	1,559	0	0	15,352
Cal.-S. Pacific	23,460	22,501	107	7,691	1,265	0	31,564

[1]Source: (216, Tables 7-3-4 and 7-3-5).

[2]Includes rural domestic, municipal, self supplied industrial, recreation, mining and thermal electric power.

[3]Includes water export to Mexico, depletion of the Upper Milk River by Canada and transfer of water from the Missouri river basin into the S.-Red-Rainy basin.

Table 4.60. Total water supply, total consumptive use and the net water balance in the 9 western river basins with D population level, present water prices, trend technology and a 45 million acre land retirement program in 2000 (Model C).

River basin	Water from natural runoff[1]	Water from inter-basin natural stream flows	Water from inter-basin transfers	Total water supply	Total consumptive use[2]	Surplus or deficit
	(thousand acre feet per year)					
	Consumptive use					
Western Basins	239,410	0	0	239,410	96,616	142,794
Missouri	28,600	0	337	28,937	15,482	13,455
Ark.-White-Red	24,390	0	-51	24,339	5,185	19,154
Texas-Gulf	12,210	0	51	12,261	11,719	542
Rio Grande	4,070	0	0	4,070	4,030	40
U. Colorado	9,830	-5,277	-337	4,216	3,600	616
L. Colorado	2,890	5,277	-2,013	6,154	6,154	0
Great Basin	3,530	0	0	3,530	3,530	0
Col.-N. Pacific	114,190	0	0	114,190	15,352	98,838
Cal.-S. Pacific	39,700	0	2,013	41,713	31,564	10,149

[1]See Table 3.3.

[2]See Table 4.59.

Table 4.61. Dryland acreages of annual crops in the 18 river basins with B population level, present water prices, advanced technology and a free market in 2000 (Model D).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
United States	176,379	219,223	52,287	46,360	25,522	19,390	2,846	67,950	3,773	1,095
New England	37	89	0	0	0	89	0	0	0	0
M. Atlantic	3,671	5,627	2,805	1,099	0	93	731	899	0	0
S. Atlantic-Gulf	10,084	13,407	0	4,305	1,664	559	0	6,879	0	0
Great Lakes	10,513	12,633	1,717	3,675	0	1,848	0	4,298	0	1,095
Ohio	16,020	19,590	1,691	7,859	0	1,015	0	9,025	0	0
Tennessee	1,215	1,839	0	361	0	27	0	361	1,090	0
U. Mississippi	37,849	44,375	3,761	18,086	1,666	4,329	0	16,533	0	0
L. Mississippi	11,154	13,933	0	7,193	0	1,420	0	2,949	2,371	0
S.-Red-Rainy	9,317	12,468	10,243	10	0	2,215	0	0	0	0
Missouri	43,416	54,501	18,012	2,027	10,898	5,687	1,252	16,625	0	0
Ark.-White-Red	18,929	21,065	6,187	1,745	1,636	610	194	10,381	312	0
Texas-Gulf	8,512	10,280	2,564	0	7,716	0	0	0	0	0
Rio Grande	374	1,014	0	0	1,014	0	0	0	0	0
U. Colorado	167	0	0	0	0	0	0	0	0	0
L. Colorado	21	9	9	0	0	0	0	0	0	0
Great Basin	320	0	0	0	0	0	0	0	0	0
Col.-N. Pacific	4,686	6,214	5,131	0	0	1,083	0	0	0	0
Cal.-S. Pacific	94	2,179	167	0	928	415	669	0	0	0

[1]Source: (186).

Table 4.62. Dryland acreages of silages, hay and pasture in the 18 river basins with B population level, present water prices, advanced technology and a free market in 2000 (Model D).

River basin	Silages		Tame hay		Wild hay		Pasture	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[2]	2000[3]
				(000 acres)				
United States	10,572	14,871	46,675	65,347	9,005	8,990	621,192	929,464
New England	138	4	1,031	0	0	0	1,551	1,475
M. Atlantic	1,041	239	4,289	4,146	0	0	8,234	9,156
S. Atlantic-Gulf	370	2,106	1,675	2,124	0	0	30,314	43,745
Great Lakes	1,402	813	5,356	7,110	35	33	7,256	9,831
Ohio	639	477	5,603	5,966	0	0	21,570	23,828
Tennessee	102	70	1,025	1,202	0	0	5,658	6,012
U. Mississippi	2,786	3,607	8,785	10,134	357	356	21,150	19,589
L. Mississippi	121	506	957	1,078	43	42	12,137	24,806
S.-Red-Rainy	425	439	1,282	1,329	771	771	4,224	4,339
Missouri	2,716	4,417	10,548	14,441	6,234	6,234	169,015	198,279
Ark.-White-Red	546	1,601	2,819	7,101	1,201	1,199	79,262	99,855
Texas-Gulf	108	402	1,387	6,880	141	140	71,139	87,260
Rio Grande	7	0	32	289	5	2	52,276	76,764
U. Colorado	9	0	68	666	10	8	15,449	46,078
L. Colorado	2	0	2	0	1	0	44,995	77,851
Great Basin	34	99	127	779	31	30	16,371	69,687
Col.-N. Pacific	122	91	1,373	1,415	139	139	35,555	87,125
Cal.-S. Pacific	. 4	0	316	687	37	36	25,036	43,784

[1]Source: (186).
[2]Source: (186). Public grazing lands not included.
[3]Includes 291 million acres of public grazing lands.

Table 4.63. Irrigated acreages of annual crops in the 9 western river basins with B population level, present water prices, advanced technology and a free market in 2000 (Model D).

River basin	Total acres 1964[1]	Total acres 2000	Projected 2000 Wheat	Corn grain	Grain sorghum	Oats	Barley	Soy-beans	Cot-ton	Sugar beets
			(000 acres)							
Western Basins	11,242	8,114	2,401	881	2,249	391	428	444	1,180	140
Missouri	2,021	1,291	114	467	64	202	0	444	0	0
Ark.-White-Red	1,568	2,012	0	295	1,650	16	0	0	51	0
Texas-Gulf	2,754	794	0	0	126	0	0	0	668	0
Rio Grande	755	413	0	0	180	25	0	0	208	0
U. Colorado	86	174	0	0	0	0	104	0	0	70
L. Colorado	661	197	0	0	0	0	197	0	0	0
Great Basin	222	213	86	0	0	0	127	0	0	0
Col.-N. Pacific	918	1,920	1,801	56	0	63	0	0	0	0
Cal.-S. Pacific	2,247	1,100	400	63	229	85	0	0	253	70

[1]Source: (186).

Table 4.64. Irrigated acreages of silages, hay, pasture and fruits, nuts, rice and vegetables in the 9 western river basins with B population level, present water prices, advanced technology and a free market in 2000 (Model D).

River basin	Silages		Tame hay		Wild hay		Pasture		Fruits, nuts, etc.	
	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000	1964[1]	2000
	(000 acres)									
Western Basins	745	902	6,150	9,195	1,361	1,247	5,093	4,108	4,096	5,102
Missouri	301	439	1,345	3,340	459	421	984	882	34	47
Ark.-White-Red	86	268	226	269	16	8	145	129	22	39
Texas-Gulf	35	1	72	39	0	0	237	127	534	544
Rio Grande	29	78	286	271	58	57	268	227	227	128
U. Colorado	15	0	532	434	174	174	580	580	66	5
L. Colorado	36	0	229	234	4	0	101	5	141	137
Great Basin	5	0	547	423	293	283	499	188	33	78
Col.-N. Pacific	93	25	1,596	2,038	291	290	1,147	1,249	621	904
Cal.-S. Pacific	145	91	1,317	2,147	66	14	1,132	721	2,418	3,220

[1]Source: (186).

Table 4.65. Unused land and land shifted from annual crops to tame hay production in the 18 river basins with B population level, present water prices, advanced technology and a free market in 2000 (Model D).

River basin	Unused dryland cropland	Unused irrigable cropland	Total unused cropland	Unused dryland hayland	Unused irrigable hayland	Total unused hayland	Total unused land	Land shifted[1]
			(000 acres)					
United States	866	520	1,386	2,545	525	3,070	4,456	21,001
New England	140	-	140	1,176	-	1,176	1,316	0
M. Atlantic	77	-	77	461	-	461	538	0
S. Atlantic-Gulf	0	-	0	292	-	292	292	2
Great Lakes	0	-	0	0	-	0	0	1,514
Ohio	0	-	0	239	-	239	239	249
Tennessee	0	-	0	0	-	0	0	0
U. Mississippi	0	-	0	0	-	0	0	902
L. Mississippi	0	-	0	0	-	0	0	0
S.-Red-Rainy	0	-	0	0	-	0	0	0
Missouri	0	0	0	0	0	0	0	5,991
Ark.-White-Red	0	0	0	254	0	254	254	4,235
Texas-Gulf	0	0	0	0	0	0	0	5,315
Rio Grande	384	0	384	21	8	29	413	185
U. Colorado	55	0	55	10	0	10	65	429
L. Colorado	162	510	672	34	98	132	804	71
Great Basin	6	10	16	4	208	212	228	610
Col.-N. Pacific	0	0	0	0	0	0	0	265
Cal.-S. Pacific	42	0	42	54	211	265	307	1,235

[1]Cropland presently in land retirement programs or used for annual crop production but used for tame hay production in 2000.

Table 4.66. Withdrawals and consumptive use of water in the 9 western river basins with B population level, present water prices, advanced technology and a free market in 2000 (Model D).

River basin	Total 1965[1]	Projected 2000: All crops	Livestock	Municipal & industrial[2]	Onsite	Other[3]	Total 2000
	(thousand acre feet per year)						
				Withdrawals			
Western Basins	151,733	95,983	1,634	58,234	4,797	2,632	163,280
Missouri	21,668	17,661	538	7,129	1,086	1,132	27,546
Ark.-White-Red	10,541	6,390	387	9,250	0	0	16,027
Texas-Gulf	18,382	5,776	239	18,268	227	0	24,530
Rio Grande	8,165	4,653	186	1,473	0	0	6,312
U. Colorado	4,500	4,170	58	1,199	198	0	5,625
L. Colorado	7,774	3,120	54	1,536	585	1,500	6,795
Great Basin	5,730	2,831	2	1,205	1,276	0	5,314
Col.-N. Pacific	33,191	20,633	54	7,773	0	0	28,460
Cal.-S. Pacific	41,782	30,749	116	10,381	1,425	0	42,671
				Consumptive use			
Western Basins	75,050	68,073	1,634	24,578	3,981	2,632	100,898
Missouri	11,822	11,959	538	1,418	1,086	1,132	16,133
Ark.-White-Red	6,580	4,312	387	1,552	0	0	6,251
Texas-Gulf	8,165	4,285	239	8,391	227	0	13,142
Rio Grande	4,632	3,211	186	669	0	0	4,066
U. Colorado	2,220	3,156	58	550	144	0	3,908
L. Colorado	3,862	2,144	54	716	351	1,500	4,765
Great Basin	2,524	2,105	2	515	908	0	3,530
Col.-N. Pacific	11,785	13,473	54	1,815	0	0	15,342
Cal.-S. Pacific	23,460	23,428	116	8,952	1,265	0	33,761

[1]Source: (216, Tables 7-3-4 and 7-3-5).

[2]Includes rural domestic, municipal, self supplied industrial, recreation, mining and thermal electric power.

[3]Includes water export to Mexico, depletion of the Upper Milk River by Canada and transfer of water from the Missouri river basin into the S.-Red-Rainy basin.

Table 4.67. Total water supply, total consumptive use and the net water balance in the 9 western river basins with B population level, present water prices, advanced technology and a free market in 2000 (Model D).

River basin	Water from natural runoff[1]	Water from inter-basin natural stream flows	Water from inter-basin transfers	Total water supply	Total consumptive use[2]	Surplus or deficit	Water from desalting
	(thousand acre feet per year)						
	Consumptive use						
Western Basins	239,410	0	0	239,410	100,898	138,512	891
Missouri	28,600	0	337	28,937	16,133	12,804	0
Ark.-White-Red	24,390	0	-51	24,339	6,251	18,088	0
Texas-Gulf	12,210	0	51	12,261	13,142	-881	891
Rio Grande	4,070	0	0	4,070	4,066	4	0
U. Colorado	9,830	-5,277	-337	4,216	3,908	308	0
L. Colorado	2,890	5,277	-3,402	4,765	4,765	0	0
Great Basin	3,530	0	0	3,530	3,530	0	0
Col.-N.Pacific	114,190	0	0	114,190	15,342	98,848	0
Cal.-S.Pacific	39,700	0	3,402	43,102	33,761	9,341	0

[1]See Table 3.3.

[2]See Table 4.66.

Table 4.68. Summary of land use under the seven alternative policy models in 2000.

Land use	1964 level[1]	Policy model in 2000		
		Model A	Model A1	Model A2
		(million acres)		
Total dryland	1,154.8	1,227.1	1,231.8	1,238.3
Annual crops	176.4	189.5	188.5	190.1
Tame hay & silages	52.7	99.1	104.7	109.4
Wild hay & pasture	921.2	938.5	938.6	938.8
Total irrigated[2]	31.3	27.2	22.6	17.2
Annual crops	13.3	6.1	6.4	5.1
Tame hay & silages	7.5	10.9	7.3	4.5
Wild hay & pasture & fruits, nuts, etc.	10.5	10.2	8.9	7.6
Unused cropland & hayland	55.5	16.4	15.1	12.9
Irrigable land switched	-	7.3	10.5	14.3
Cropland shifted	-	49.3	49.8	49.4

[1]Source: (93, 186).

[2]Estimated at 38.5 million acres in 1969. Source: (225, 226).

Policy model in 2000					
Model A3	Model B	Model C	Model D	Model E	Model F
		(million acres)			
1,242.0	1,191.9	1,197.0	1,237.8	1,194.7	622.8
187.7	177.3	188.0	219.2	179.6	170.5
115.5	77.8	70.2	80.2	78.0	96.1
938.8	936.8	938.8	938.4	937.1	356.2
12.4	26.0	29.2	28.6	26.5	26.4
4.1	6.1	8.9	8.1	6.5	6.5
2.3	9.8	10.1	10.1	9.9	10.3
6.0	10.1	10.2	10.4	10.1	9.6
12.5	51.0	44.9	4.5	48.1	20.1
15.0	7.6	2.7	6.8	7.4	7.9
52.1	42.8	2.1	21.0	42.4	50.1

Table 4.69. Summary of water use in the 17 Western States under the seven alternative policy models in 2000.

Item	1965 level[1]	Policy model in 2000		
		Model A	Model A1	Model A2
	(million acre feet per year)			
Total withdrawals	151.7	155.9	139.3	120.3
Total consumptive use	76.0	97.3	85.9	71.8
Agriculture[2]	70.0	68.1	56.7	42.6
Municipal & industrial[3]	6.0	22.6	22.6	22.6
Other[4]	n.a.	6.6	6.6	6.6
Total water supply	n.a.	239.4	239.4	239.4
Water released	-	-	11.4	25.5
Surplus water	n.a.	142.1	153.5	167.6

[1]Source: (216).

[2]Includes water consumed by crops and livestock.

[3]Includes water consumed by municipal and industrial uses, rural domestic, recreation, mining and thermal electric power.

[4]Includes water for fish and wildlife, wetlands, swamps and water exports.

Policy model in 2000					
Model A3	Model B	Model C	Model D	Model E	Model F
(million acre feet per year)					
105.0	147.1	154.6	163.3	151.7	151.7
61.1	92.0	96.6	100.9	93.3	93.8
31.9	64.3	68.9	69.7	65.6	66.1
22.6	21.1	21.1	24.6	21.1	21.1
6.6	6.6	6.6	6.6	6.6	6.6
239.4	239.4	239.4	239.4	239.4	239.4
36.2	-	-	-	-	-
178.3	147.4	142.8	138.5	146.1	145.6

Table 4.70. Production of livestock and livestock products in the United States under three alternative policy models in 2000.

Item	Unit	Actual 1969[1]	Projected 2000		
			Model A	Model B	Model D
Dairy cows	thou. head	14,106	8,573	8,020	9,378
Beef cows	thou. head	36,002	85,395	79,768	73,561
Beef feeding	thou. head	24,022	63,705	59,464	71,507
Hogs	mill. lbs.[2]	12,953	19,531	18,230	21,225
Milk	mill. cwt	1,120	1,187	1,108	1,290
Lamb & mutton	thou. cwt[2]	5,082	8,478	7,262	8,914
Broilers	thou. cwt[2]	80,540	123,472	115,354	134,759
Turkeys	thou. cwt[2]	16,140	26,220	24,440	28,542
Eggs	mill. doz.	5,757	5,206	4,685	5,606

[1]Source: (124, 146, 154, 167).

[2]Pork and lamb and mutton are reported in carcass weight and broilers and turkeys are reported in ready-to-cook weight.

Table 4.71. Average prices received by farmers for selected crops and livestock in the United States under the nine alternative policy models in 2000.[1]

Item	Unit	Actual 1969[2]	Projected 2000 Model A	Model A1	Model A2
Crop prices					
Corn-sorghum[3]	dol./bu.	1.12	1.10	1.13	1.19
Barley-oats[4]	dol./bu.	0.88	1.02	1.05	1.11
Soybeans	dol./bu.	2.33	2.25	2.34	2.54
Wheat	dol./bu.	1.24	1.49	1.52	1.61
Cotton	dol./lb	0.21	0.14	0.15	0.16
Sugar beets	dol./ton	n.a.	8.62	8.71	8.92
Hay	dol./ton	25.00	25.01	26.01	27.81
Silage[5]	dol./ton	n.a.	7.09	7.37	7.82
Livestock-products[6]					
Cattle & calves	cents/lb[7]	26.20	33.90	34.88	36.70
Hogs	cents/lb[7]	22.20	15.26	15.63	16.32
Milk	dol./cwt	5.46	3.41	3.44	3.51

[1]All prices for 2000 are measured in 1970 equivalent dollars and do not take into account inflation from 1970 to 2000.

[2]Source: (165).

[3]Corn equivalent.

[4]Barley equivalent.

[5]Wet tons.

[6]Farm prices of 24.5 cents per pound for lambs, 15.0 cents per pound for broilers and 35.0 cents per dozen for eggs are assumed under all policy models in 2000.

[7]Live weight prices.

Projected 2000					
Model A3	Model B	Model C	Model D	Model E	Model F
1.21	0.93	1.38	1.58	0.94	1.05
1.13	0.90	1.30	1.54	0.91	0.97
2.58	1.78	2.89	3.80	1.83	2.10
1.65	1.22	1.93	2.25	1.23	1.41
0.16	0.14	0.23	0.20	0.15	0.14
8.97	8.15	13.15	10.69	6.57	8.40
28.22	21.10	39.40	33.46	21.25	23.88
7.92	6.18	10.27	9.00	6.21	6.86
37.07	29.93	46.62	37.57	30.08	32.81
16.48	13.45	17.92	16.85	13.58	14.76
3.53	3.22	3.77	4.38	3.25	3.34

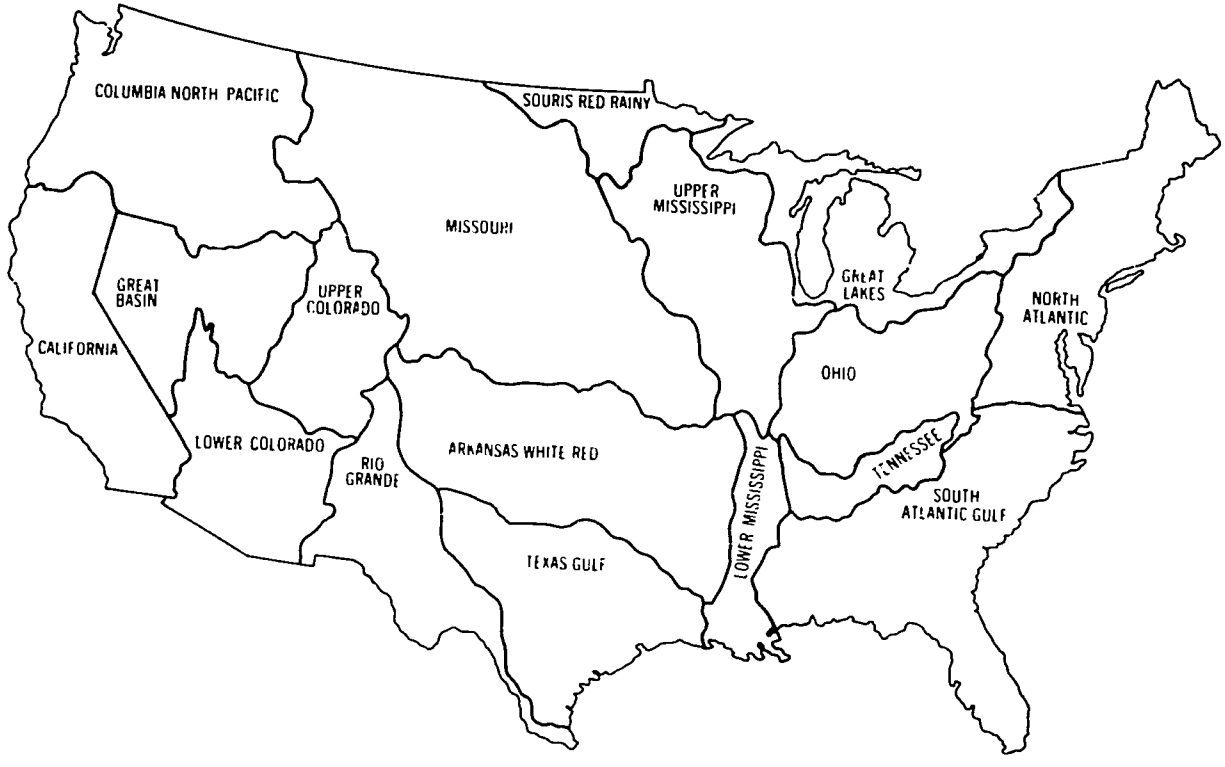

Figure 4.1. River basins in the United States as defined by the Water Resources Council

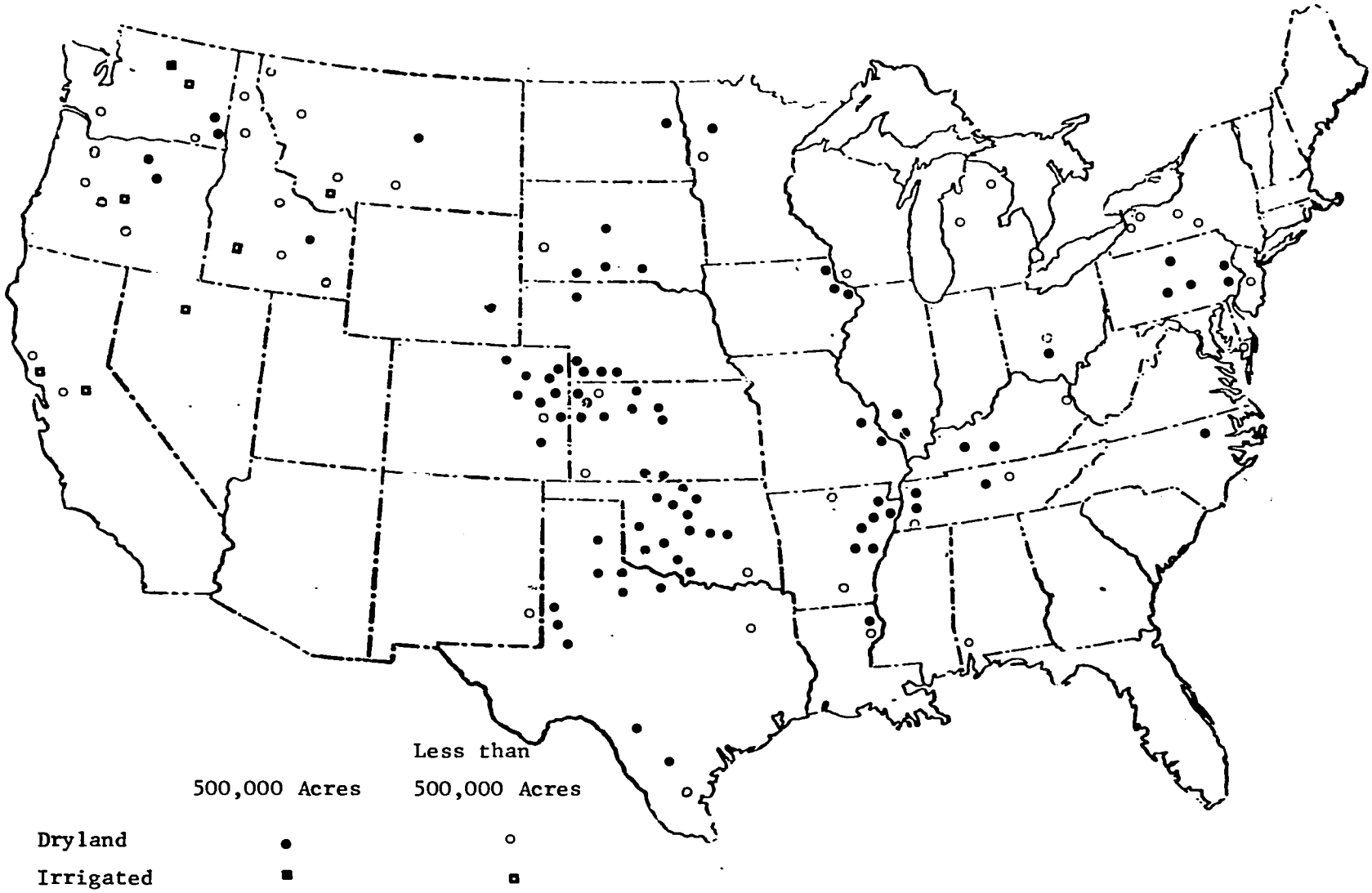

Figure 4.2. Location of dryland and irrigated wheat under Model A in 2000

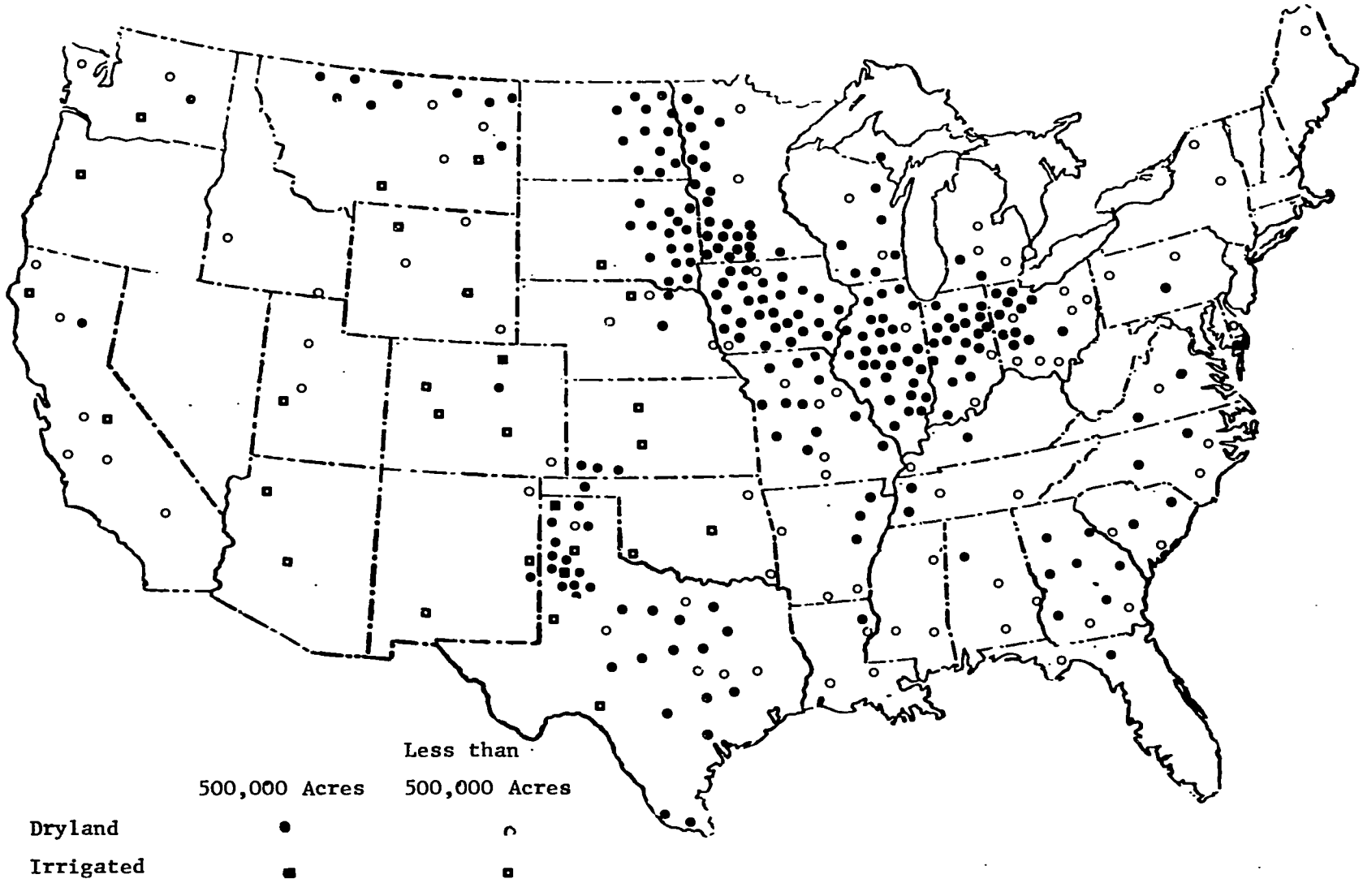

Figure 4.3. Location of dryland and irrigated feed grains and soybeans under Model A in 2000

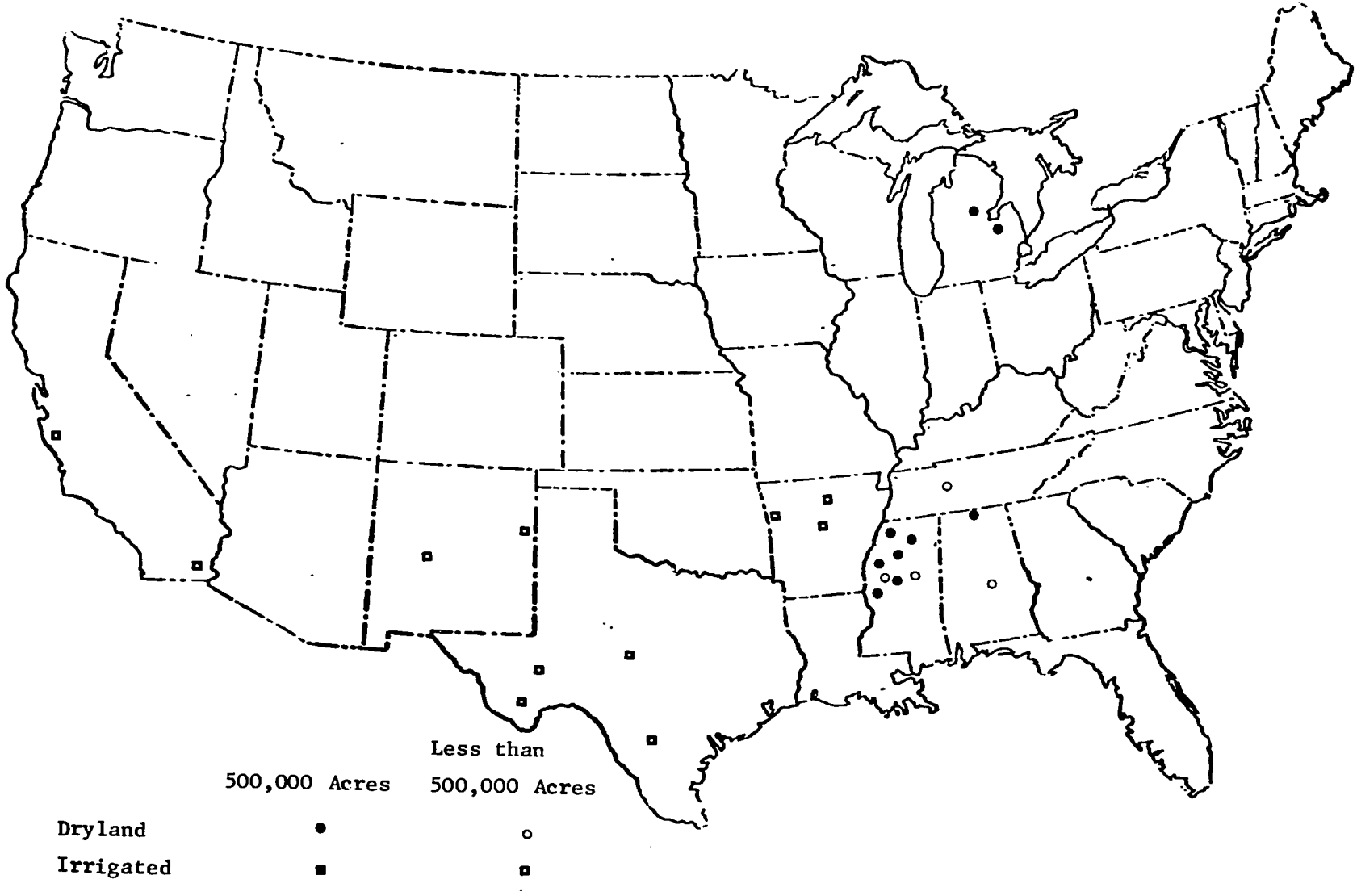

Figure 4.4. Location of dryland and irrigated cotton and sugar beets under Model A in 2000

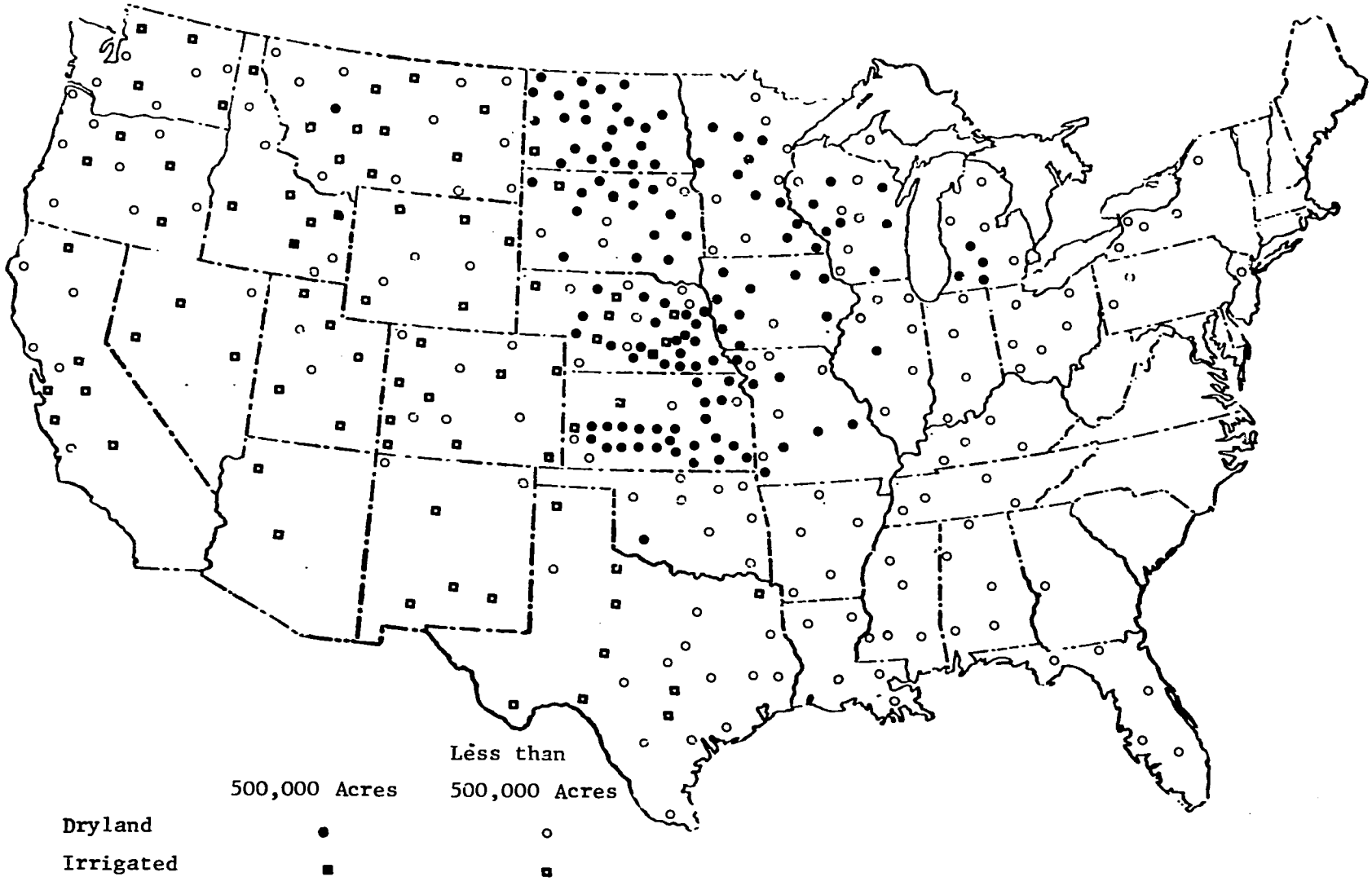

Figure 4.5. Location of dryland and irrigated hay under Model A in 2000

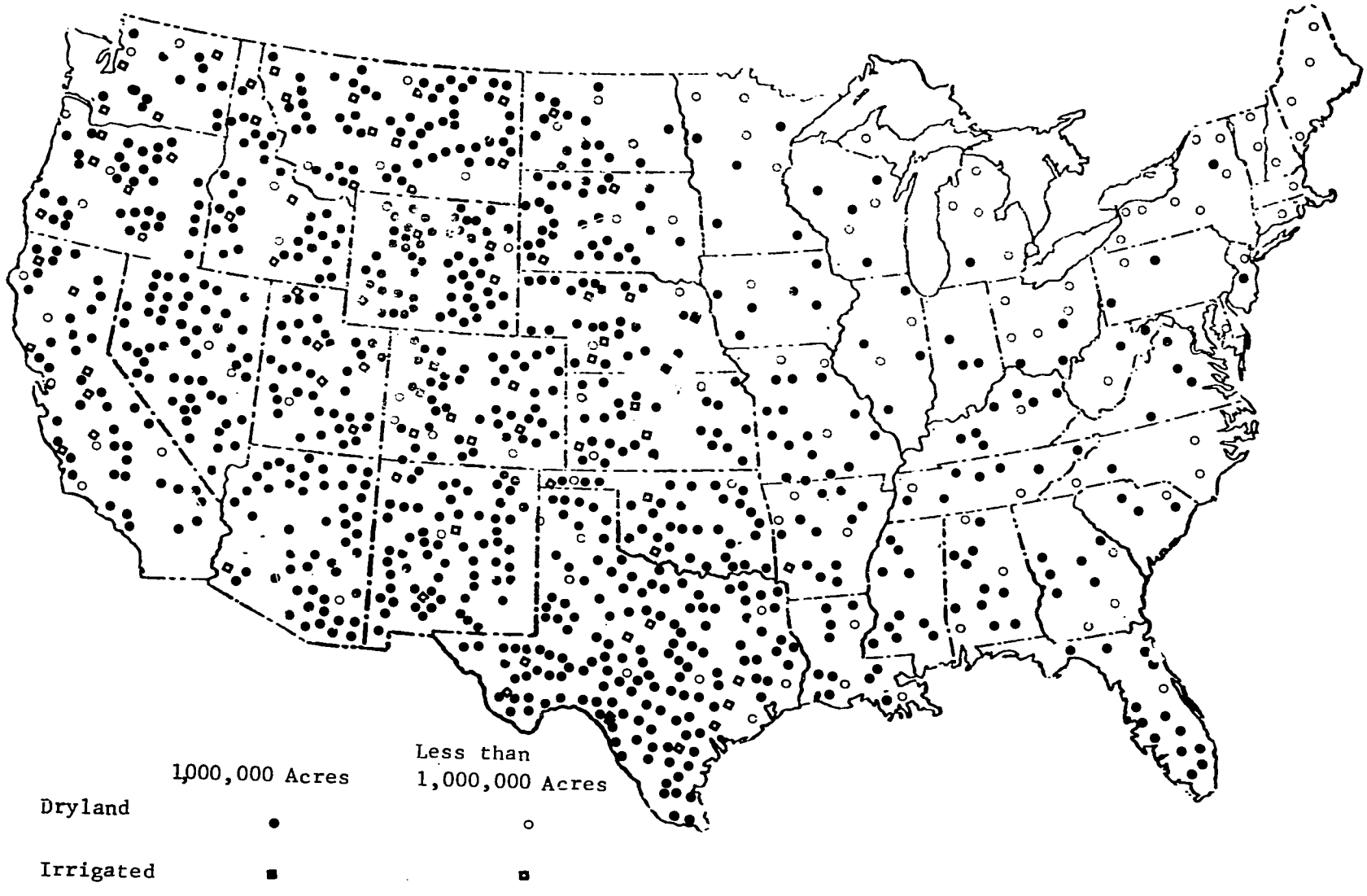

Figure 4.6. Location of dryland and irrigated pasture under Model A in 2000

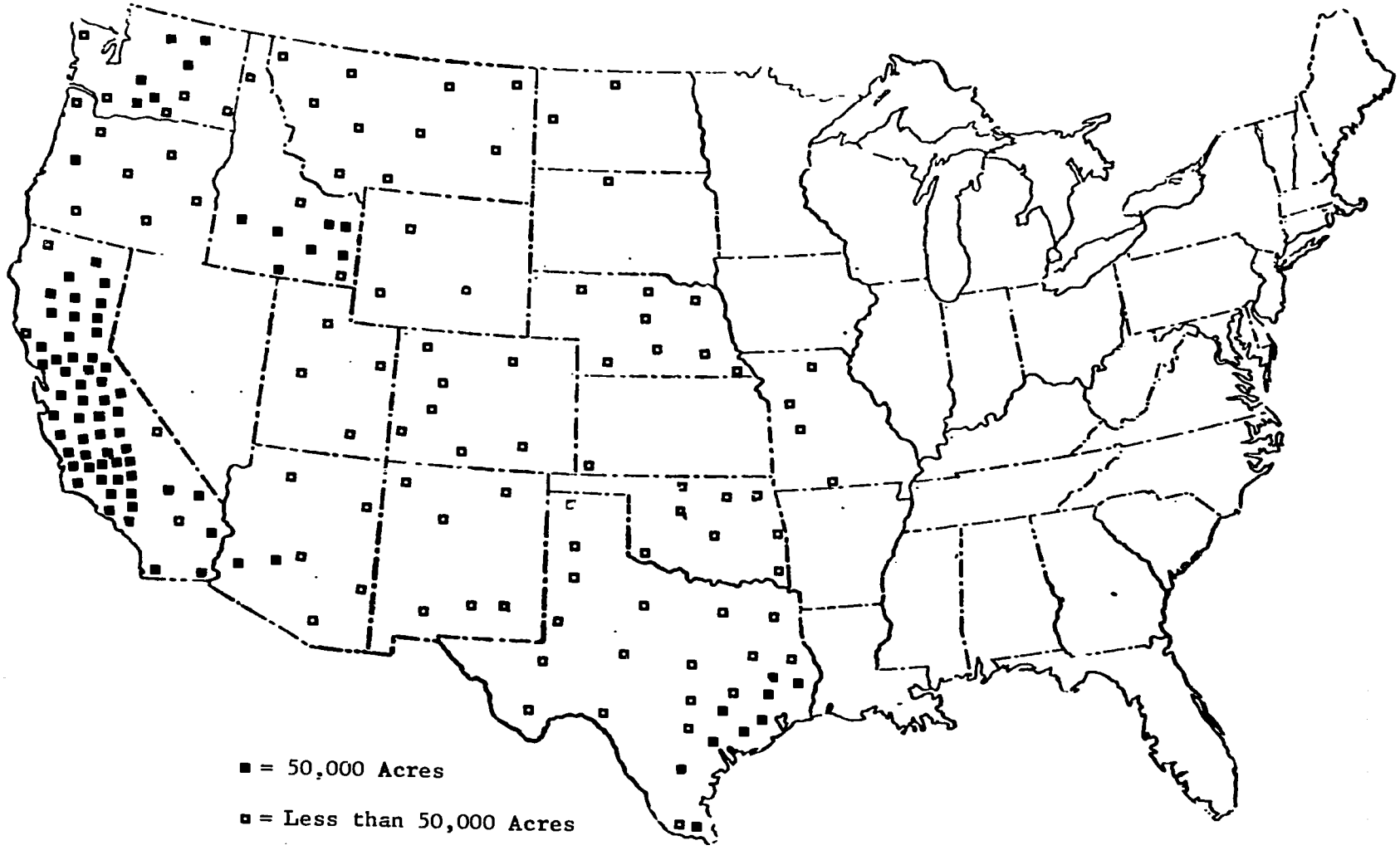

Figure 4.7. Location of irrigated fruits, nuts, rice and vegetables under Model A in 2000

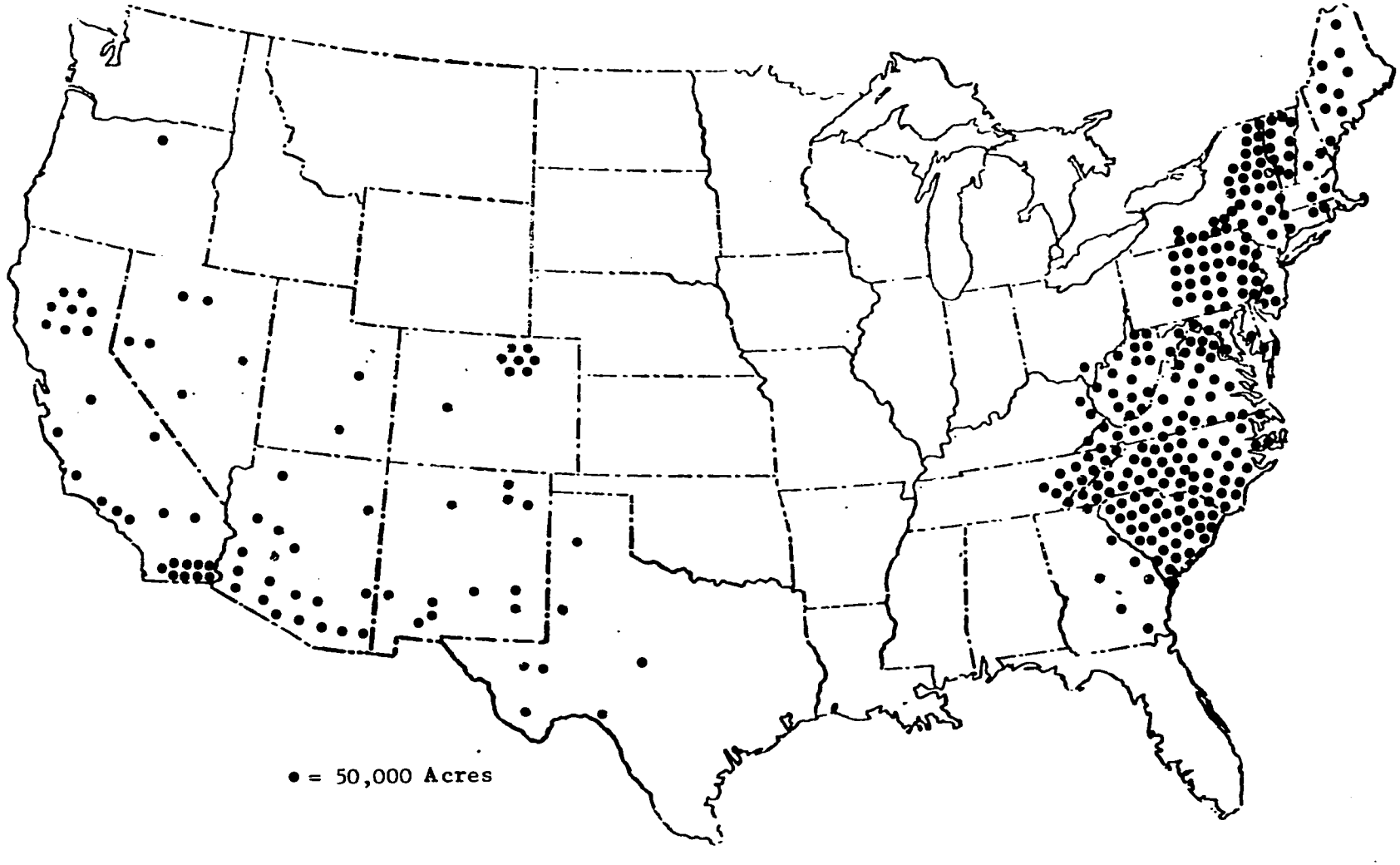

Figure 4.8. Location of unused land under Model A in 2000

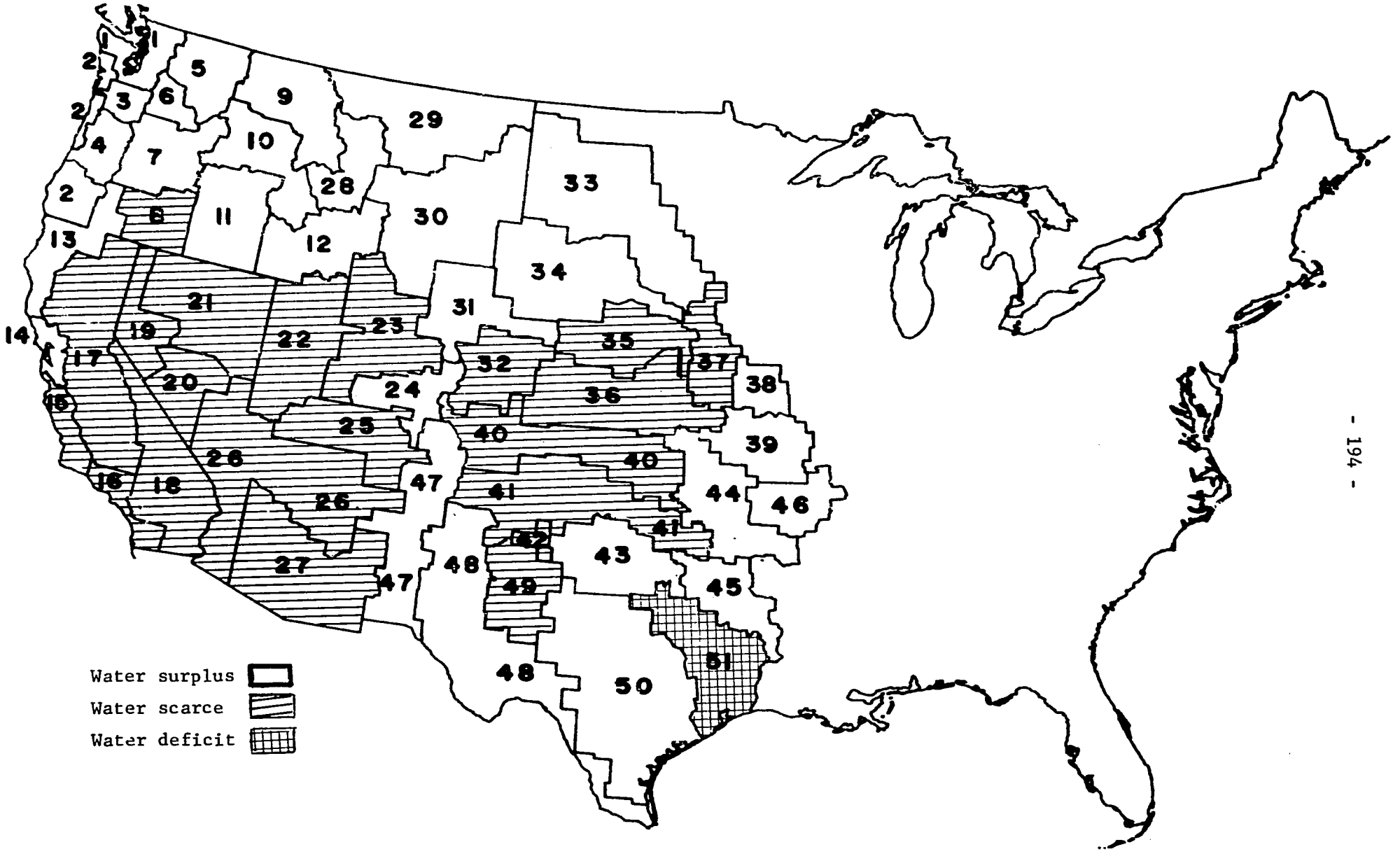

Figure 4.9. Water supply-demand balances under Model A in 2000

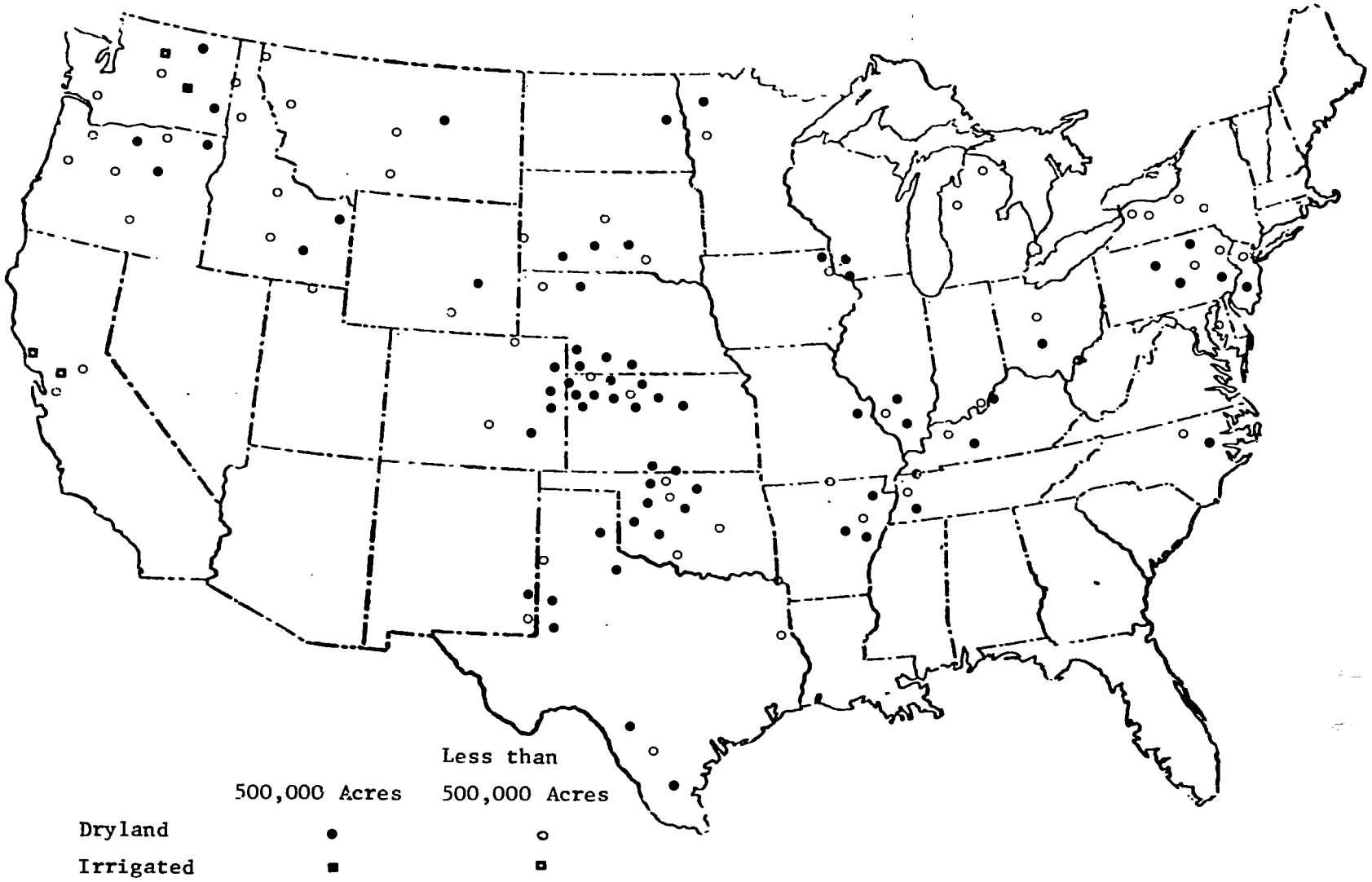

Figure 4.10. Location of dryland and irrigated wheat under Model A3 in 2000

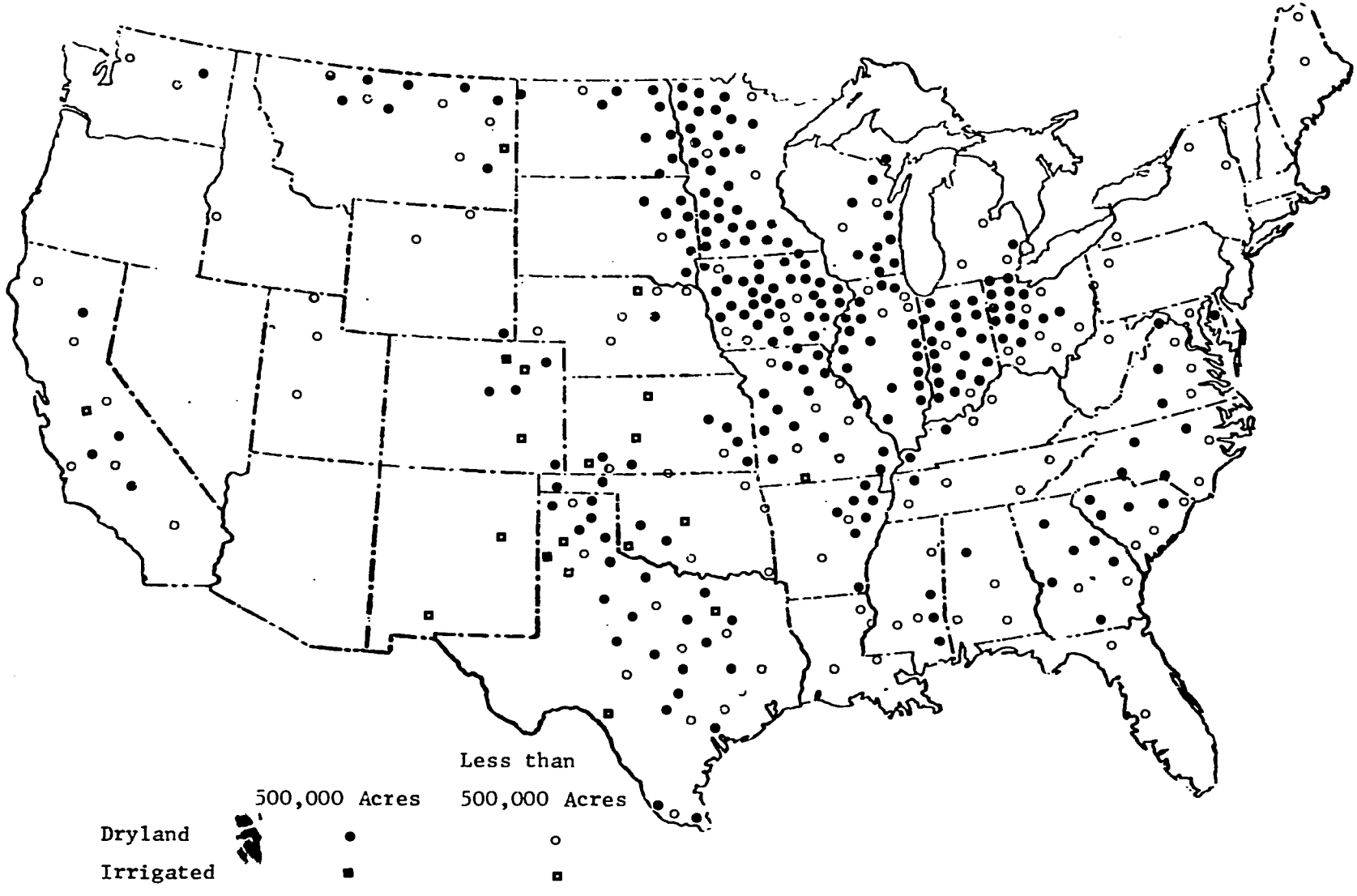

Figure 4.11. Location of dryland and irrigated feed grains and soybeans under Model A3 in 2000

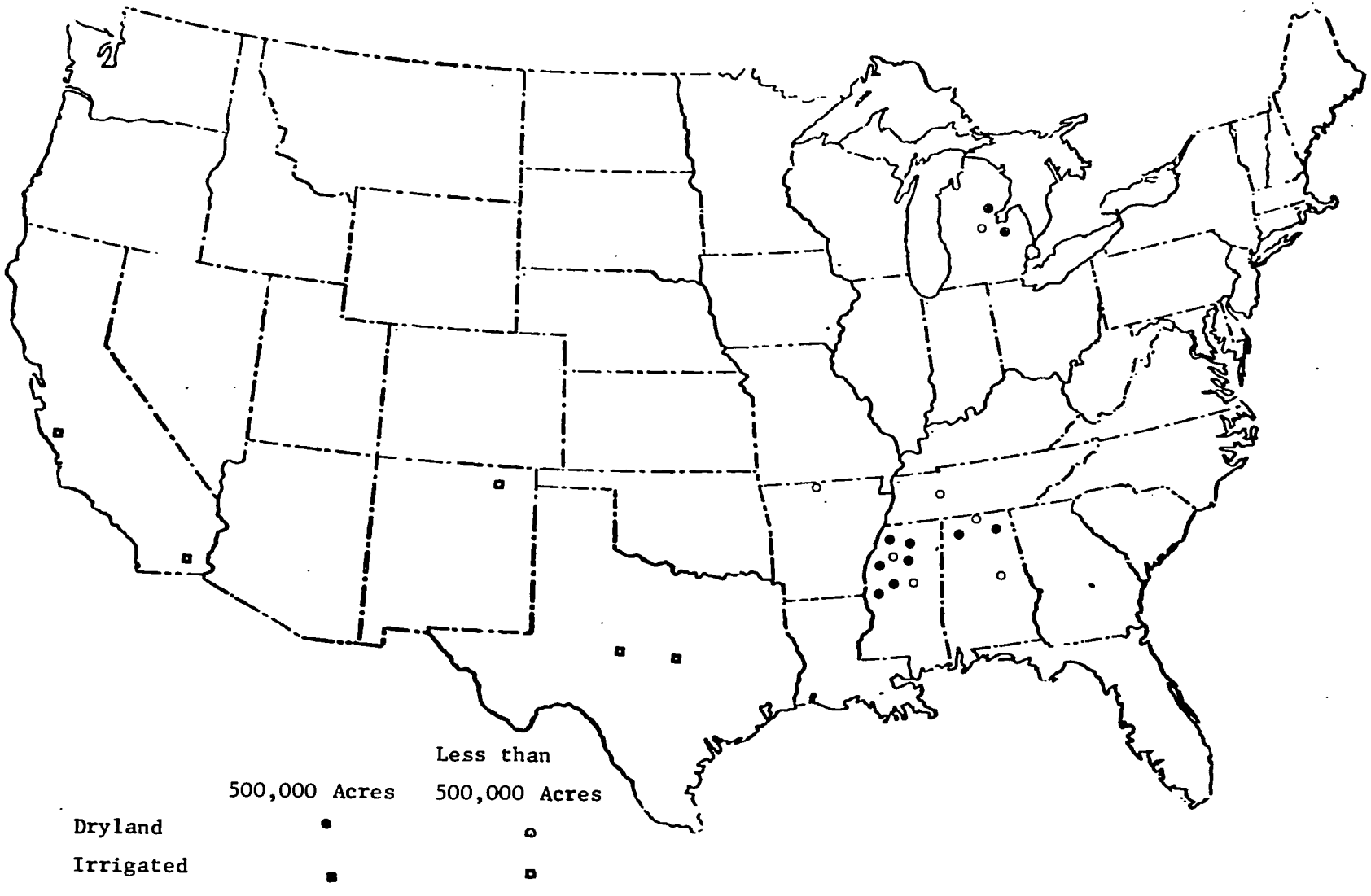

Figure 4.12. Location of dryland and irrigated cotton and sugar beets under Model A3 in 2000

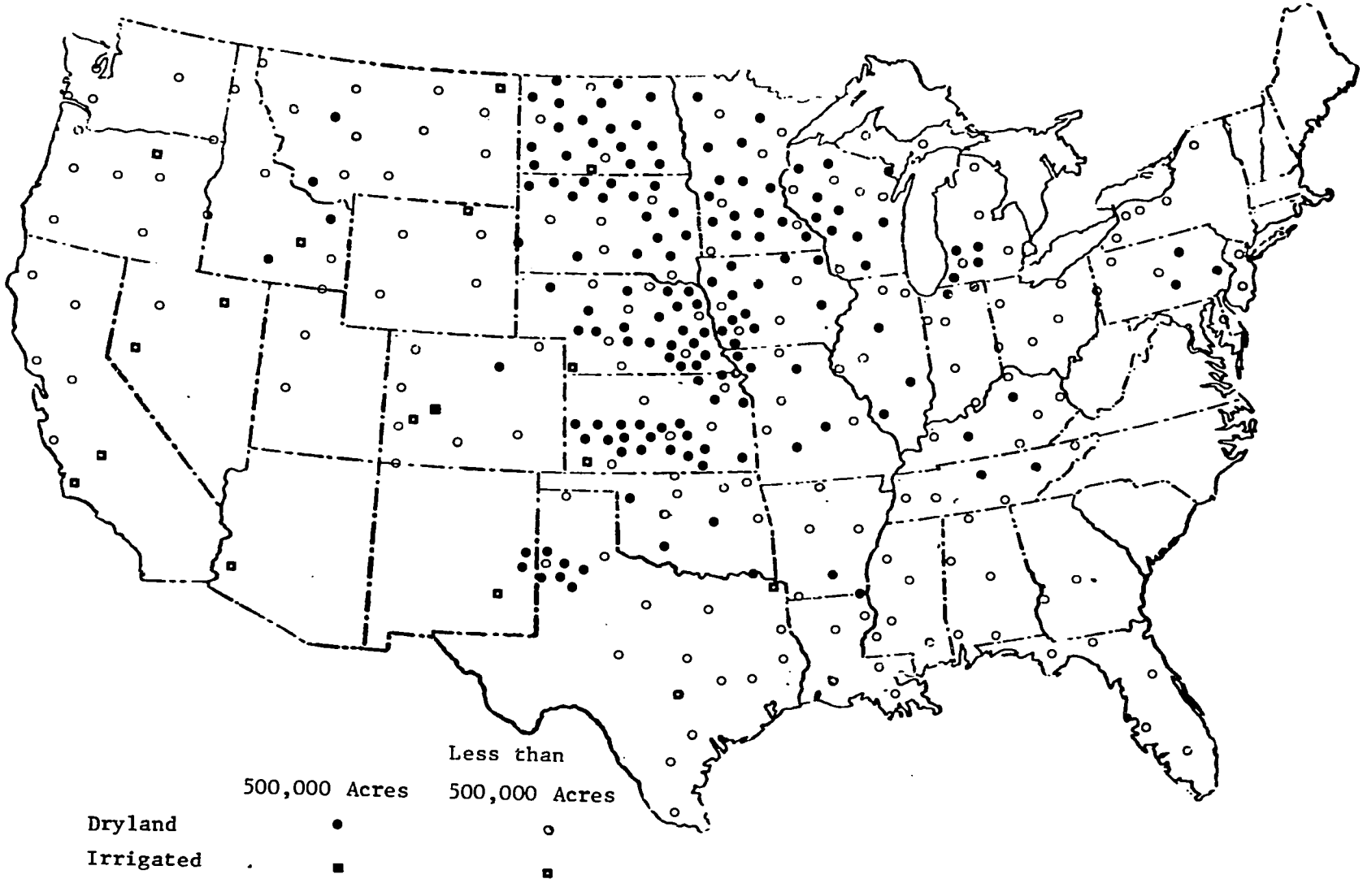

Figure 4.13. Location of dryland and irrigated hay under Model A3 in 2000

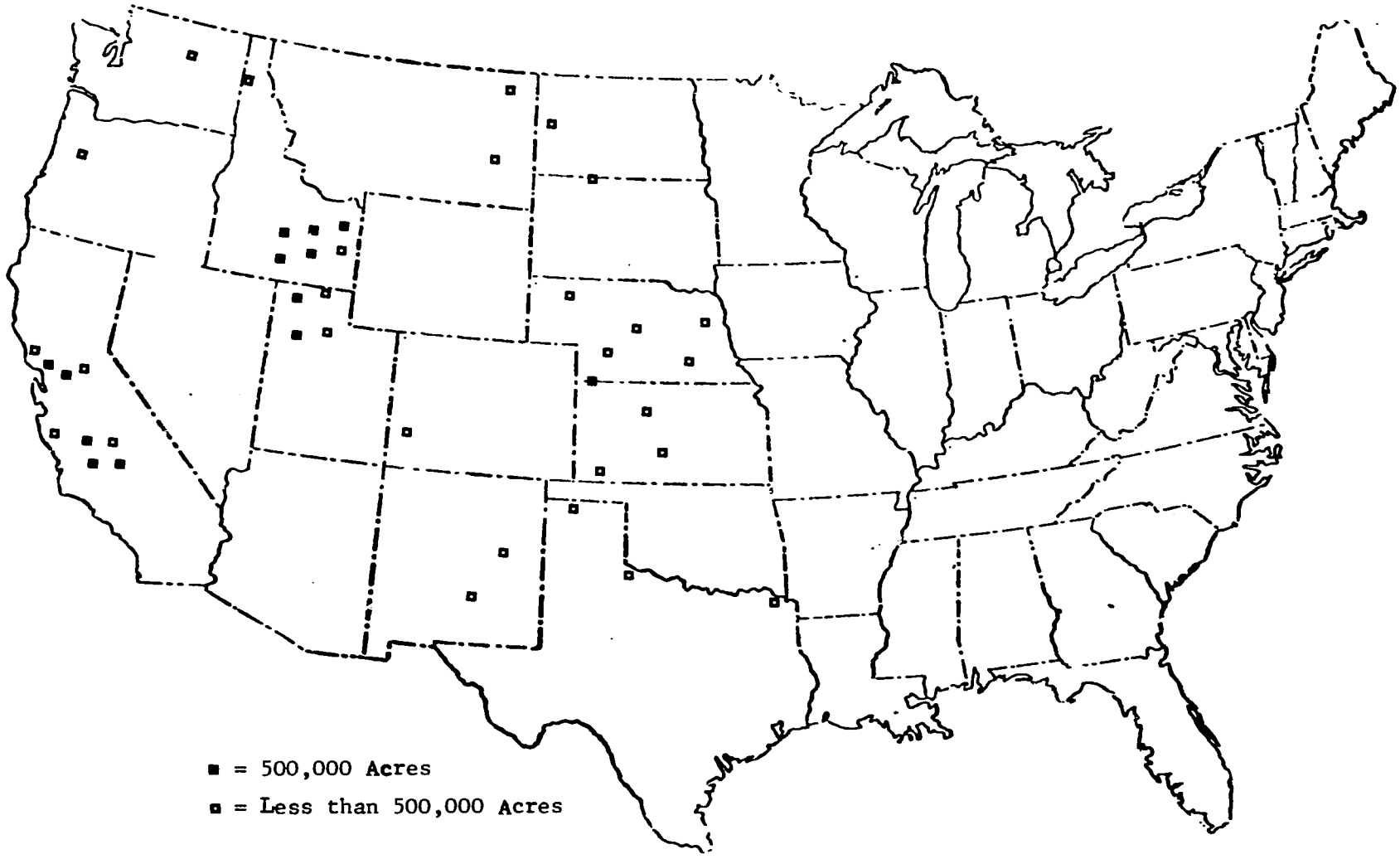

Figure 4.14. Location of irrigated pasture under Model A3 in 2000

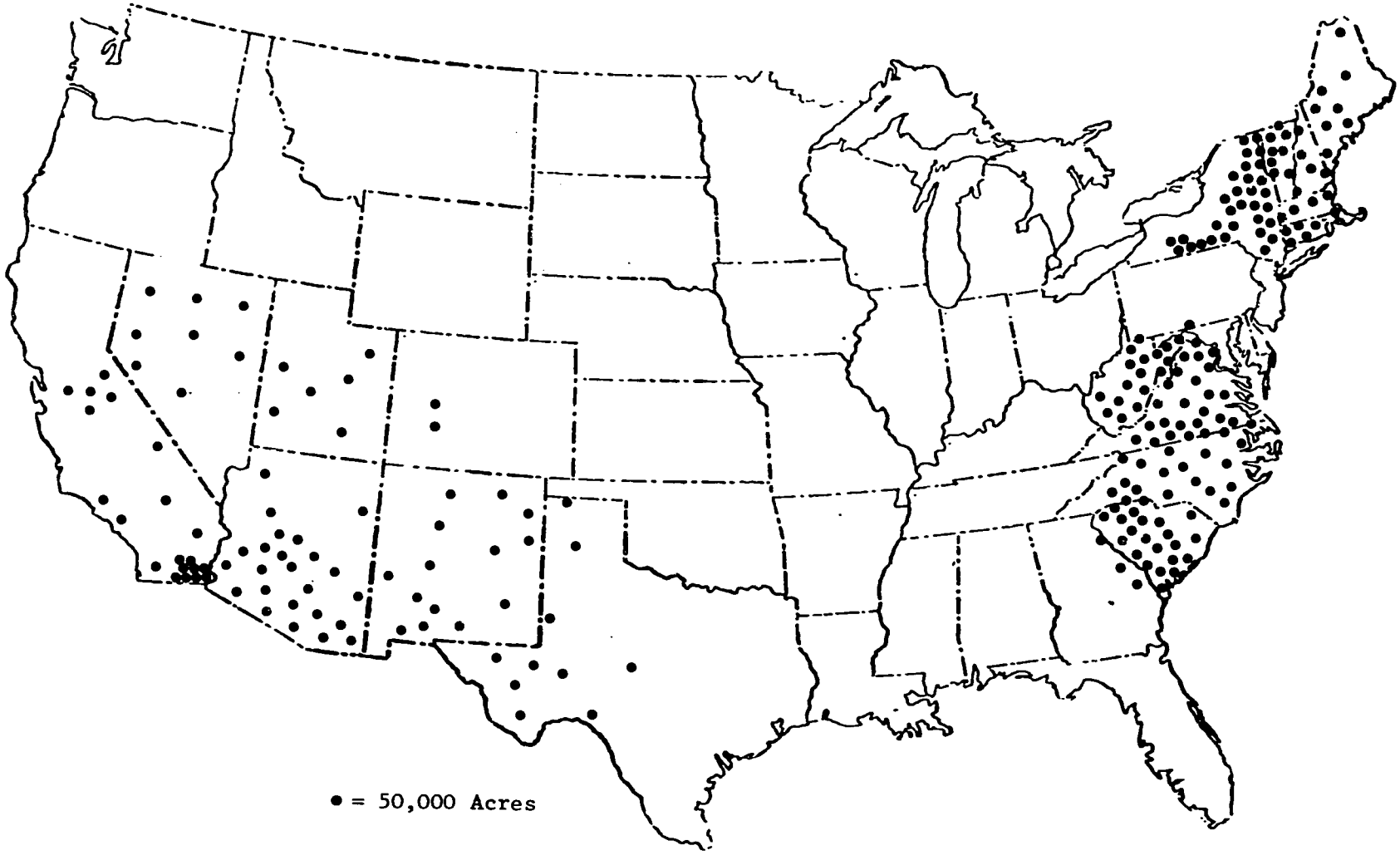

Figure 4.15. Location of unused land under Model A3 in 2000

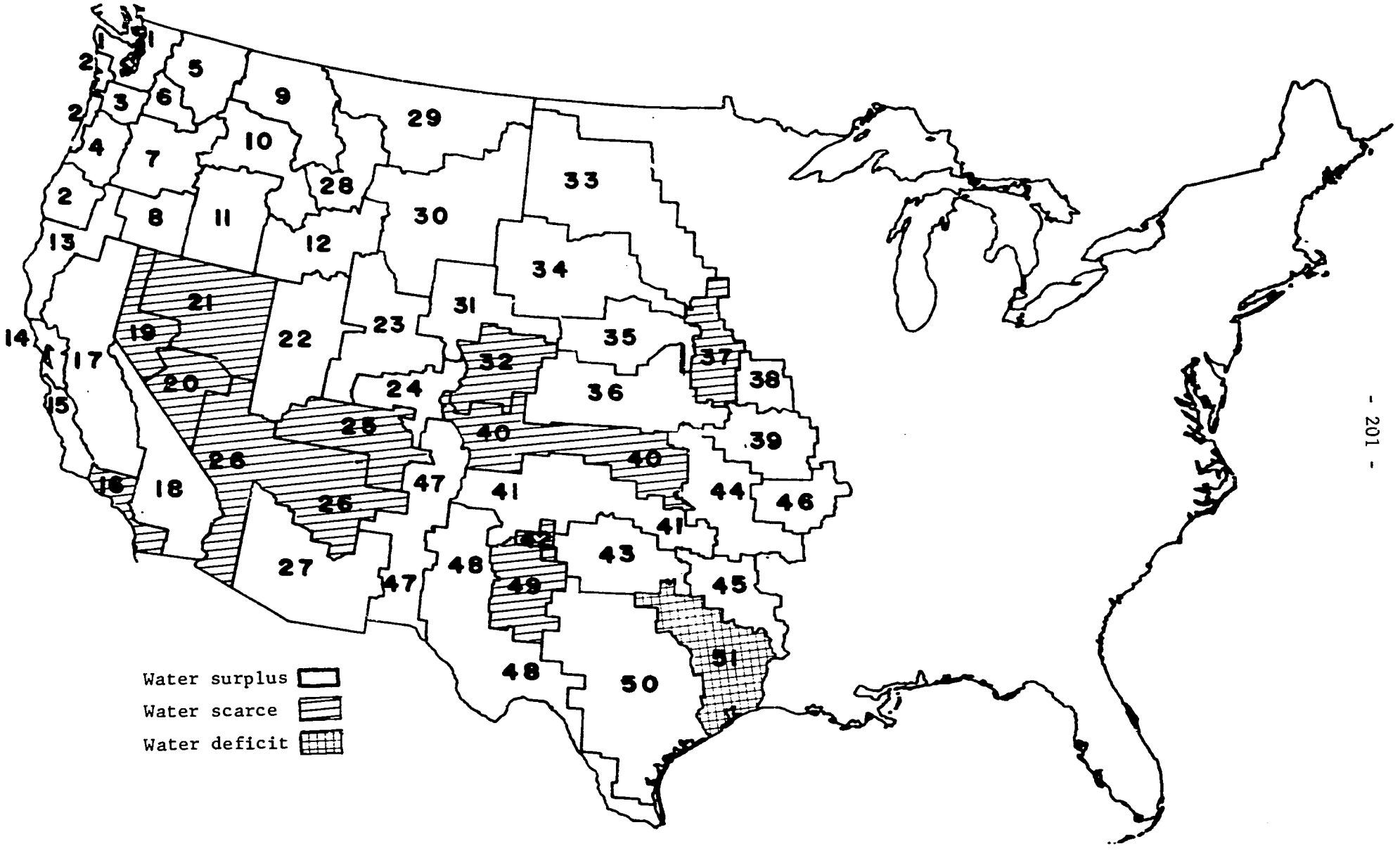

Figure 4.16. Water supply-demand balances under Model A3 in 2000

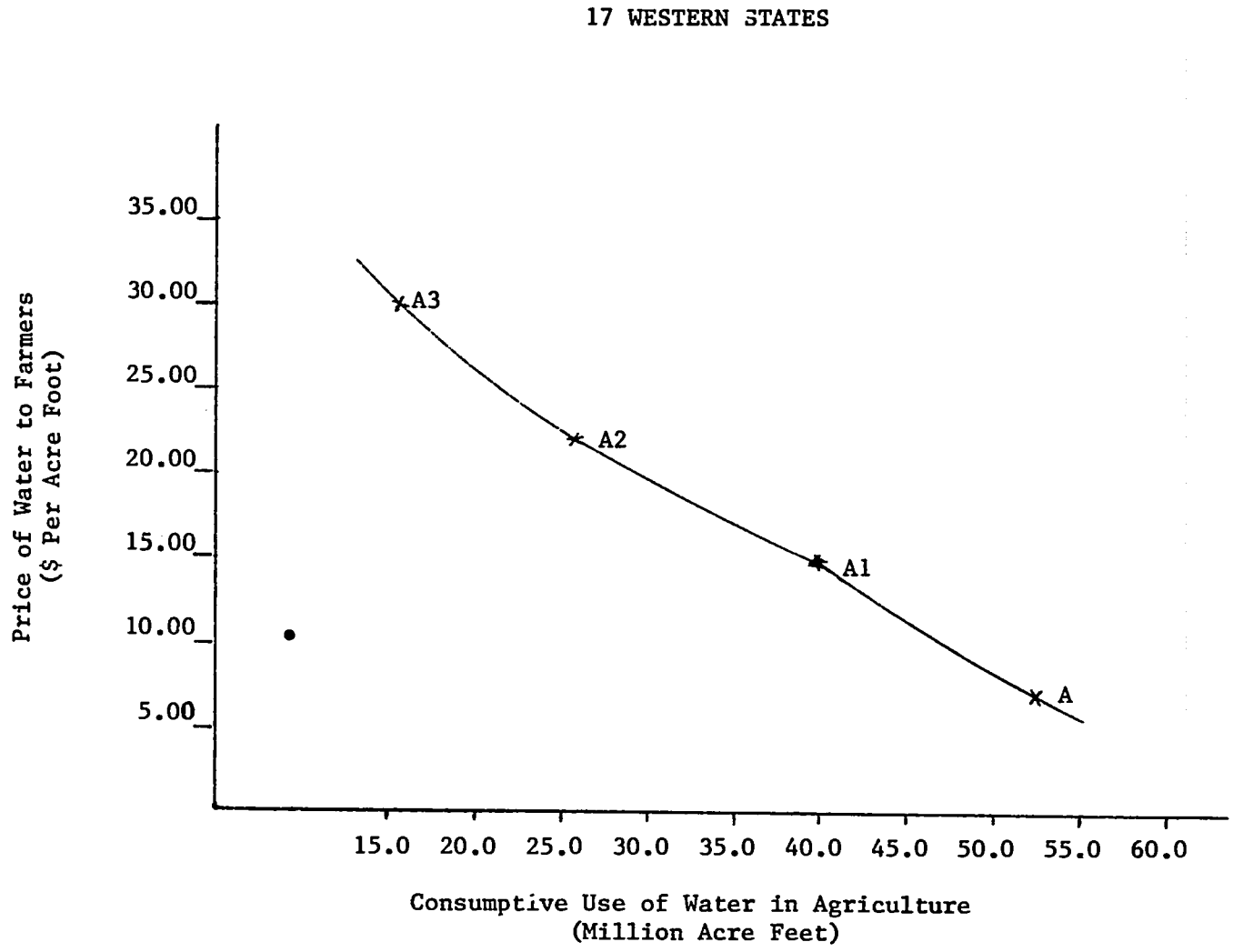

Figure 4.17. Agricultural demand for water in the 17 Western States

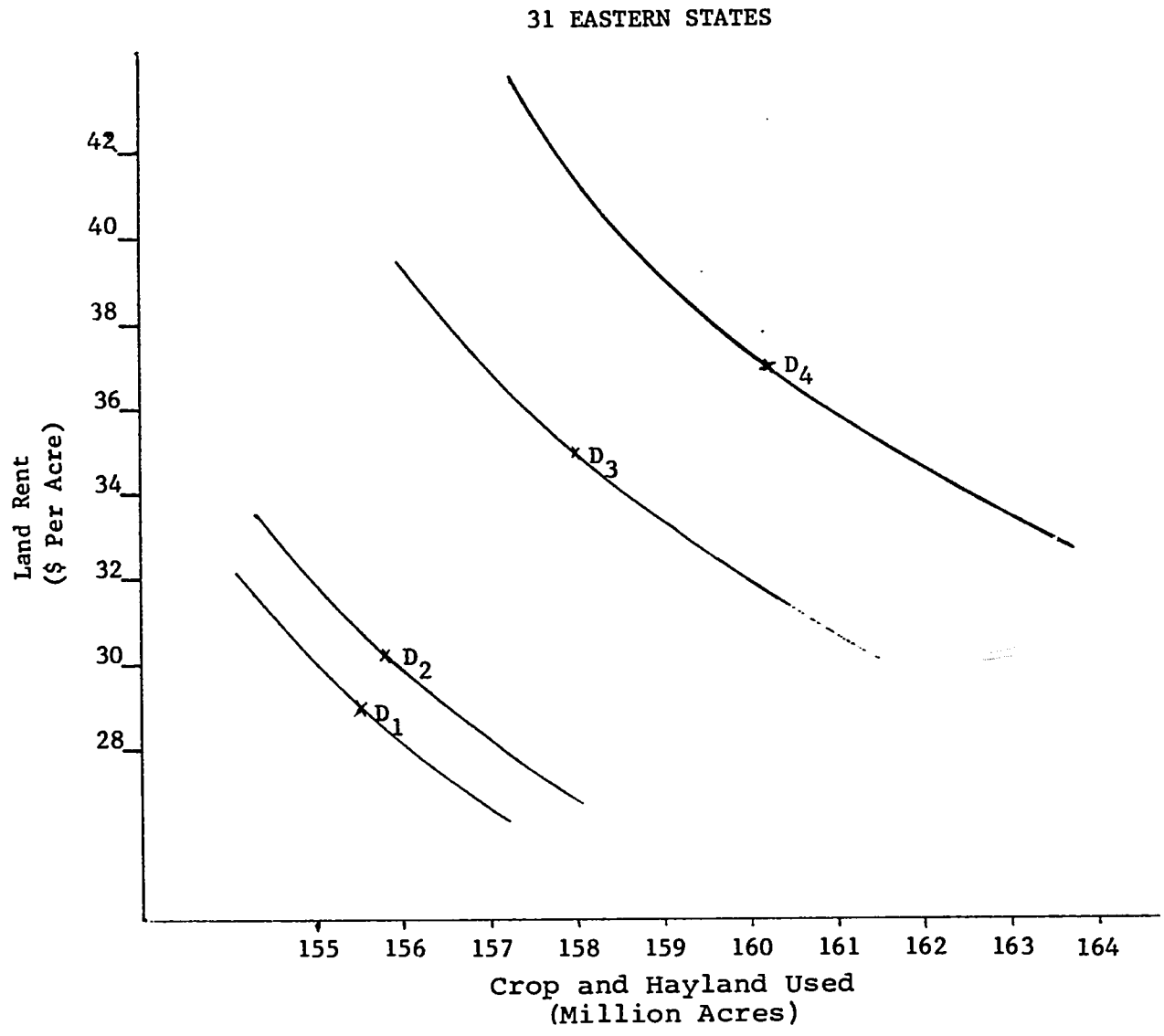

Figure 4.18. Agricultural demand for land in the 31 Eastern States

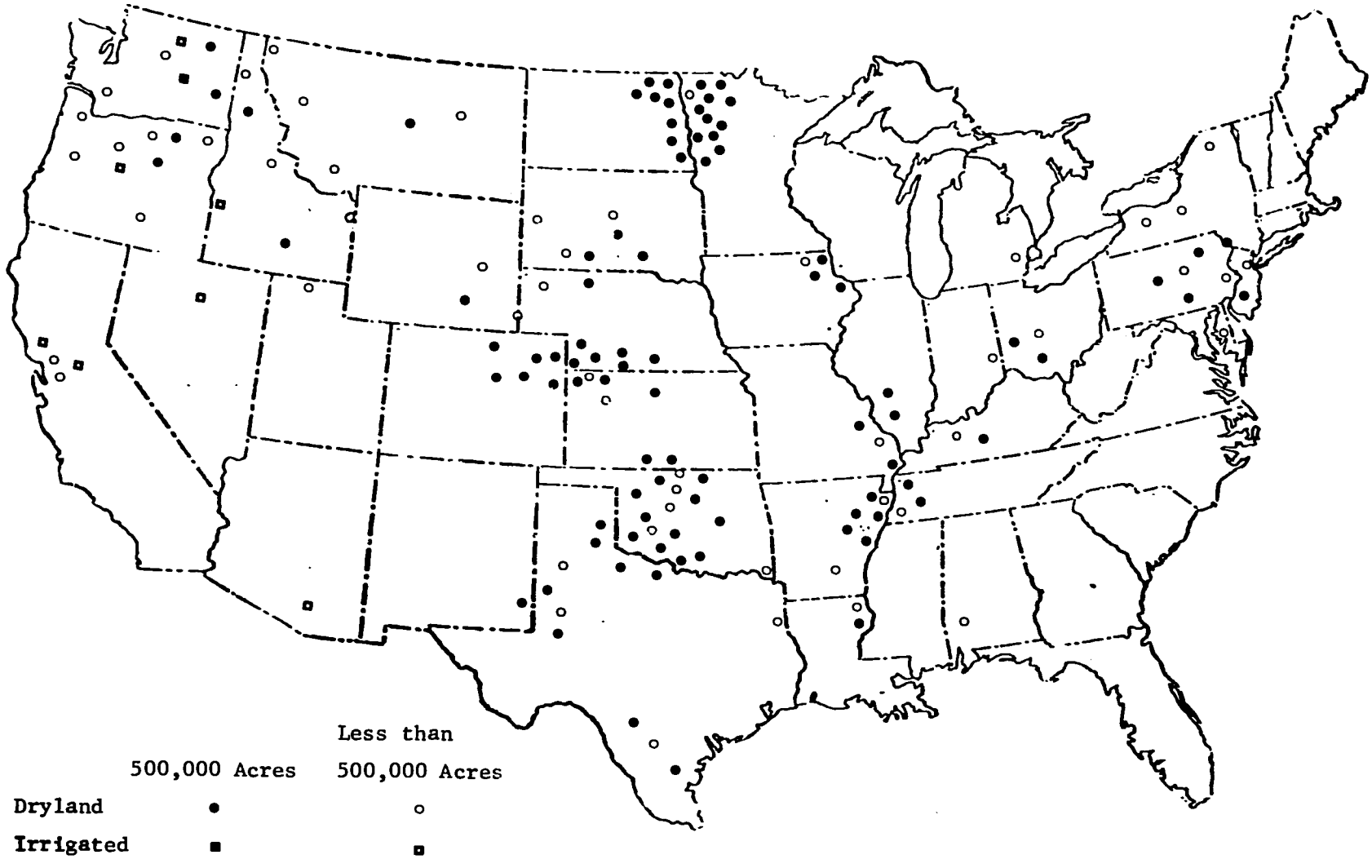

Figure 4.19. Location of dryland and irrigated wheat under Model B in 2000

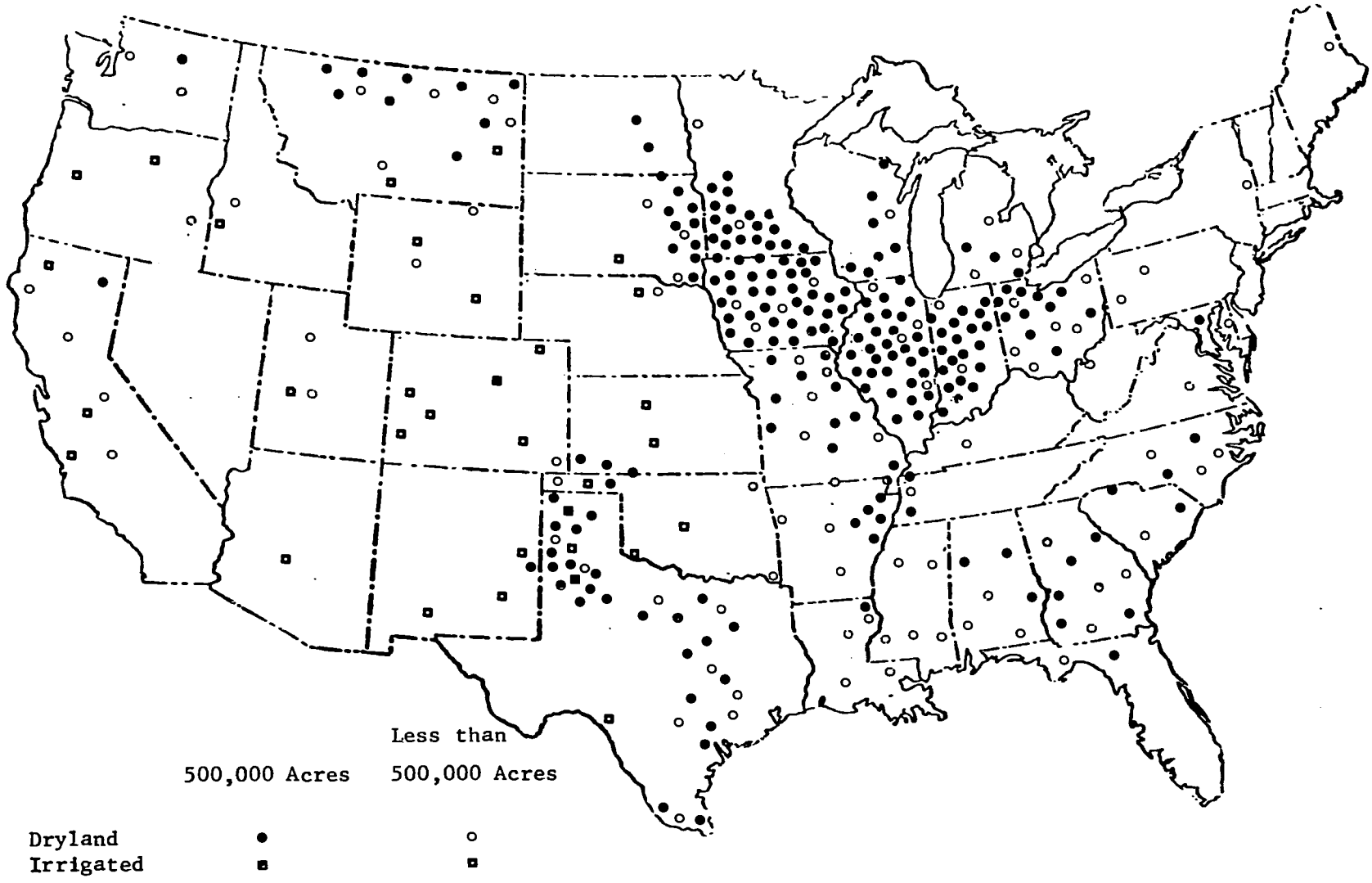

Figure 4.20. Location of dryland and irrigated feed grains and soybeans under Model B in 2000

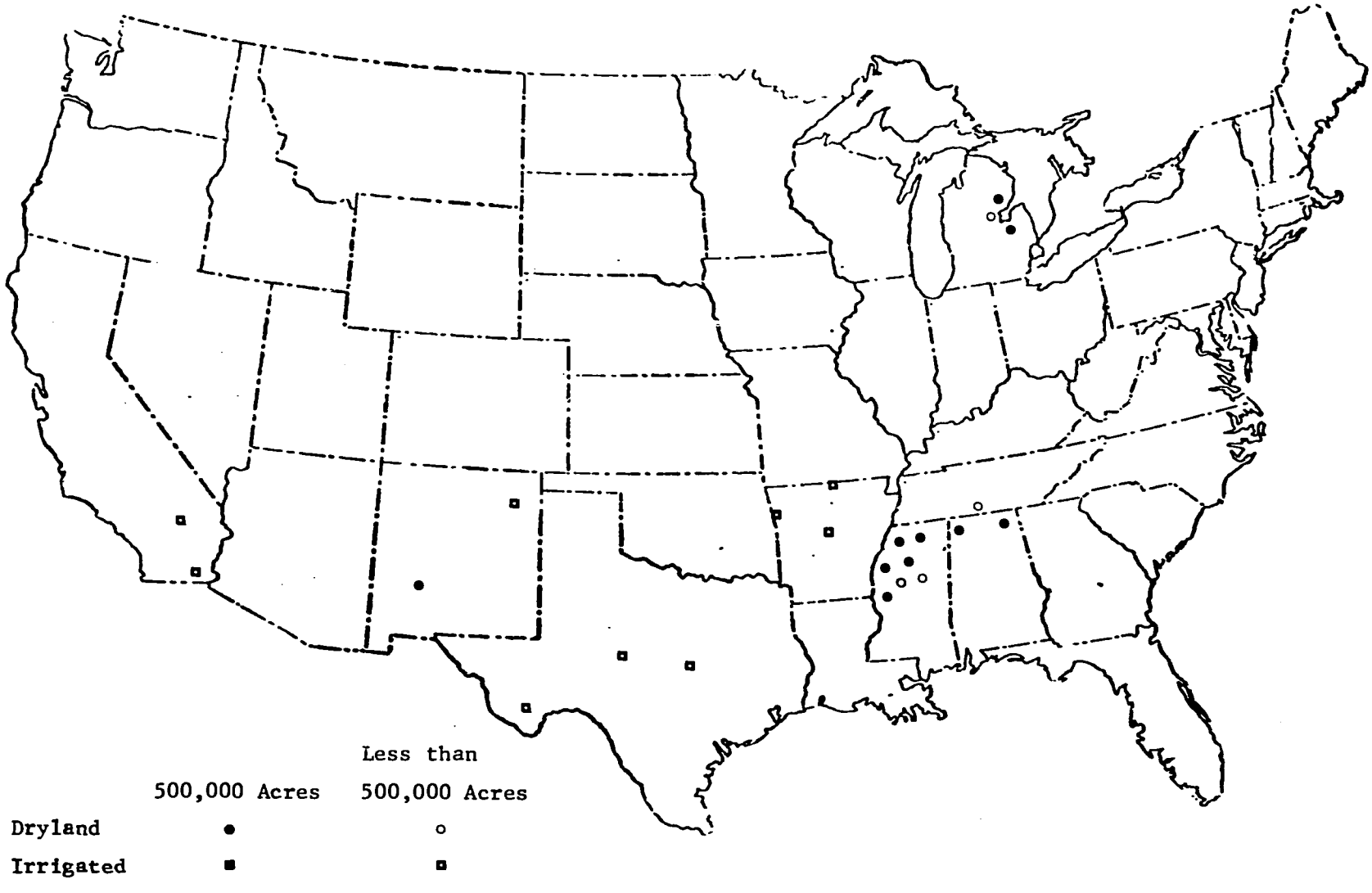

Figure 4.21. Location of dryland and irrigated cotton and sugar beets under Model B in 2000

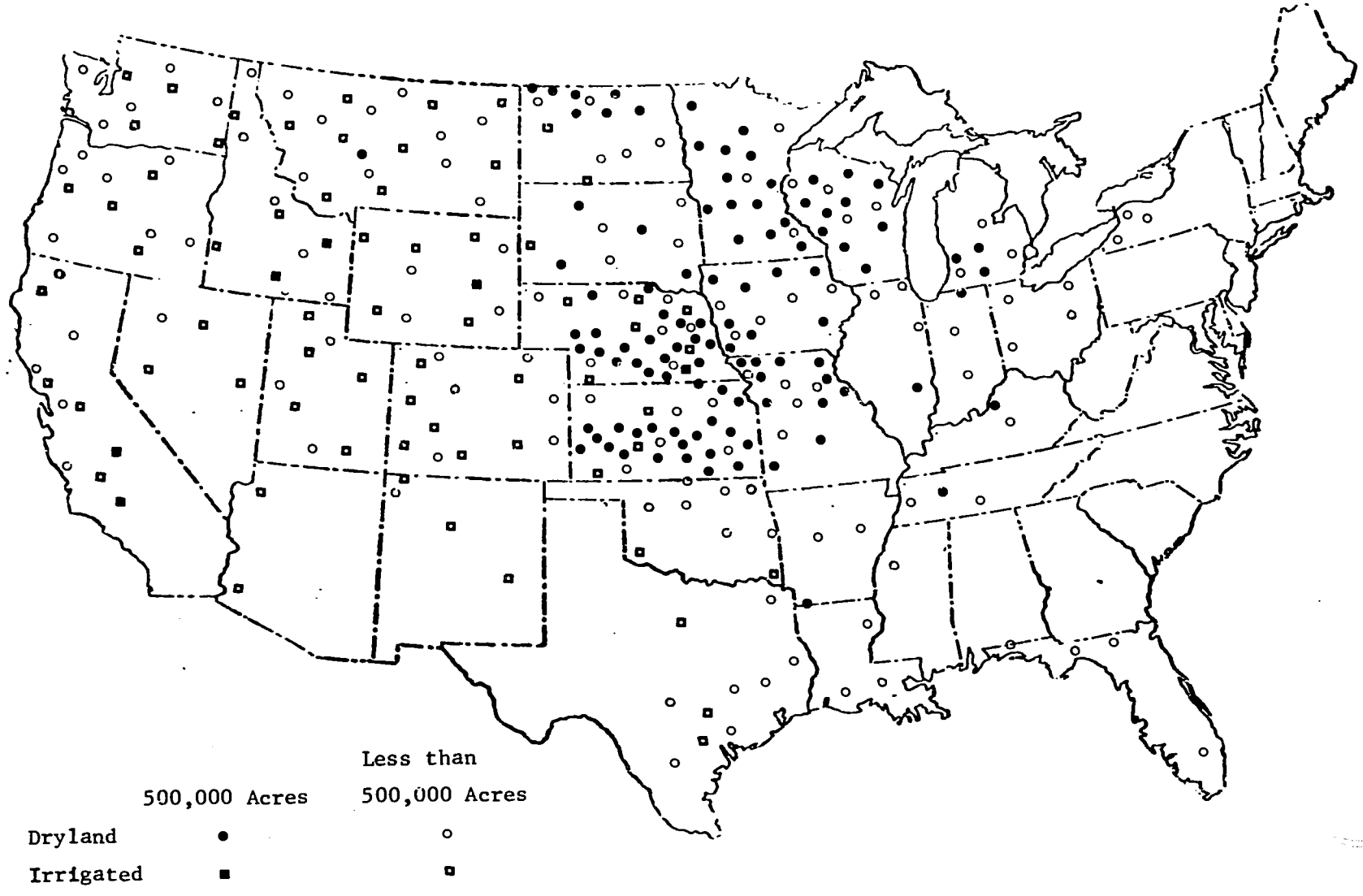

Figure 4.22. Location of dryland and irrigated hay under Model B in 2000

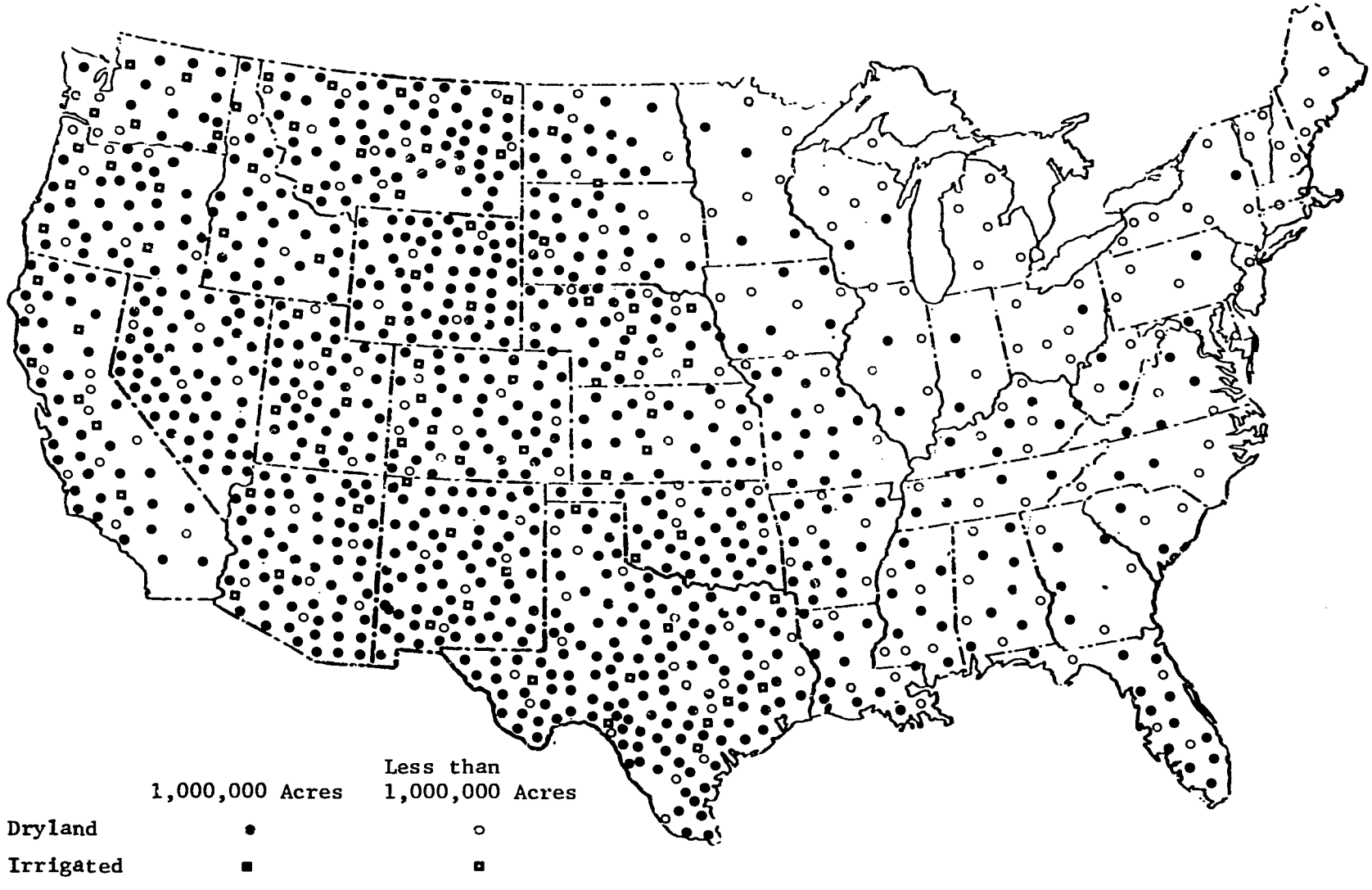

Figure 4.23. Location of dryland and irrigated pasture under Model B in 2000

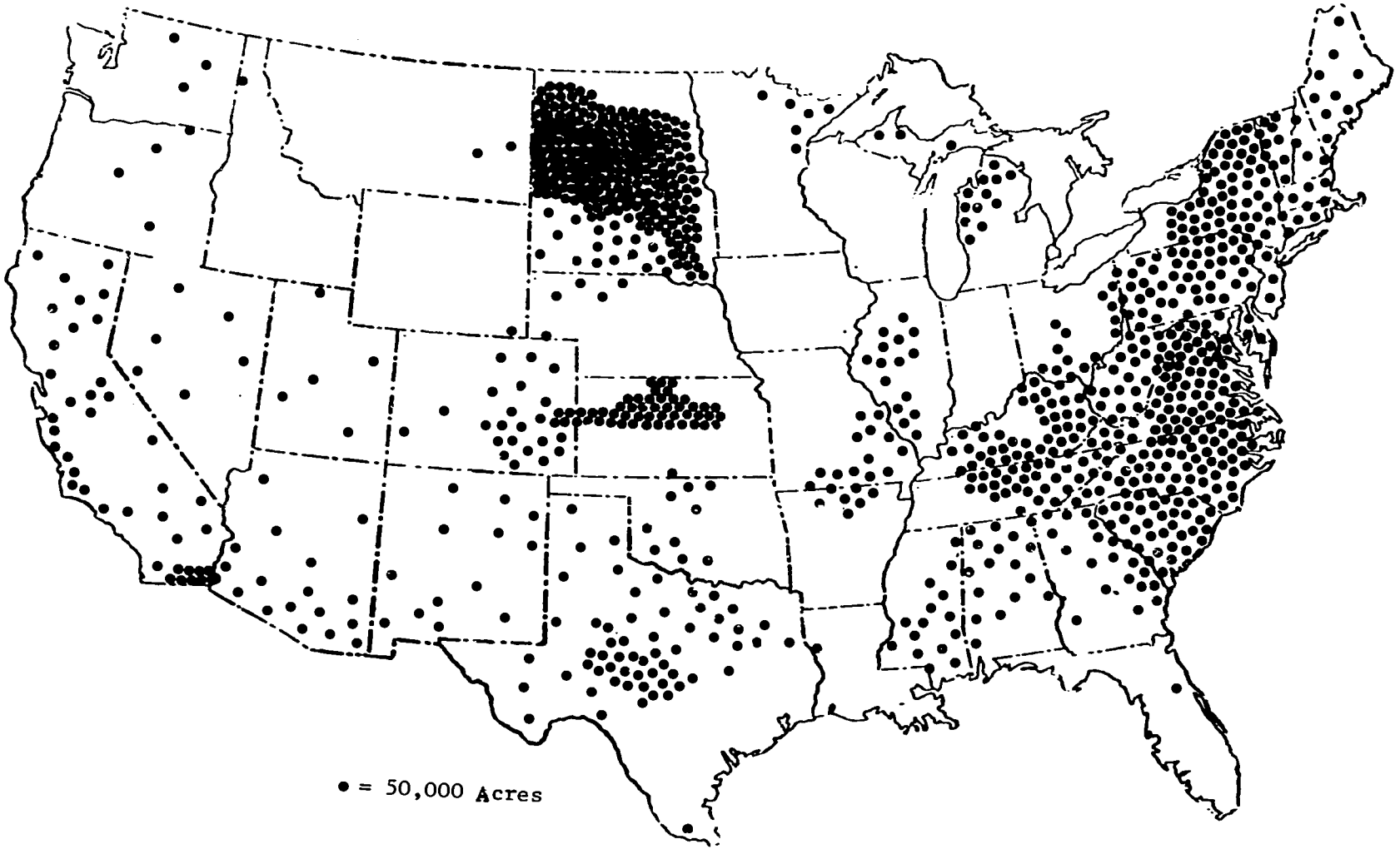

Figure 4.24. Location of unused land under Model B in 2000

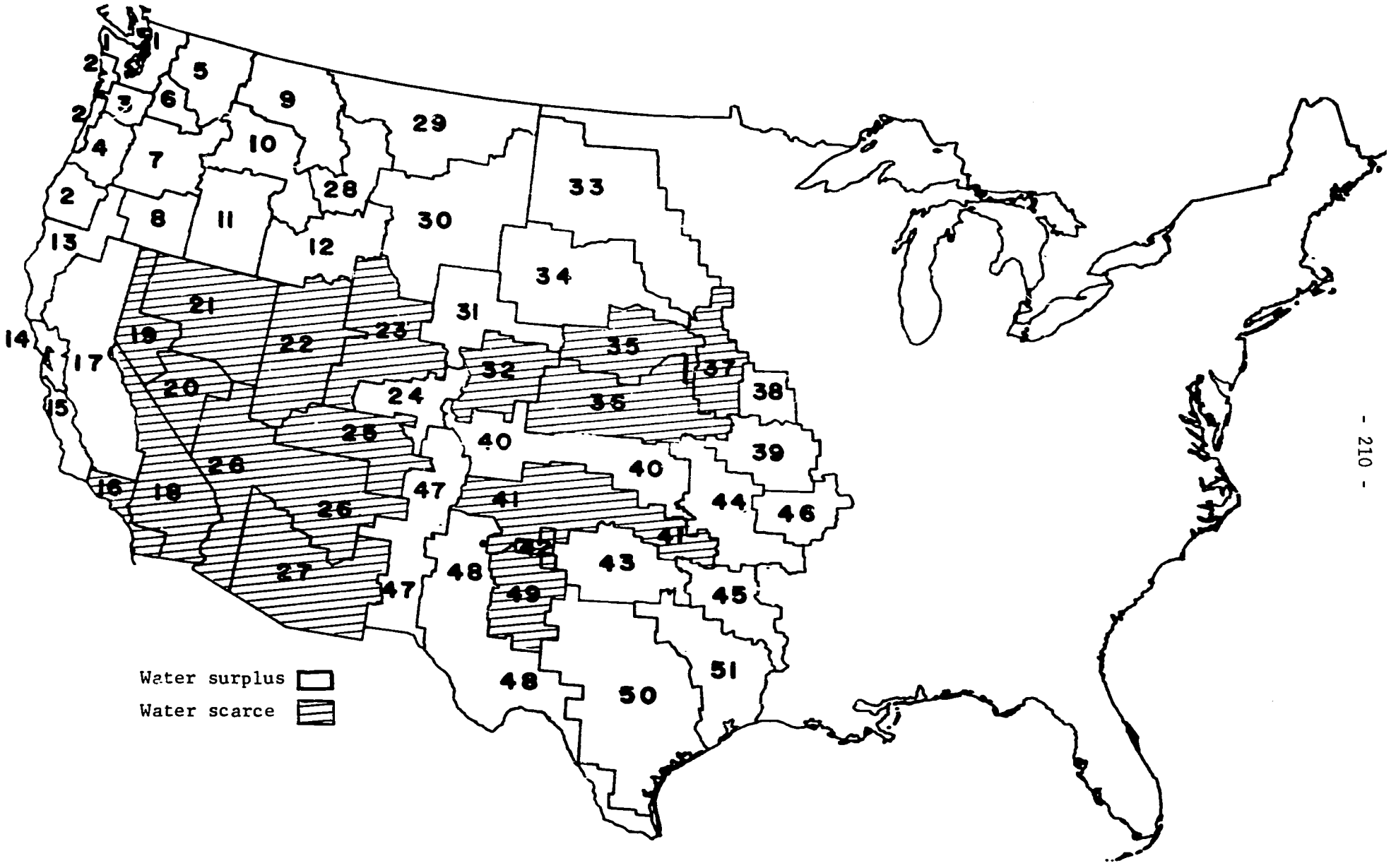

Figure 4.25. Water supply-demand balances under Model B in 2000

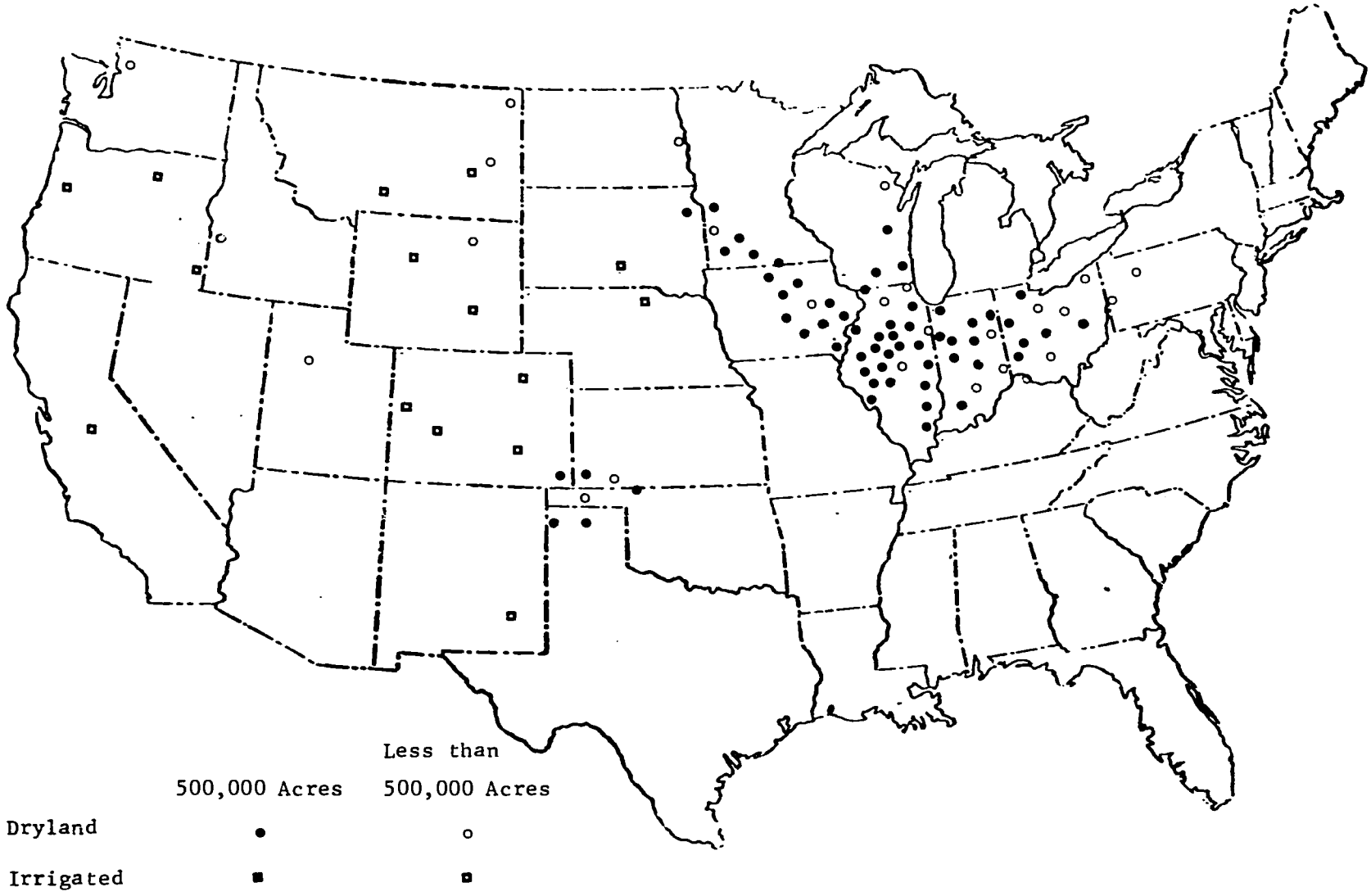

Figure 4.26. Location of dryland and irrigated corn under Model E in 2000

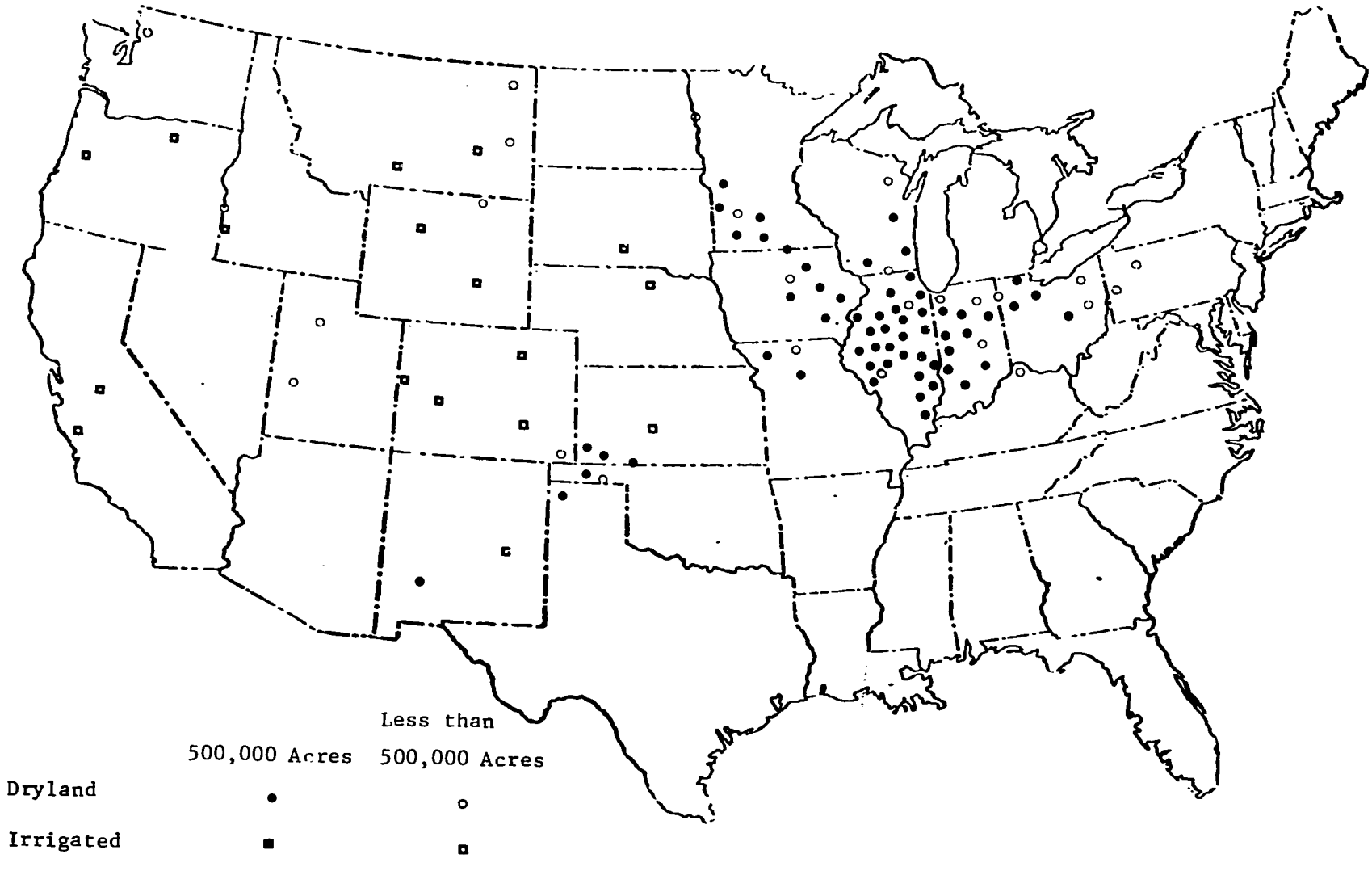

Figure 4.27. Location of dryland and irrigated corn under Model B in 2000

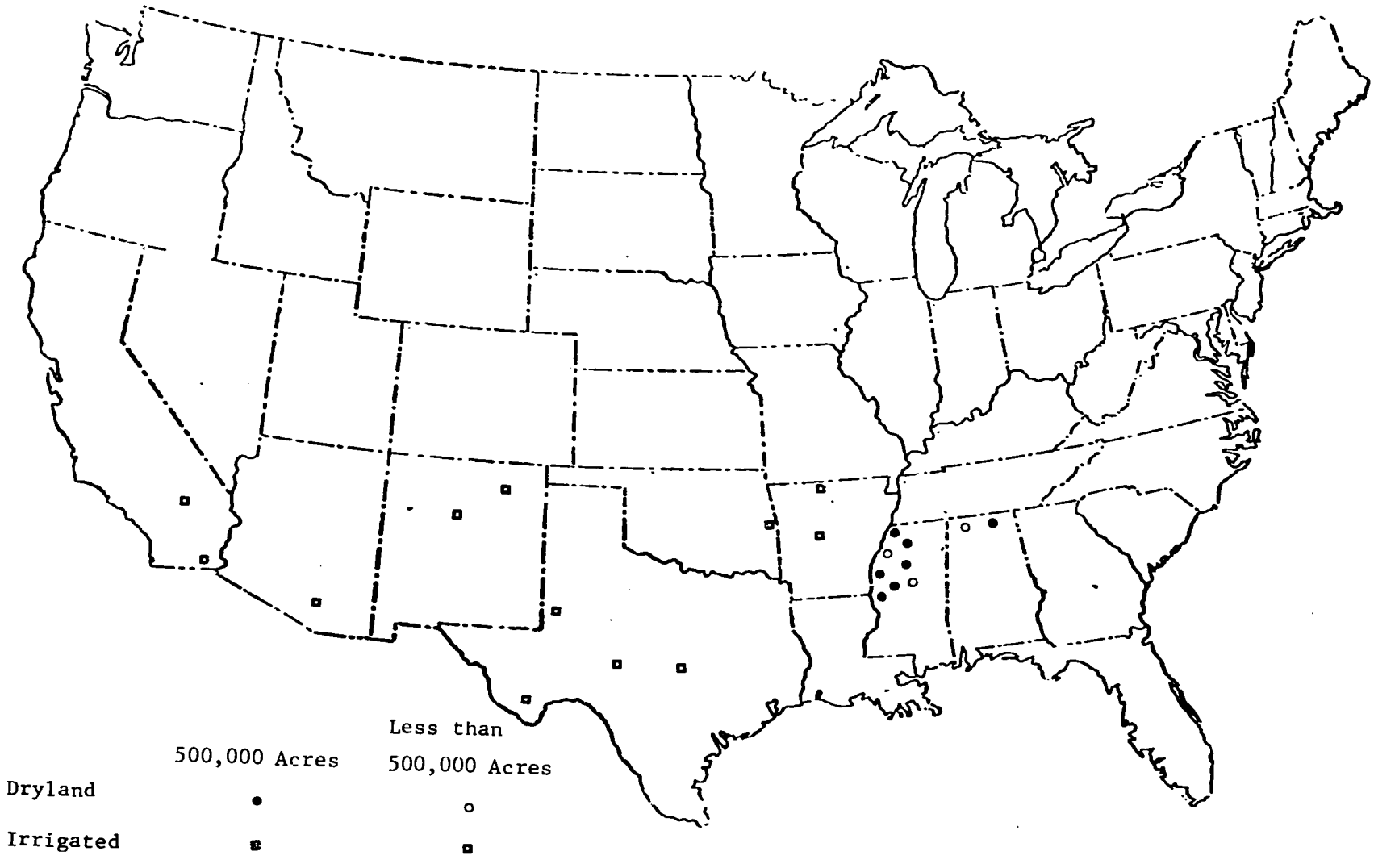

Figure 4.28. Location of dryland and irrigated cotton under Model E in 2000

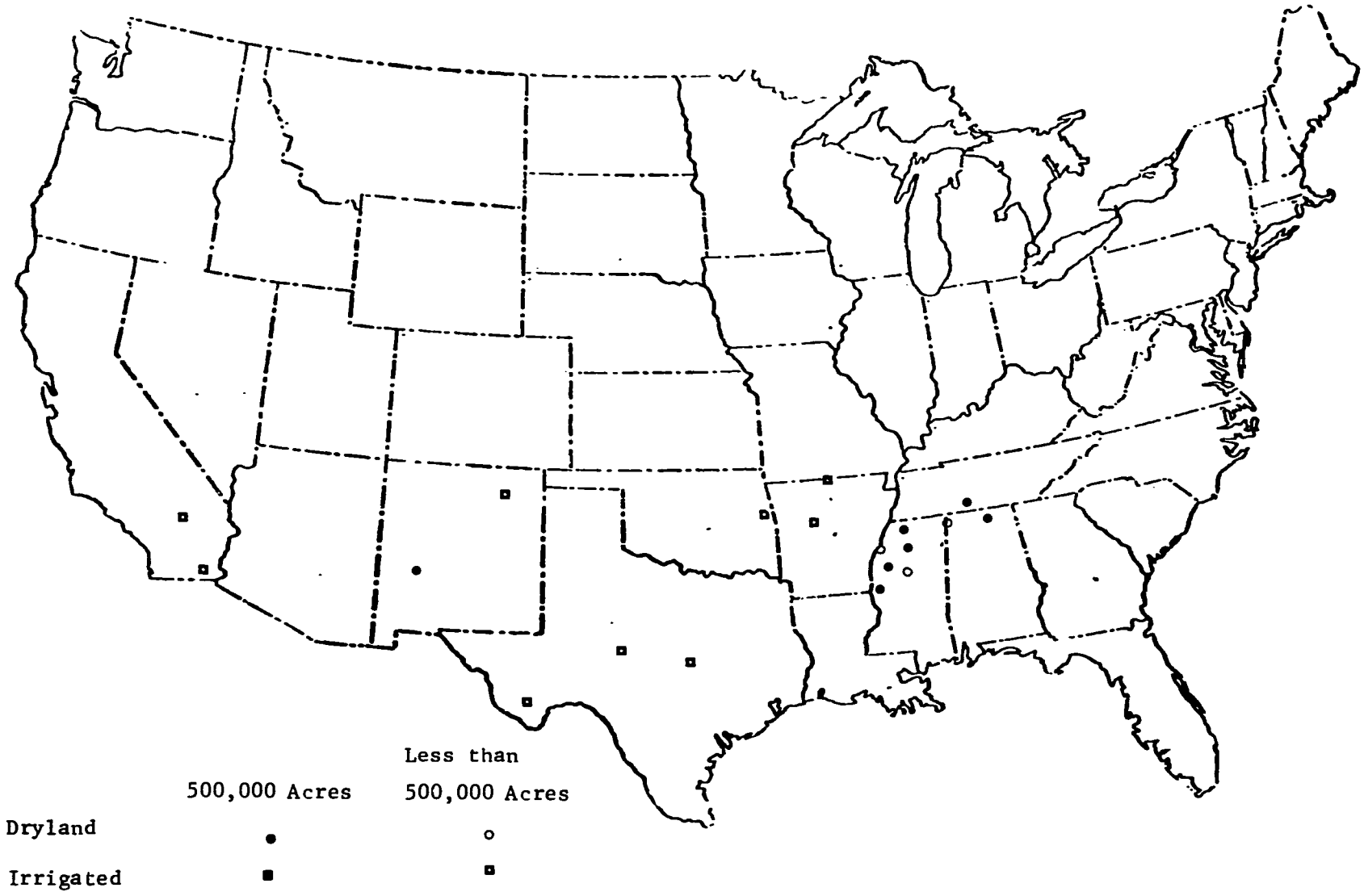

Figure 4.29. Location of dryland and irrigated cotton under Model B in 2000

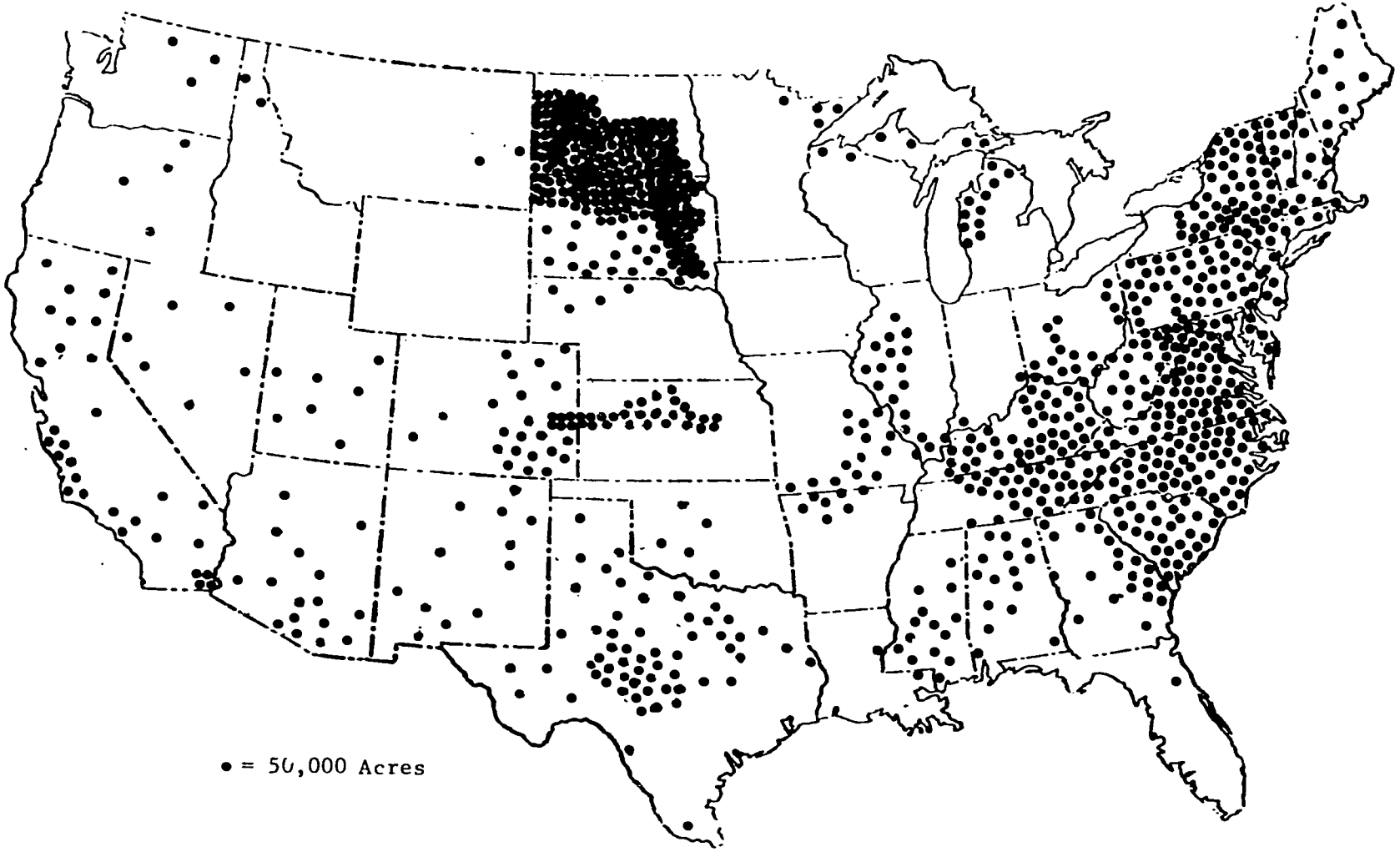

Figure 4.30. Location of unused land under Model E in 2000

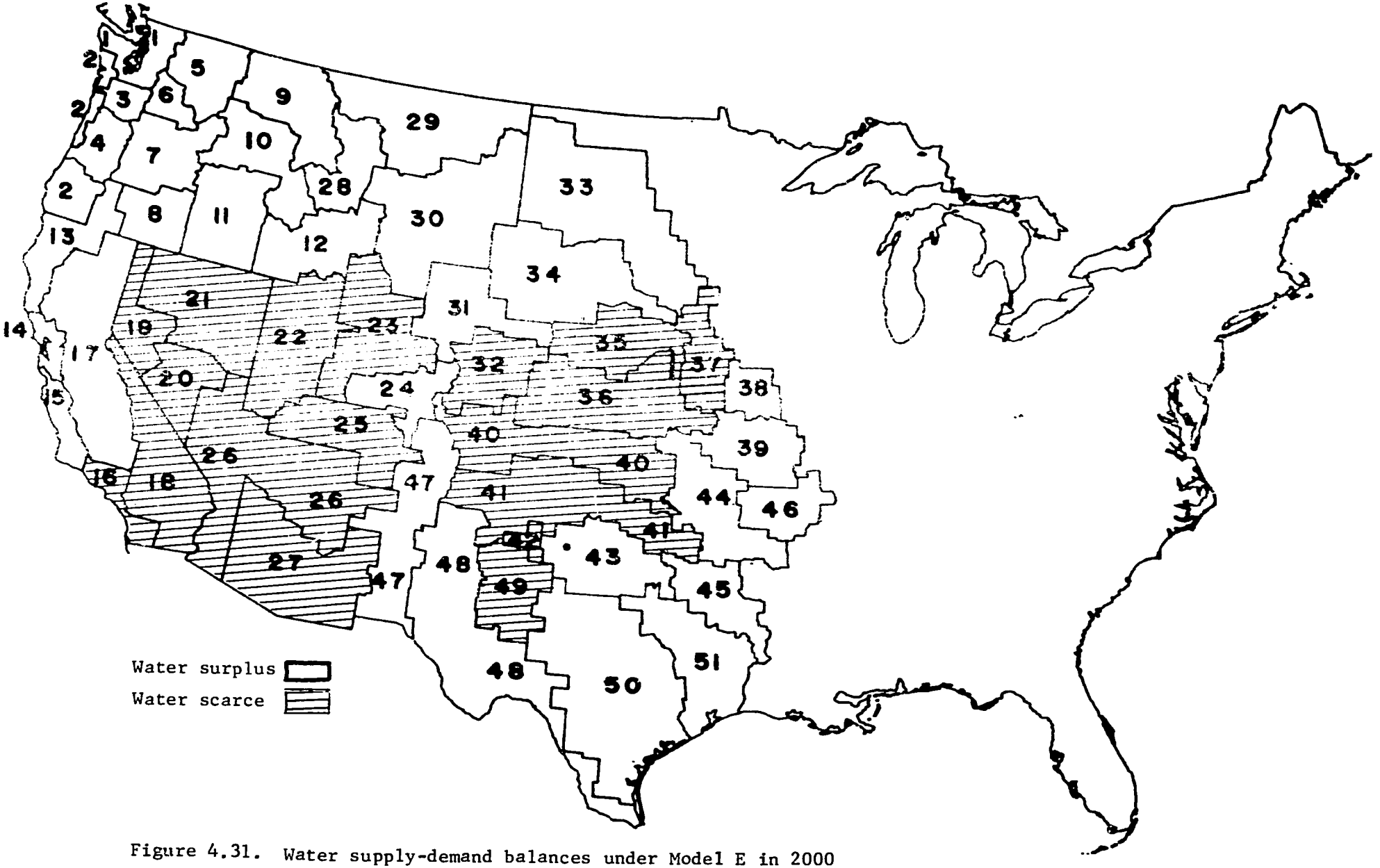

Figure 4.31. Water supply-demand balances under Model E in 2000

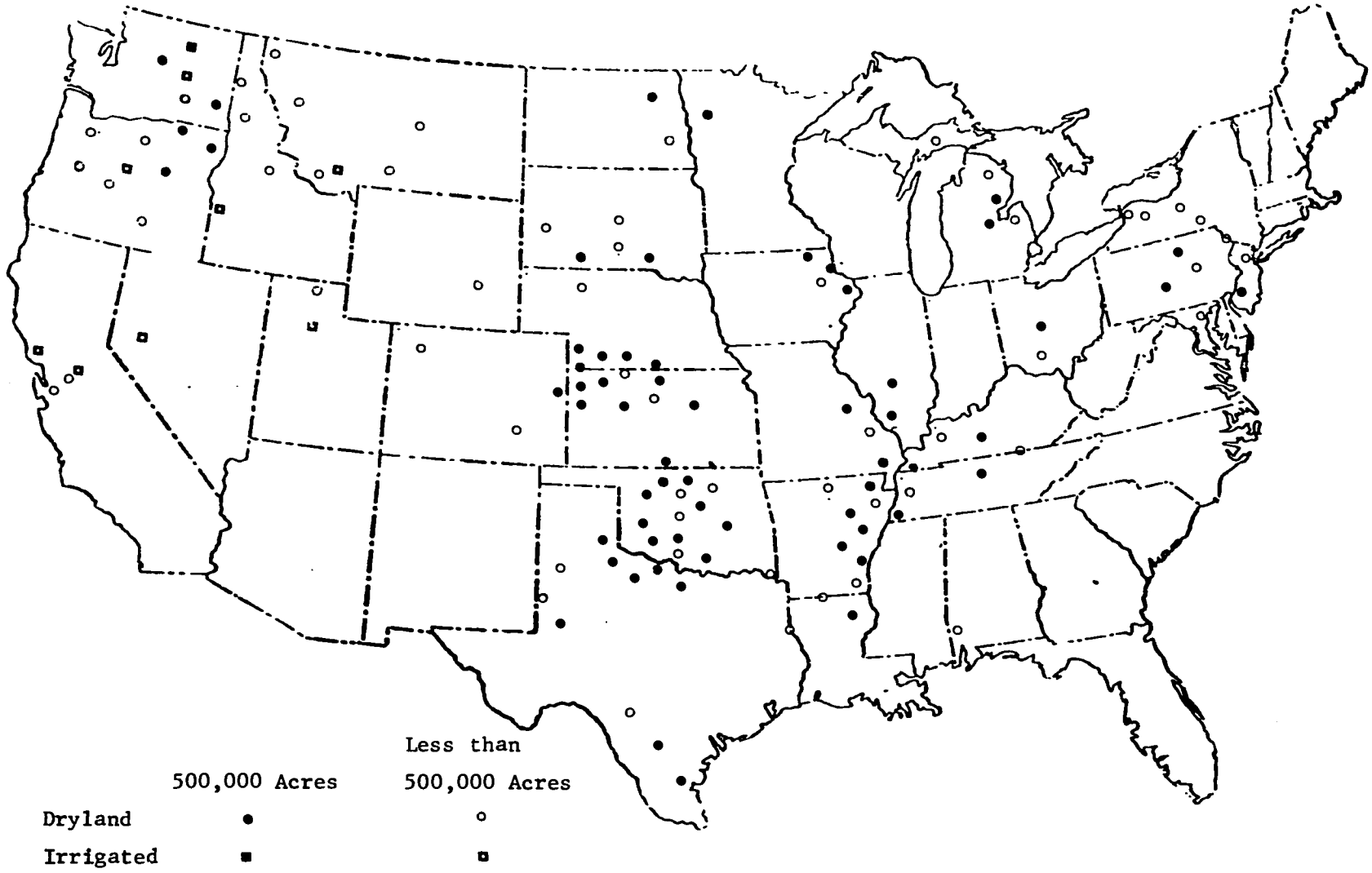

Figure 4.32. Location of dryland and irrigated wheat under Model F in 2000

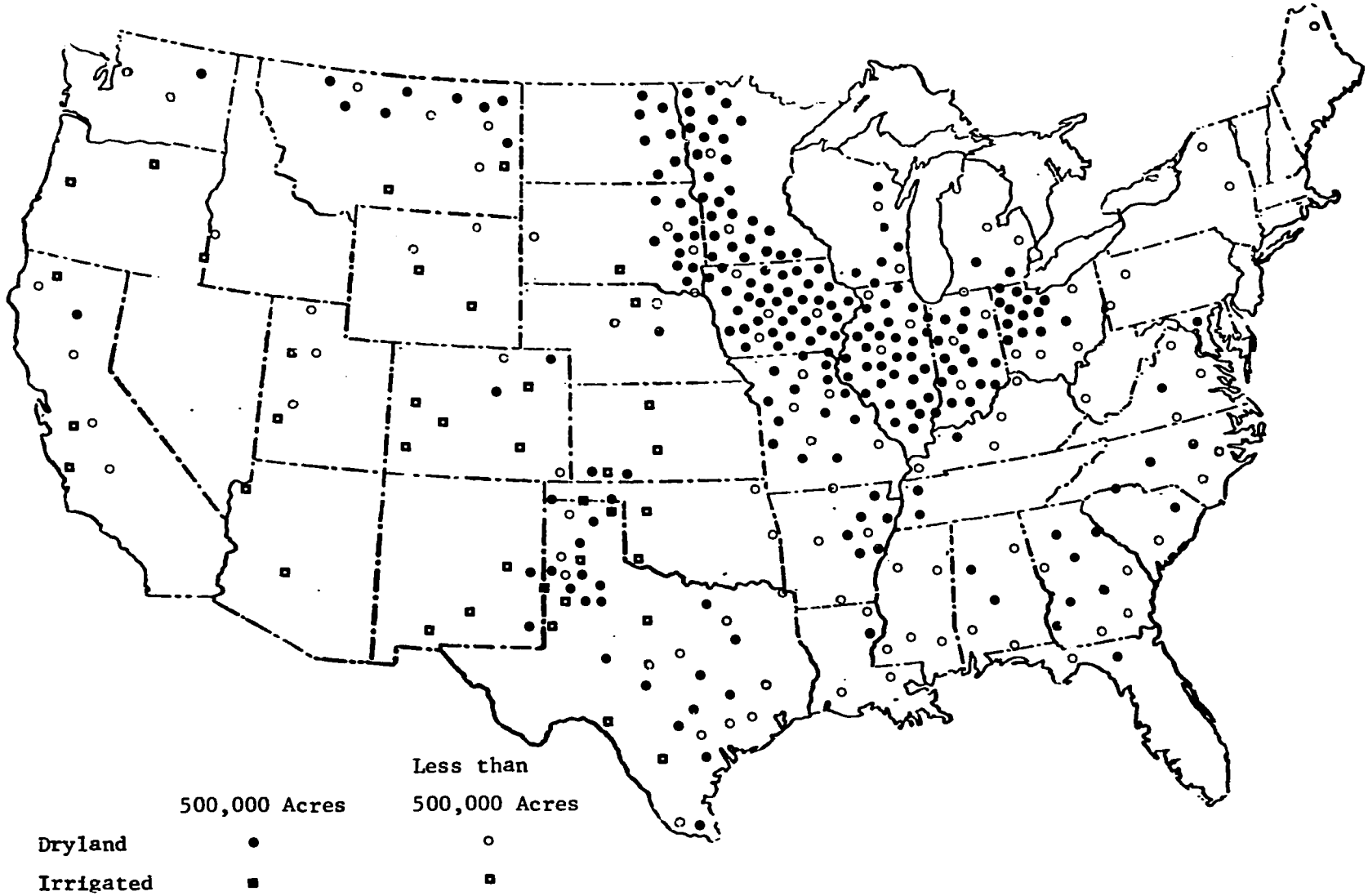

Figure 4.33. Location of dryland and irrigated feed grains and soybeans under Model F in 2000

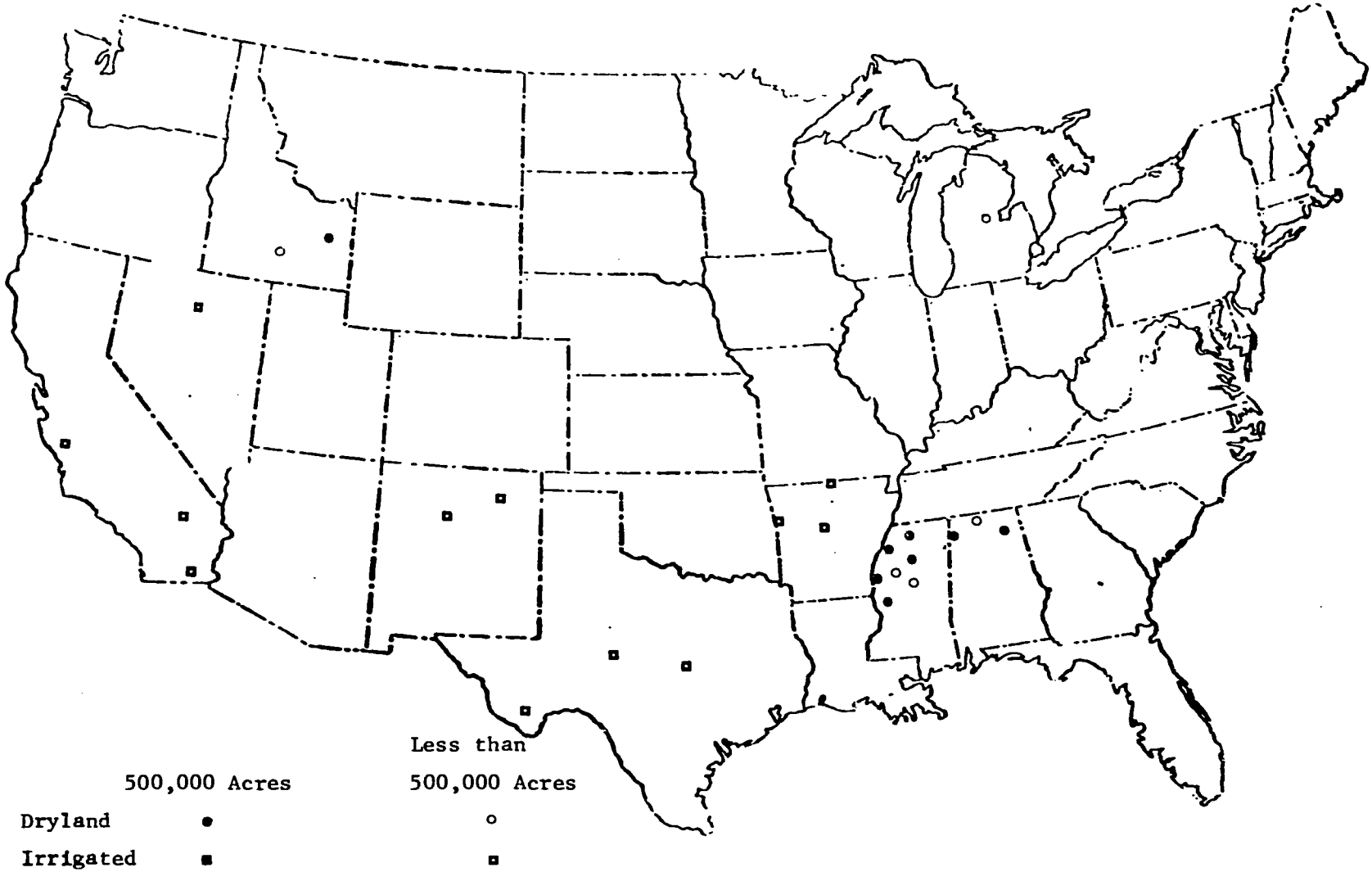

Figure 4.34. Location of dryland and irrigated cotton and sugar beets under Model F in 2000

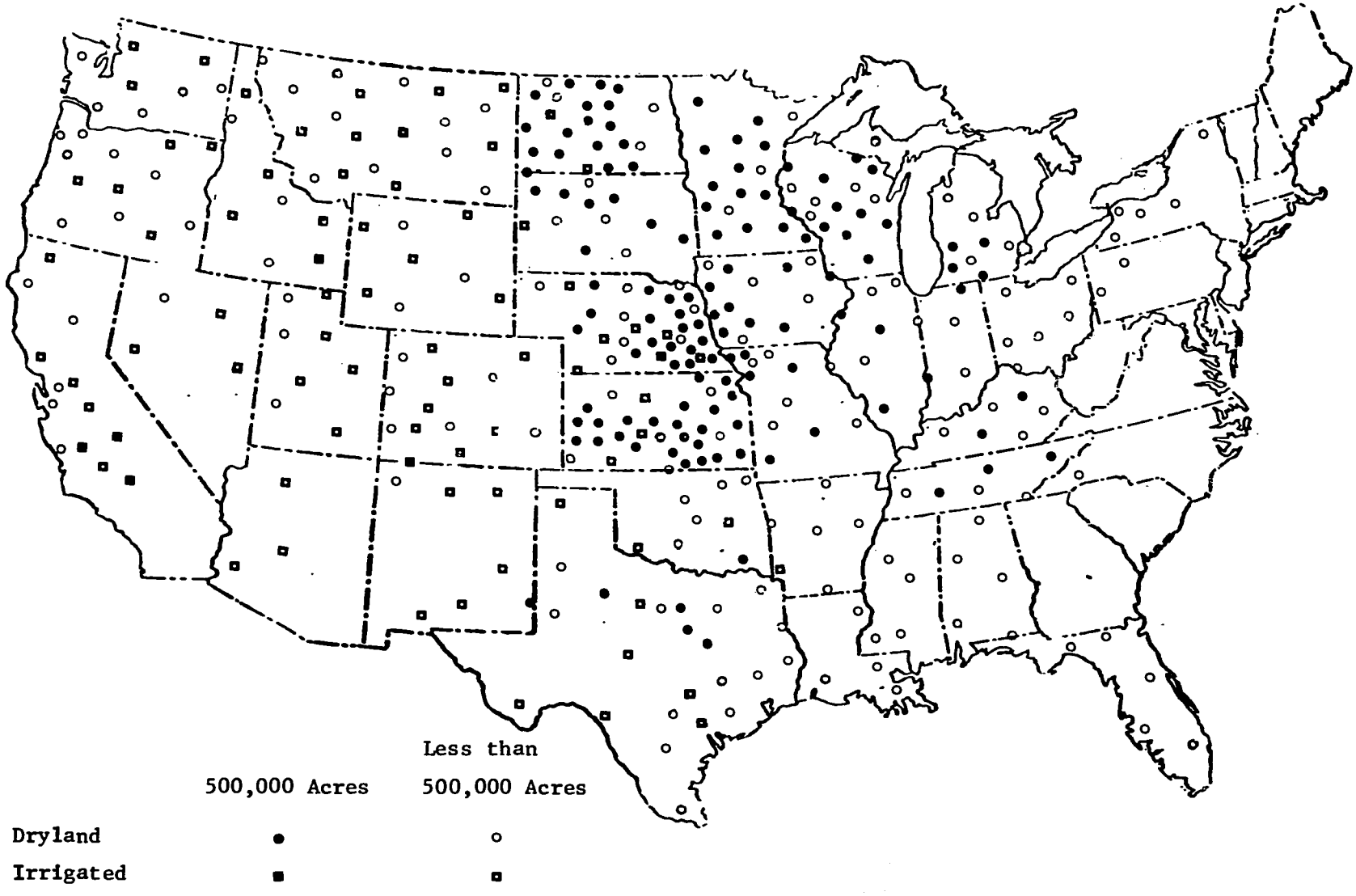

Figure 4.35. Location of dryland and irrigated hay under Model F in 2000

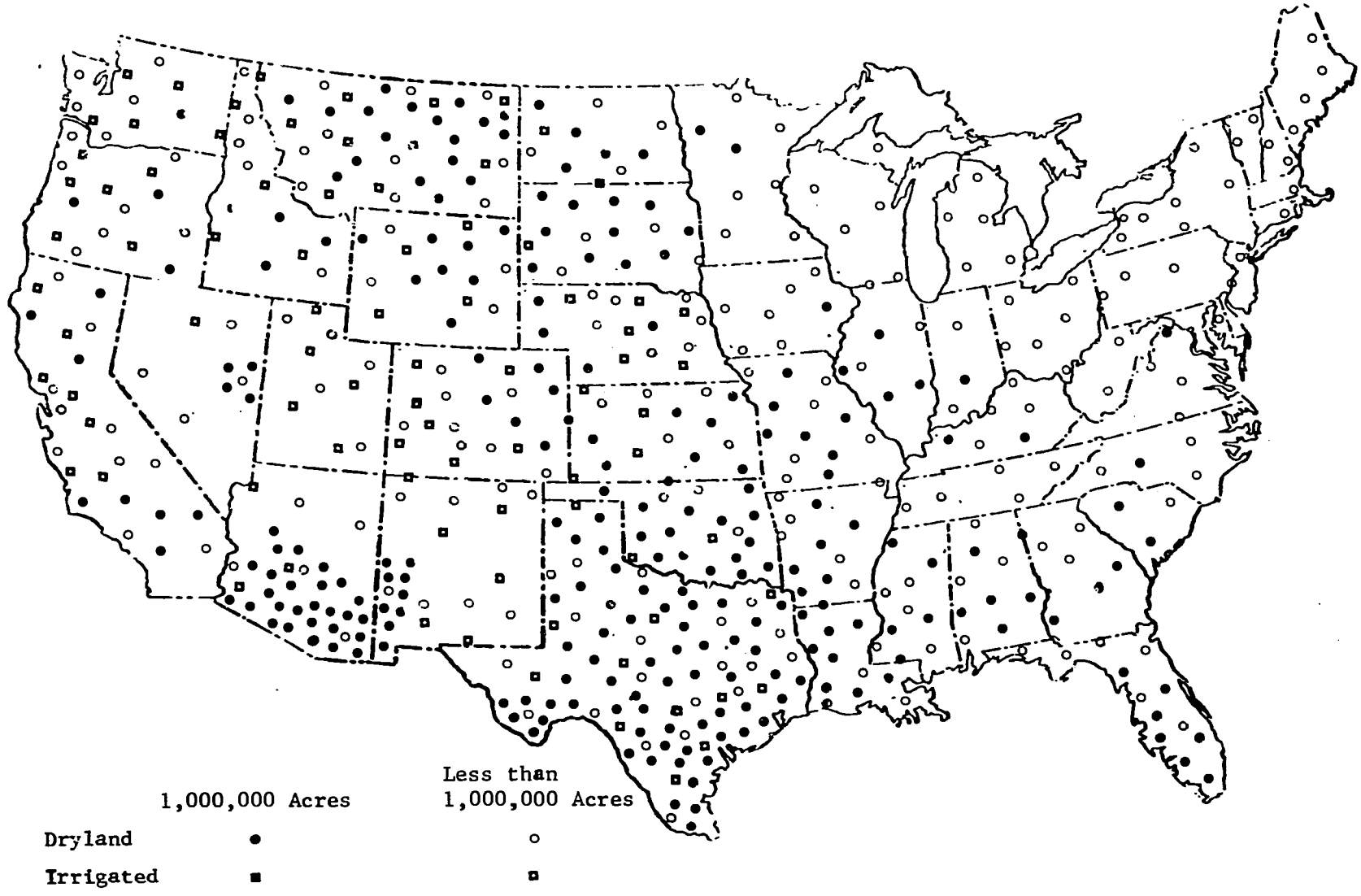

Figure 4.36. Location of dryland and irrigated pasture under Model F in 2000

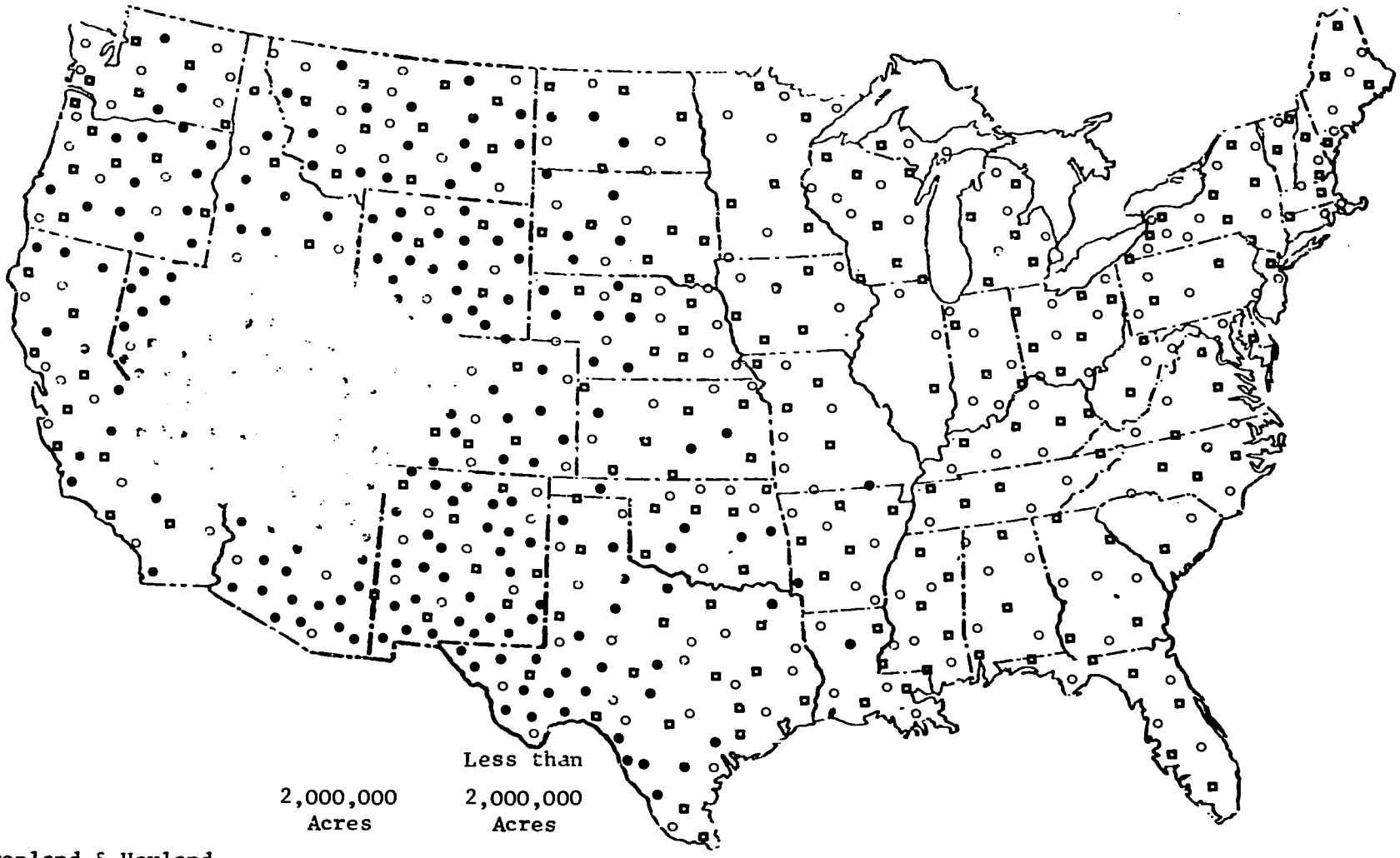

Figure 4.37. Location of fragile lands removed under Model F

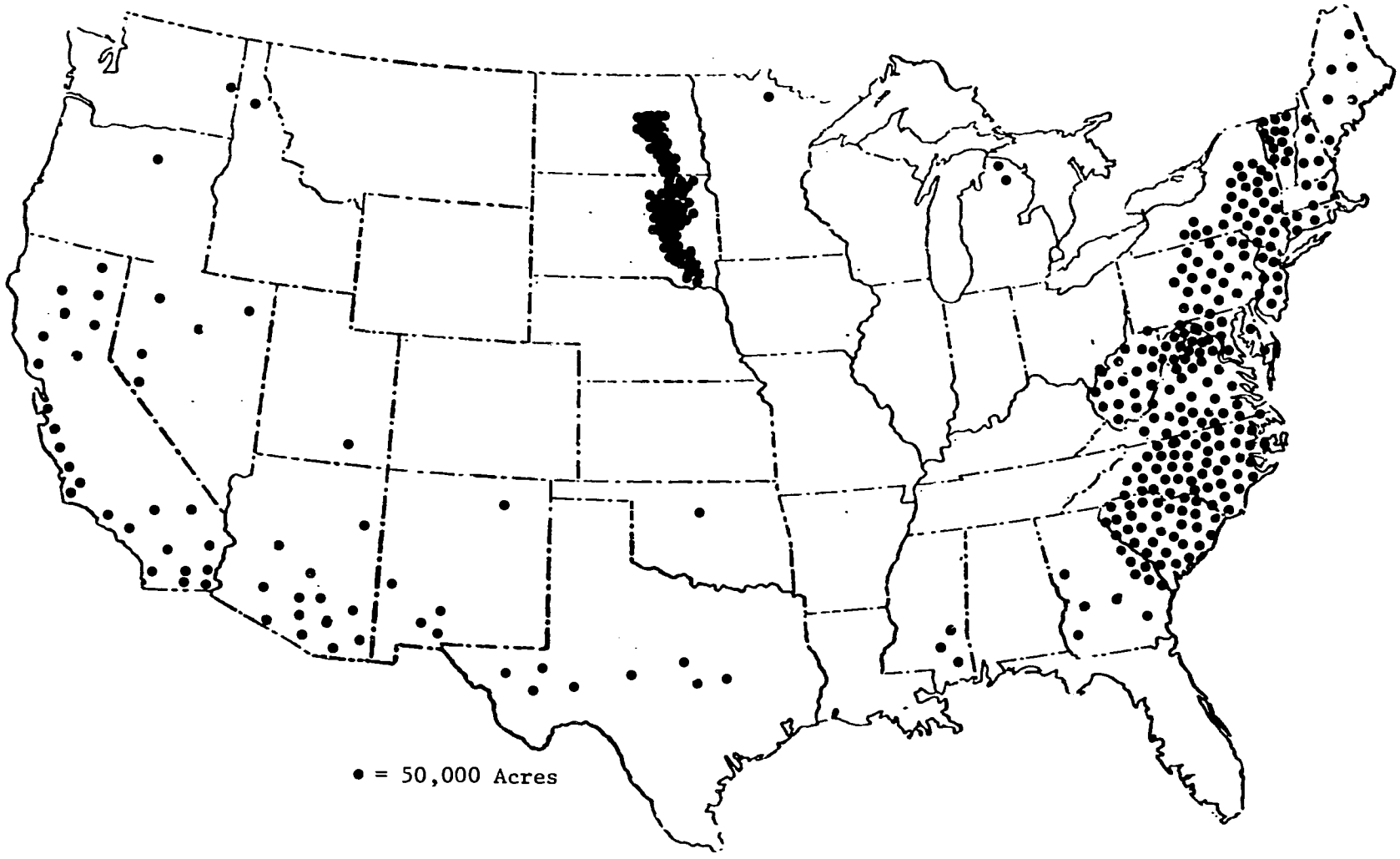

Figure 4.38. Location of unused land under Model F in 2000

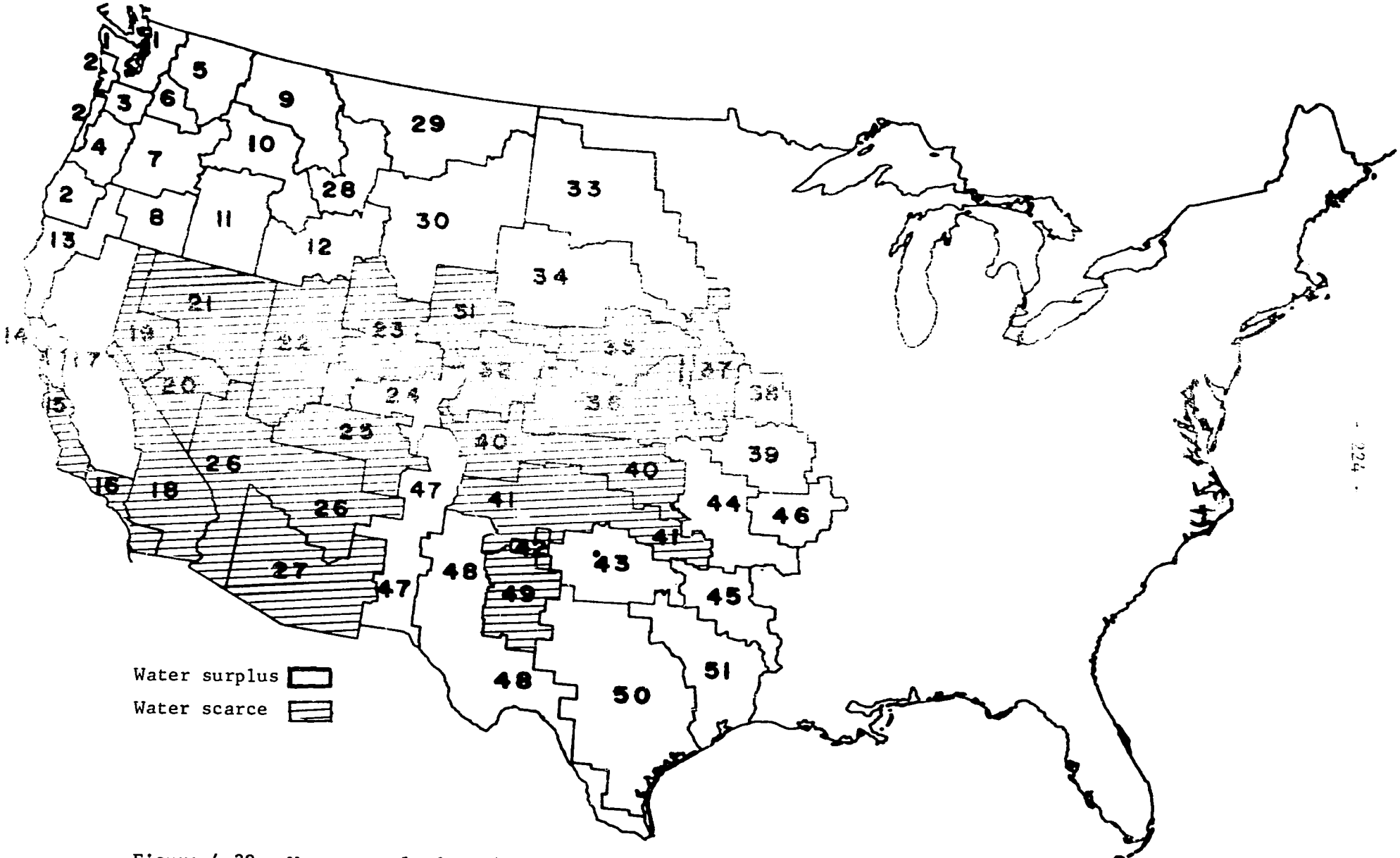

Figure 4.39. Water supply-demand balances under Model F in 2000

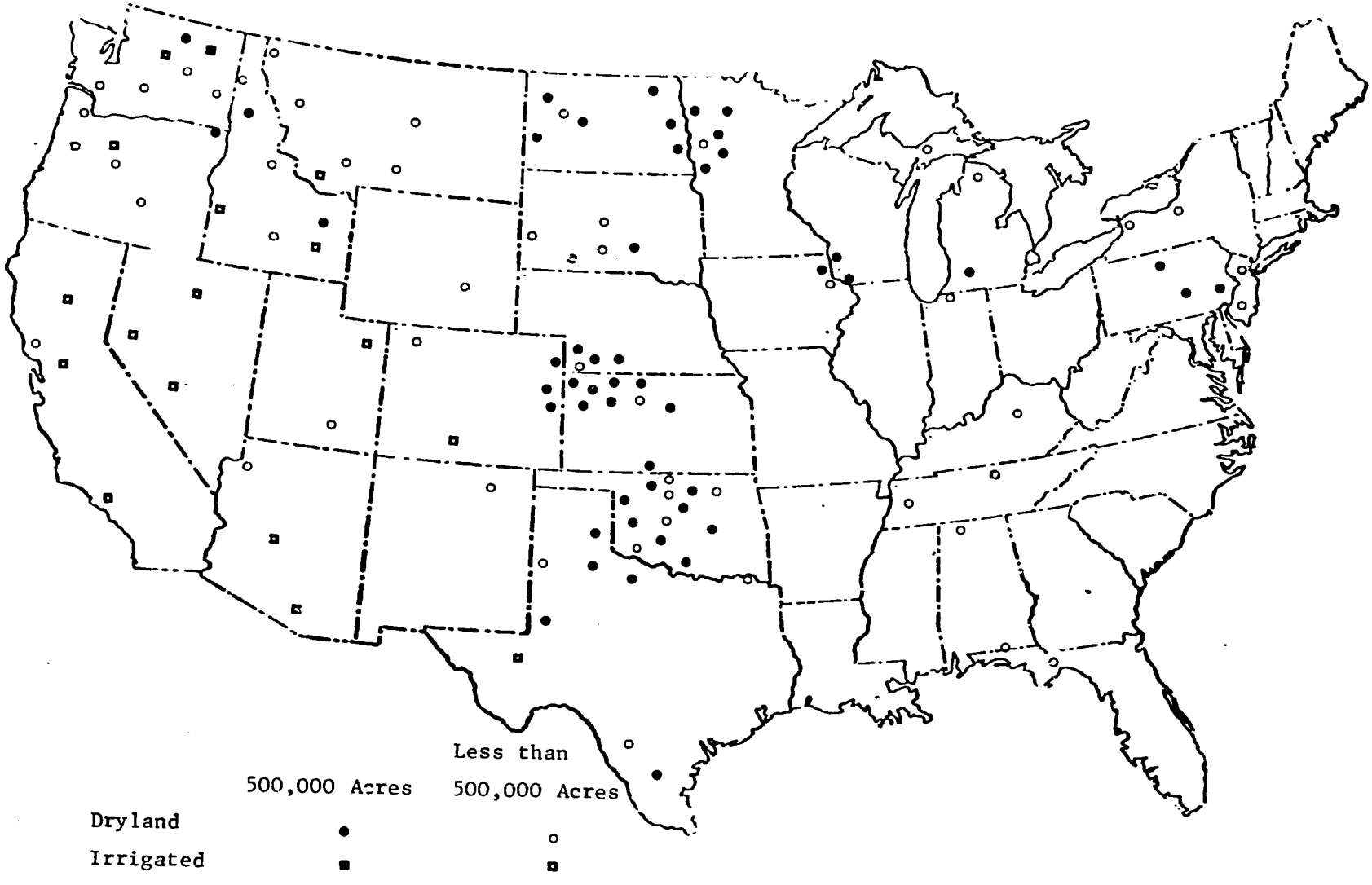

Figure 4.40. Location of dryland and irrigated wheat under Model C in 2000

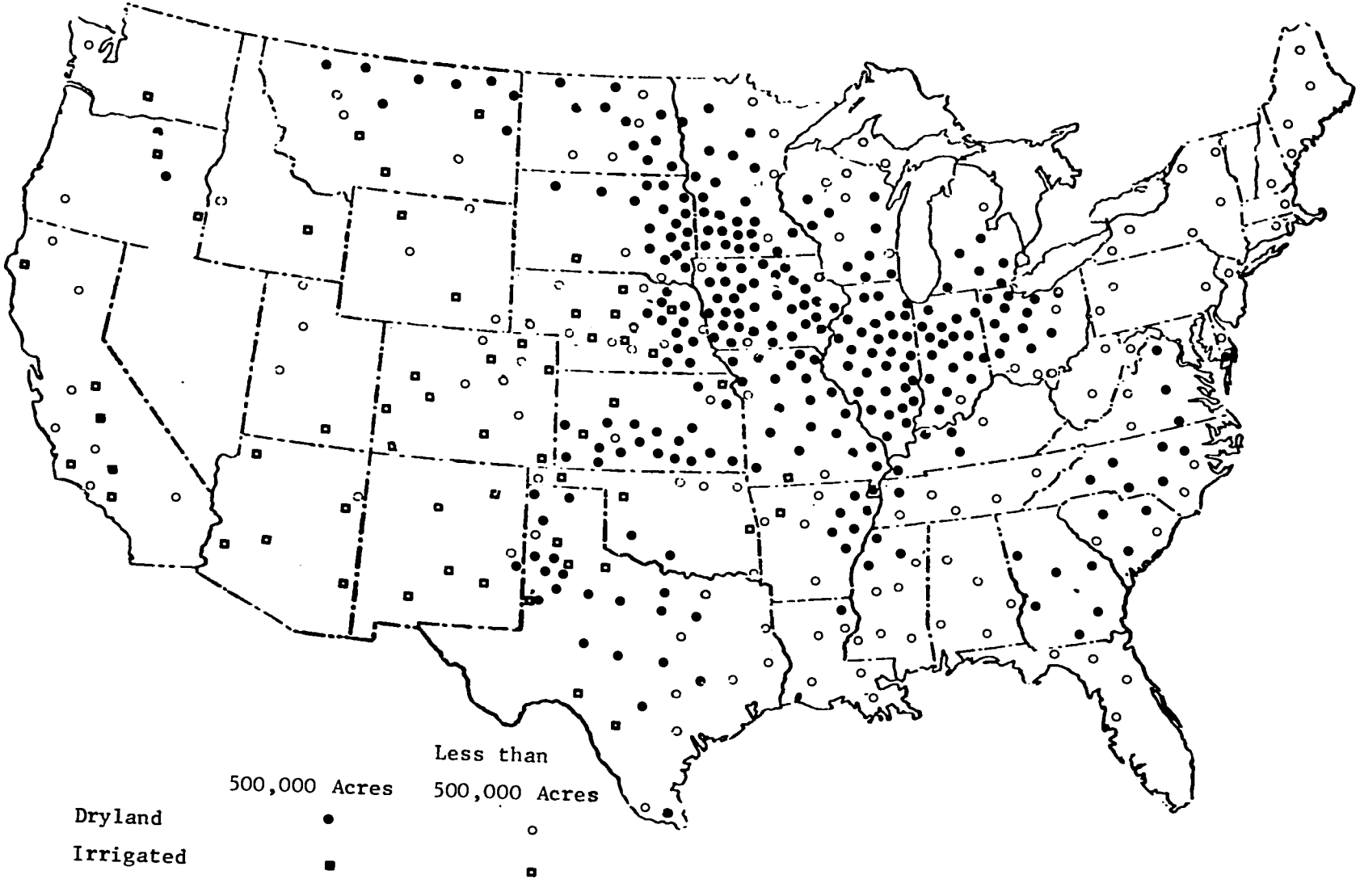

Figure 4.41. Location of dryland and irrigated feed grains and soybeans under Model C in 2000

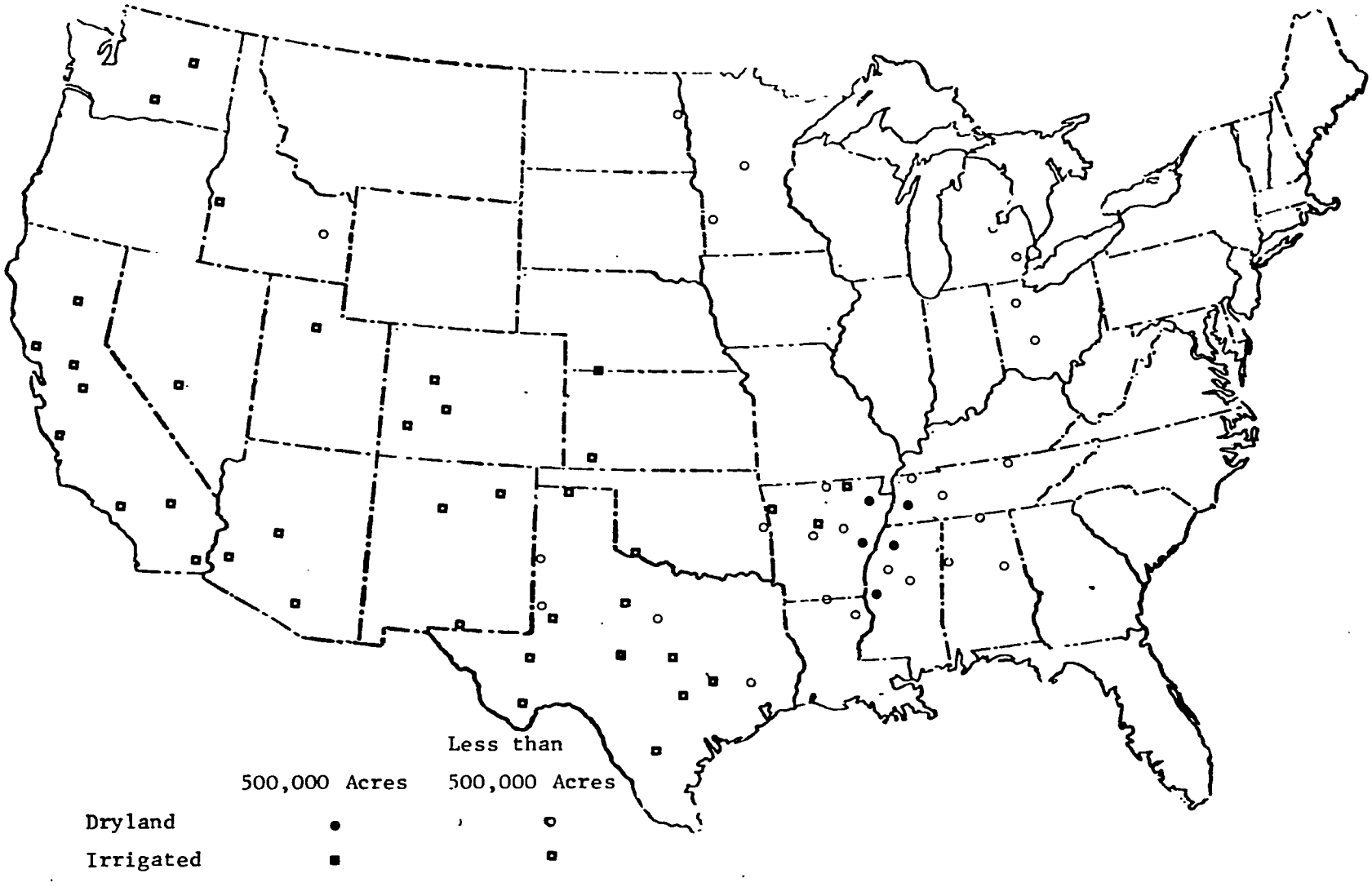

Figure 4.42. Location of dryland and irrigated cotton and sugar beets under Model C in 2000

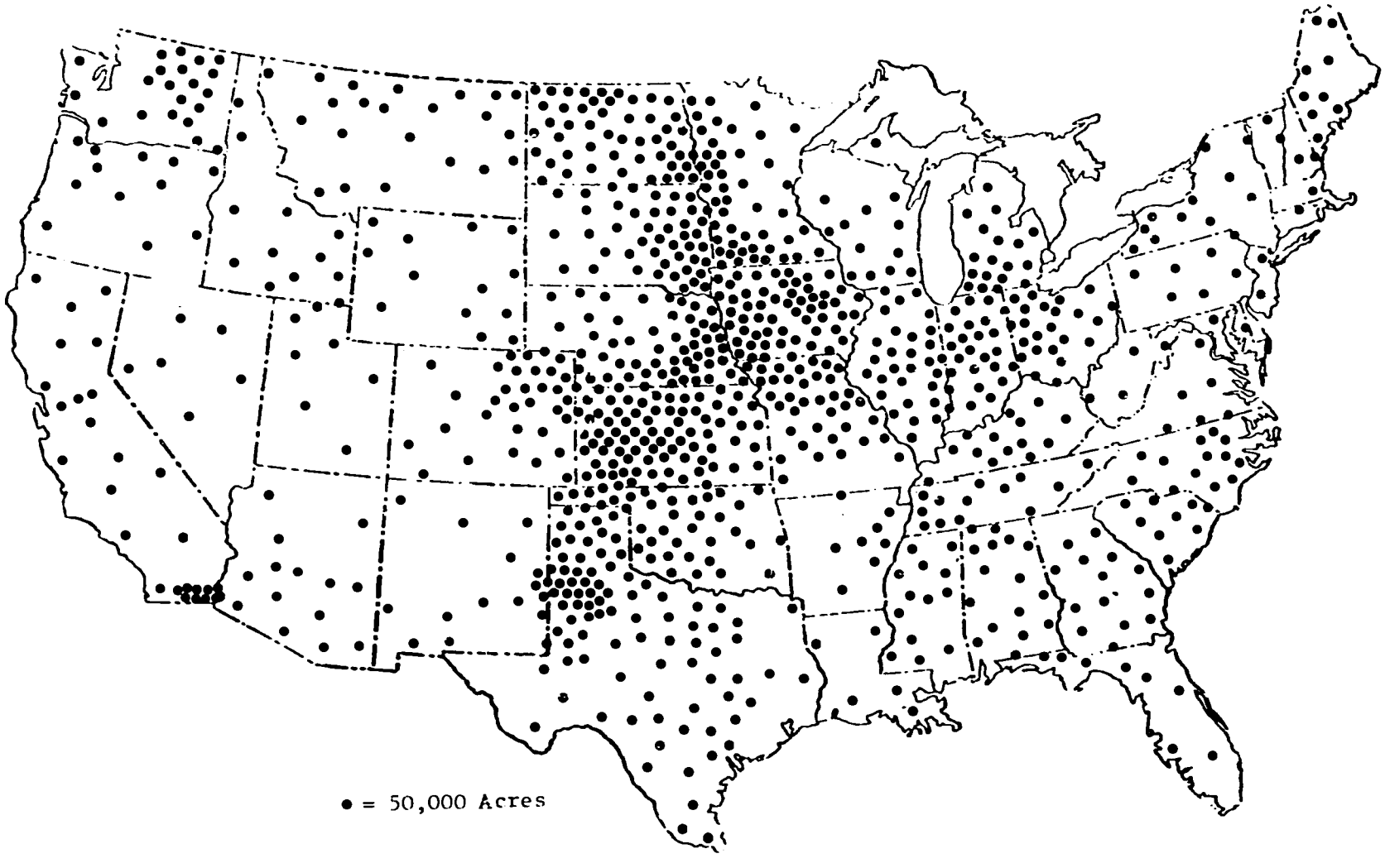

Figure 4.43. Location of unused land under Model C in 2000

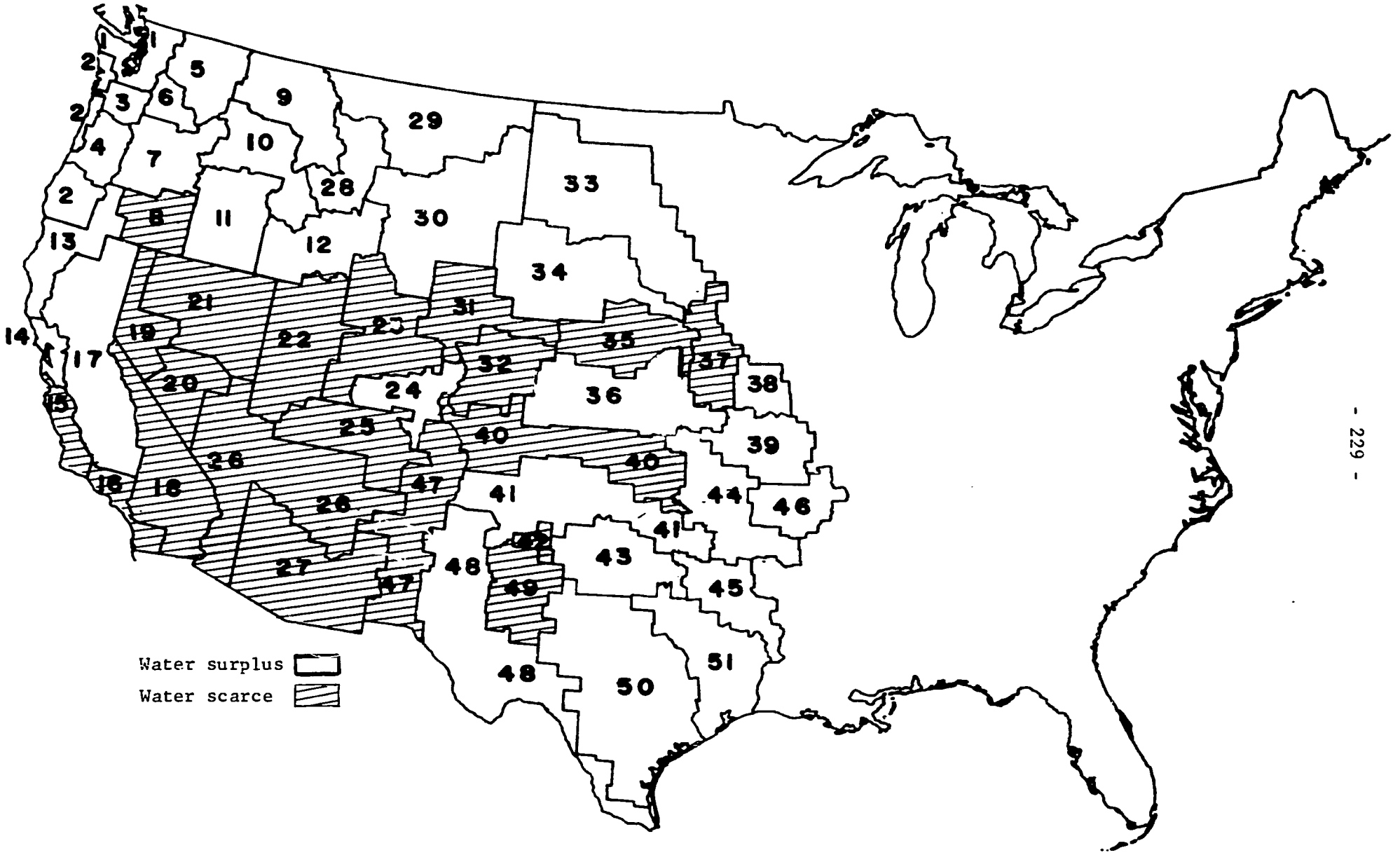

Figure 4.44. Water supply-demand balances under Model C in 2000

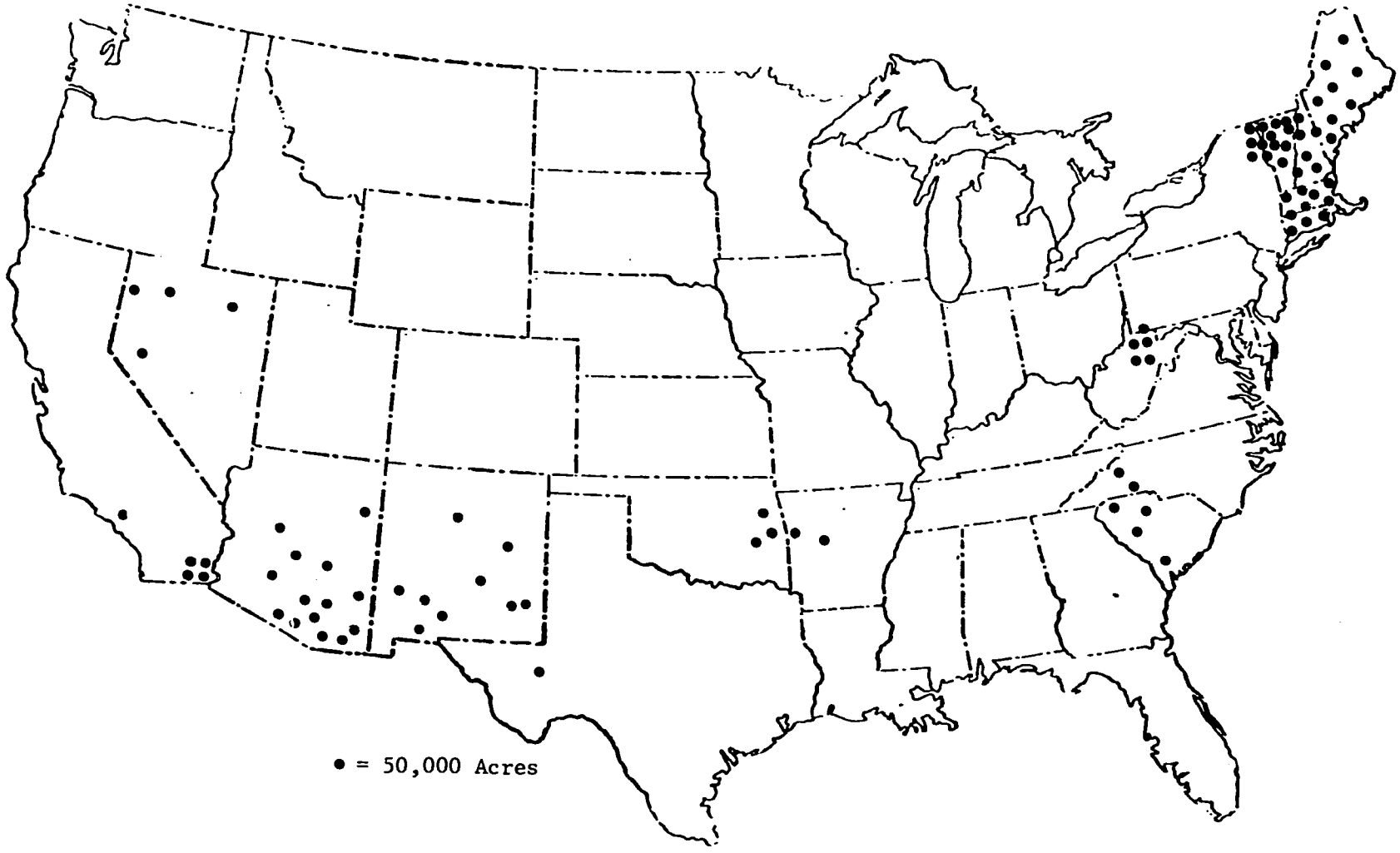

Figure 4.45. Location of unused land under Model D in 2000

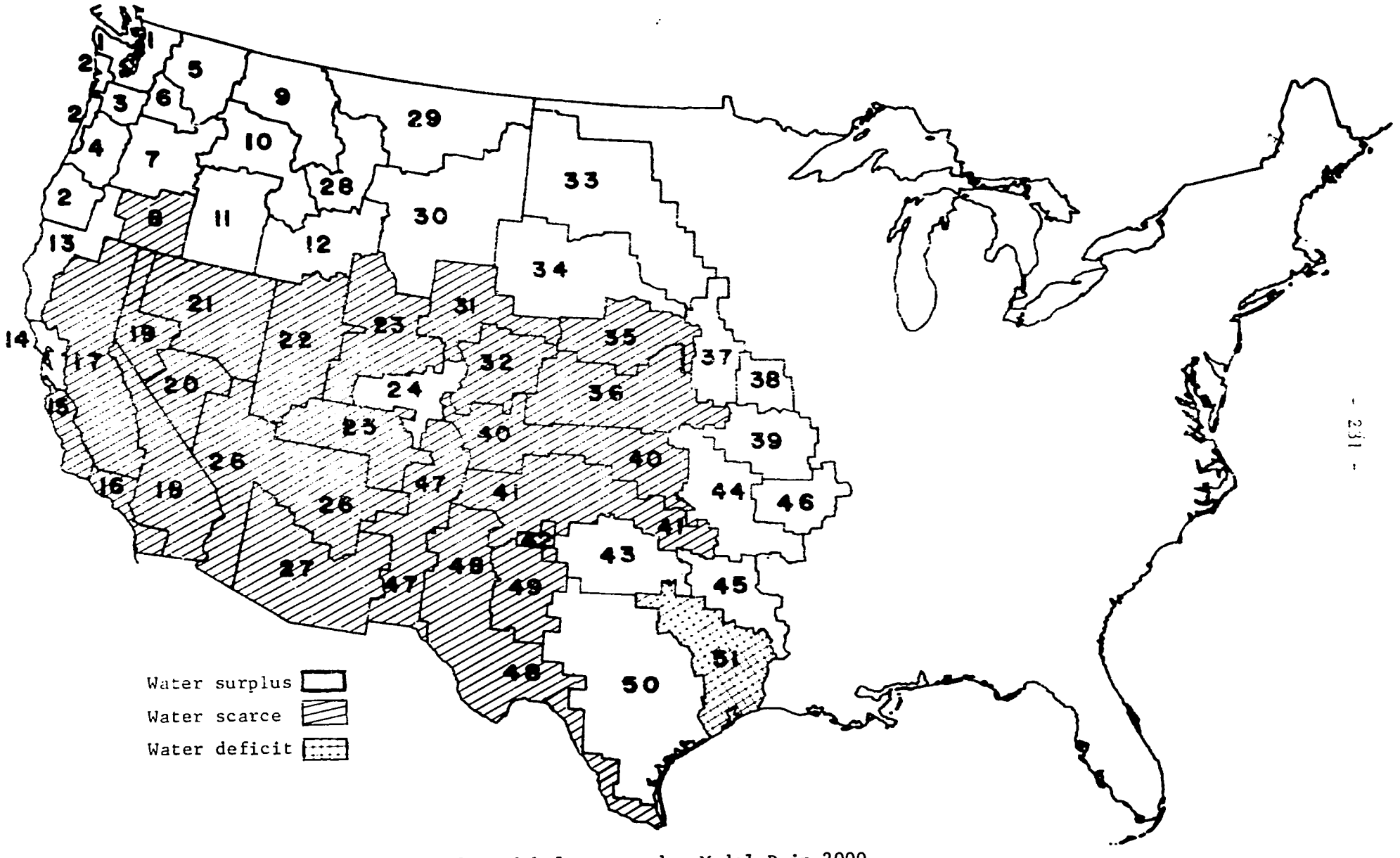

Figure 4.46. Water supply-demand balances under Model D in 2000

V. SUMMARY OF LAND AND WATER USE, LIVESTOCK PRODUCTION AND COMMODITY PRICES UNDER ALTERNATIVE POLICY MODELS

Projected land and water use under the nine alternative policy models are summarized in Tables 4.68 and 4.69 (p.179). Three things are evident from the results: (1) Land would not be a physically or economically scarce resource in 2000, although under Model D only 4.5 million acres of cropland and hayland remain unused.[1] (2) With a national objective function of economic optimum in food production and water and land use, such as the one employed in the policy models of this study, land irrigated in the West would be less than at present. (3) Relative to this objective function, water would be in surplus supply in the West under all policy models for the year 2000.

Land Use

For the nine policy models analyzed, total land used for all crops would be highest under Model D and lowest under Model F (Table 4.68). Total unused cropland and hayland would be lowest under Model D and highest under Model B. Under Model D, a high level of domestic and export demands for farm products is specified and only 4.5 million acres of cropland and hayland would remain unused. As noted in Part III, however, other researchers have estimated that from 50 to 150 million acres of new land could be brought into production if needed. The higher price levels resulting from Model D could encourage reclamation of these new lands. Total land used for all crops would be lowest under Model F because nearly 656 million acres of fragile lands are taken out of production. Under Model B, a low level of domestic and export demands for farm products is specified. Thus, 51 million acres of cropland and hayland would remain unused, and surplus capacity would approach levels of the 1961-71 decade. Projected farm prices also are low. Model C, the annual land retirement policy model, places part of the land base in retirement and farm prices would rise accordingly. With 300 million people in 2000 (Models A, A1, A2, and A3), 12.5 to 16.4 million acres of cropland and hayland would remain unused.

Compared with that in 1964, land irrigated in 2000 under the nine alternative policy models would range from 2.1 to 18.9 million acres less. Total irrigated acreage would be highest under Model C, the annual land retirement policy model, and lowest under Model A3, the $30.00 water price policy model. From 2.7 million to 15.0 million acres of land either currently irrigated or in authorized reclamation projects would be switched to dryland crop production in 2000. Some of this irrigable land also would be unused in 2000, mostly because of projected scarcity of water in some regions.

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[1]Unused refers to the amount of the land resource (cropland and hayland) not needed to meet the domestic and export demands specified for the year 2000.

A large amount of cropland either currently in land retirement programs or currently used for annual crop production would shift to tame hay production in 2000. Under Model C, only 2.7 million acres would be shifted because of the nearly 45 million acres of cropland in the annual land retirement program. Under Model A3, however, nearly 52.1 million acres of cropland would be shifted to tame hay production in 2000. Thus, a clear conclusion appears. Present land surpluses could substitute for future water and irrigated land development projects in agriculture.

The large projected increase in forage production and the resulting shifts of cropland to tame hay production are results of the large increases in projected numbers of beef cows and fed beef. In general, compared with current levels, beef cow numbers would more than double and fed beef numbers would nearly triple by the year 2000 (Table 4.70). The relationship between projected forage requirements and land surpluses can be illustrated by comparing Model A with Model B. Under Model A, with a population of 300 million, 16.4 million acres of cropland and hayland would remain unused. Under Model B with a population of 280 million, 51.0 million acres of cropland and hayland would remain unused. About one-third of the unused land under Model B would be located in the Missouri river basin, which includes part of the Northern Plains, and this land would be used mostly for tame hay production under Model A. Thus, projected land needs are highly sensitive to future food and fiber requirements, especially forage requirements for beef production.

Two environmental control policy models are analyzed in this study (Model E and Model F). Model E measures the projected impacts on land and water use and farm prices when insecticides are eliminated in corn and cotton production. Model F measures these same projected impacts when fragile lands are removed from crop production in attempts to improve the quality of air and water, vegetative cover, wildlife, etc.

As expected, when insecticides are banned in corn and cotton production (Model E), there is a smaller projected land (and water) surplus. But the reductions in land and water surpluses would be very small at the implied population and demand level. Even with the removal of nearly 656 million acres of fragile lands in 2000 (Model F), over 20 million acres of cropland and hayland would remain unused (Table 4.68). Since the fragile land removed is low yielding (primarily pasture), it could be replaced with a much smaller increased use of higher yielding cropland and hayland.

Water Use

Relative to the objective function employed, there would be surplus water in the West under all nine alternative policy models in 2000 (Table 4.69). As pointed out in the previous sections, however, the distribution of water supplies still could be a problem in 2000. The Lower Colorado, Great Basin and Rio Grande river basins most frequently appear as

regions of projected water scarcity. Under the 325 million population and the 300 million population policy models, the Texas-Gulf river basin would be water deficient. The deficit, however, could be solved through additional reservoir construction, since rainfall is plentiful in the region.

Agriculture was the biggest consumer of water in 1965 and our projections indicate that it will continue to be, even in 2000. But projected nonagricultural water requirements in 2000 are nearly four times larger than the 1965 level. Thus, there would be a relative shift of water consumption toward municipal, industrial and other uses by 2000. If nonagricultural water requirements projected for 2000 are underestimated, agriculture could release additional water for these other uses. With a $15.00 water price (Model A1), more than 11 million acre-feet of water per year would be released from agriculture. Thus, adoption of a pricing system for agricultural water use would release water from agriculture for other uses if needed.

Under the alternative policy models, total consumption of water in 2000 would be highest under Model D, with high domestic and export food and fiber demands, and lowest under Model A3, the $30.00 water price policy model. Under Model D, 42.0 percent of the total water supply would be consumed, while under Model A3, only 27.3 percent of the total water supply would be consumed. Thus, a large proportion of the water supply would be surplus, even with a maximum foreseeable level of food and fiber demand in 2000. With either a ban on insecticides in corn and cotton production (Model E) or removal of fragile lands from crop production (Model F), total water consumed would increase only slightly. Under all the policy models analyzed, the Columbia-North Pacific river basin always has the largest projected water surplus.

In summary, even with little further development of present water supplies, there does not seem to be an absolute water shortage in 2000. The distribution of the water supply, however, still could be a problem. In general, present land surpluses could substitute for future irrigated land developments, reduce pressures on water supplies and, hence, release plenty of water for increased nonagricultural uses in 2000.

Livestock and Poultry Production in 2000

Projected livestock and poultry production for three alternative policy models are reported in Table 4.70. Figures are not reported for Models A1, A2 and A3, since they are nearly the same as for Model A. Likewise, projected livestock and poultry production under Models C, E and F are nearly the same as for Model B.

The production of a specific kind of livestock or poultry is dependent on the level of population, per capita consumption, level of imports or

exports and the rate of technological advance. Thus, aside from beef cows, livestock and poultry production would be highest under Model D, with 325 million population and advanced technology, and lowest under Model B, with 280 million population and trend technology. The number of beef cows would be less under Model D because of the higher calving rate used under the advanced technology assumption.

The most significant change in projected livestock output under the policy models analyzed is the large increase in beef production. Of course, this increased production is a result of higher per capita consumption of beef and veal in 2000 discussed in Part III (Table 3.8). With higher levels of both per capita consumption and population in 2000, beef cow numbers would more than double over the 1969 level. Fed beef would nearly triple in number by 2000 under Model D with a 325 million population. The higher projected beef production in 2000 is reflected in the crop-feed requirements and resulting acreages and water use discussed in the previous sections of Part IV. Both beef cows and fed beef use large quantities of forage. As a result, the increased land which would be needed for concentrates and forages and the much larger exports under Model D would leave only 4.5 million acres of cropland and hayland unused in 2000 (see footnote 1 for definition of unused).

Under Model A (300 million population), 16.4 million acres of cropland and hayland would remain unused. Model B, with 280 million population, would require about 10 million acres less land for forages as compared with Model A. As much as 51.0 million acres of cropland and hayland would be left unused, however, under Model B. Thus, the projected level of future forage requirements can have an important role in need for or the formulation of water and land policies, especially since a large percentage of irrigated land would be used for forage production (about 40 percent in 1959; 185).

Crop and Livestock Prices in 2000

Farm commodity prices projected under the nine policy models are summarized in Table 4.71.[2] In general, prices would be (a) lowest under Model B because of its smaller population and (b) highest under Model D because of its large food and fiber demands. Both Model B and Model D are free market policy models, and production would be allowed to concentrate in areas of greatest comparative advantage. Some prices under Model C would be higher than those under Model D. Model C incorporates supply control features to disperse production throughout the United States to restrain output and increase prices (and also force a substitution of water in the 17 Western states for land in the East). More marginal and lower-yielding areas would

[2]The commodity prices reported in Table 4.71 are the shadow prices for commodities determined by the programming model. These shadow prices are available for each of the 27 consuming regions, but only national averages are reported here. The lower prices for hogs indicate that hog production costs may be underestimated in the programming model.

be brought into production under both Model C and Model D, and prices would rise accordingly.

Farm prices under Model A would be nearly the same as 1969 actual prices for corn grain, soybeans and hay. They would be higher for cattle and calve , barley and oats, but lower for hogs, milk and cotton. The higher projected prices for livestock and livestock feeds can be explained by increased demand for livestock, especially beef and veal. Although the average price received for sugar beets is not available for 1969, the price under Model A would be only 40 to 50 percent of current levels in some states. Thus, those products that have "tight" controls over production (sugar beets, cotton and milk) could have lower prices in the future (as well as the present) in the absence of production controls or marketing quotas. Even with the large increase in food and fiber demands under Model D, prices of these "controlled" products would not exceed current levels in 2000. These are products for which competitive substitutes may be more widely used. Imports and domestic cane are substitutes for sugar beets. Synthetic fibers have already captured a large part of the market for cotton. Dry milk, soybean milk, margarine and dairy imports already have an adverse effect on the market for fluid milk. (The impact of soy substitutes on future meat consumption is not evaluated in this study.)

Results from Model A3 indicate that 36.2 million acre feet of water could be released from agriculture annually for other uses in 2000, if the minimum water price were increased from present levels to $30.00 per acre foot. Generally, if such a policy were adopted farm prices would rise by about 10 percent. But cotton, sugar beets and milk prices would still stay below current levels. Under Model B, however, a free market and the 280 population level, farm commodity prices generally would be even lower than in 1969. Except for cattle and calves, most commodity prices would be around 18 percent lower than under Model A and about 18 percent below the 1969 level. Thus, policy makers might consider a price support program to increase farm prices. Under Model C, a geographically-dispersed land retirement program, farm prices generally would be more than a third higher than in 1969 and over 50 percent higher than under Model B.

With a ban on insecticides in corn and cotton production (Model E), projected prices do not increase significantly from Model B. Thus, the costs to society in terms of food costs and resource use would not increase substantially under Model E. But the detrimental effects of some insecticides on the environment could be reduced. The quality of the environment also could be improved with removal of fragile lands from crop production (see earlier definition of fragile). Under Model F, the fragile lands policy model, prices would be about 12 percent higher than under Model B, with the same population and aggregate levels of domestic and export demands. In general, under the higher demands of Model D, prices of crop commodities would be about 50 percent higher and livestock prices about 12 percent higher, than those under Model A.

In summary, farm prices under Model A would not be significantly higher than at the present. Under Model B, they would be substantially lower and under Model C and Model D, they would be substantially higher than in 1969. Thus, consumer food costs would not rise significantly under any of the policy models based on a C population level. They would decline under the D population level of Model B, but would rise substantially under the supply control features of Model C or the high level of domestic and foreign demands under Model D.

Differences in projected net farm income among the policy models and the present, including the free market of Model B, would parallel those of prices and food costs. Net farm income in 2000 would be lowest under Model B and highest under either Model C or Model D depending upon the level of government payments under Model C. In addition to the higher food costs under Model C, government payments also would be required to insure farmer participation. Thus, not only would consumers pay more for food, but also taxpayers would contribute to farm income through price support and land diversion payments. Prices about 12 percent higher than Model B could be obtained with relatively low levels of government payments by removal of nearly 656 million acres of fragile land (Model F). Most fragile land in the nation already is owned by the government (Bureau of Land Management permit and lease lands and Forest Service lands). Government payments to take other fragile lands out of production would not be substantial.

A number of studies have indicated the effect on farm prices and incomes of removing all production controls (e.g., 46). In general, conclusions are that aggregate net farm income initially would drop by as much as 40 percent in the sudden turn to a free market. After a period of adjustment, farm prices would rise again, but aggregate net farm income still would remain from $4 to $5 billion below comparable levels under land retirement programs of the type in effect.

VI. POLICY IMPLICATIONS

The results of this study, based on conservative yield trends, indicate that U. S. agriculture should not be faced with aggregative strains on food-producing capacity and water supplies relative to needs in the year 2000. Rather, the projections suggest that, even by 2000, U. S. farmers still could be faced with a large supply capacity relative to food demands. Farmers in specific locations and operating under particular agro-climatic conditions will continue to be faced with depressed yields due to limited rainfall and ground water or stream flows. Relative to projected demand and food supplies, however, there should not be an aggregative food supply problem for the nation.

The study indicates that even if the irrigated area is not increased over the next 30 years, capacity of American agriculture will be sufficiently large to extend potential depressed prices and incomes to the year 2000. The term "depressed" refers to real prices compared to levels being realized through the supply control and price support programs financed from the U. S. Treasury. If the full supply capacity projected for the year 2000 were used in the absence of government programs, real prices would be lower than those realized by farmers in recent years. The level of farm income in 2000 under any level of prices also will depend on the number of farms existing at that time and the prices paid for farmland (and hence, on the number of acres farmers with given investment funds can operate, the amount of interest paid on credit for land investment, etc.).

The study results also indicate that projected food demands in 2000 could be met by returning land now idled under government programs to production and by using less irrigated land than at the present. If the U. S. had a 300 million population in the year 2000 (Model A), projected food demand could be met with 11.3 million acres less irrigated land than in 1969, with 5.3 million acres of cropland (including that now withheld from production by government supply control programs) remaining out of production, with 7.3 million acres of irrigable land switched to dryland production and with 49.3 million acres of cropland shifted to less intensive uses such as pasture and hay. Under a 280 million population (Model B), 12.5 million acres less of irrigated land would be needed than in 1969, 25.6 million acres of present cropland could remain idle, 7.6 million acres of irrigable land would be switched to dryland production and 42.8 million acres of cropland could be shifted to less intensive uses. With a 325 million population in 2000 (Model D), but also with higher levels of exports and advanced technology, food and fiber demands could be satisfied with 9.9 million acres less of irrigated land than in 1969, with 1.4 million acres of present cropland idled, with 6.8 million acres of irrigable land switched to dryland production and with 21.0 million acres of cropland shifted to less intensive uses. (These are the aggregative patterns which optimize national food production for the demand and implied price levels

of this study.)

Hence, in the case of future water scarcities, especially in the West, agriculture need not use more but actually could release a fairly large supply of water for industrial and urban uses. As study results indicate, if the price of water were increased to $30.00 per acre foot as a minimum for the 17 Western States, this would allow release of an additional 36.2 million acre feet per year from agriculture compared with Model A (with crops reallocated among producing areas of the nation in a manner consistent with the objective function of the programming model employed at the 300 million population level). Clearly then, if the value of water in nonfarm uses specifies it, water could be released from agriculture to uses in other sectors and locations. This transfer of water from agriculture to other uses would not put pressure on the nation's food supplies or export possibilities. Neither would it have other than minimal effects on the cost of food to the nation's consumers.

Alternatives and Options in Policy

If the major objective of public agricultural policies were to attain specified national minimum farm price levels and income at minimum treasury cost, the present policy mix of (a) supply control measures and (b) continued investment in irrigation would be highly inconsistent. Each increment in public irrigation investment and improved water use is effectively linked with a parallel increment of public expenditure to control supply and lessen output. In other words, the increase in yields and production forthcoming from further irrigation development requires expenditures to induce farmers at other locations to retire land to offset the increased output in the newly irrigated area. To the extent that these increases and decreases in output at different locations cancel each other, the public must pay twice to hold supply at a given level; once to increase production in the newly irrigated area and once to reduce it in nonirrigated areas.

If the public employed a criterion of minimum public costs to maintain given nationwide levels of farm prices and income, a recommendation of minimal water development and use would prevail: further public investment should not be made in irrigation development. Under this restraint, farmers on potentially irrigable land would make no absolute or actual sacrifice in income and capital values. Also, the public would not be faced, as it has in the past, with expenditures for supply control on both irrigated and nonirrigated land to offset the added production forthcoming from newly developed irrigated land.

Interactions of Water and Agricultural Policies

As indicated in Part I, the dominant increase in water use and irrigated acreage over the last 30 years has been through private investment,

especially by individual farmers in wells and irrigation systems based on groundwater supplies. Individual farmers have made these investments because they have been profitable. In this sense their decisions and actions have been exactly the same as for farmers producing under rainfed conditions who have added more fertilizer, pesticides, improved varieties and better livestock rations. In terms of proportion of total farm output, the latter group is even more responsible than the former group for the large supplies which press heavily on prices in a market environment of very low price elasticities of demand. Federal supply control and price support programs which offset supply increments due to use of more inputs and improved practices encourage the farmer with profitable water supplies available to him to develop them. Similarly, these programs make it profitable for farmers in the Corn Belt, Southeast and elsewhere to use more fertilizer, pesticides and improved strains and rations. Because of the greater cropland acreage involved, even the subsidization of inputs through SCS technical aid and ASCS payments increases output as much or more for rain fed agriculture than for irrigated farming. In both cases, the individual farmer makes investments and uses public aids because it is profitable for him to do so. When the majority of farmers do so, the inelastic demand causes market revenue to decline because prices fall by a greater percentage than output increases. Federal supply control, price support and international food aid programs have been initiated to offset these mass market effects of actions of individual farmers as the agricultural sector develops further. It is no more appropriate to claim that these federal programs are needed to offset the effects of farmers who increase output through their own irrigation investments than it is to claim that they are needed for farmers depending on rainfall who use more fertilizer, pesticides, machines, high-yielding varieties and improved additives for livestock rations. Neither is it any more appropriate to suggest that profitable development or irrigation by individuals should be restrained than it is to suggest that fertilizer and similar input restraints should be imposed on farmers who depend on rainfall. True, farmers do invest in irrigation which produces more, then receive direct government payments to leave land idle so that supply will be reduced. But on an even broader geographic and volume basis, farmers apply added fertilizer and other modern inputs so that each acre produces more, then idle part of their land upon receipt of public payments.

Some land idled under government supply control programs is irrigated land served through federal projects. Howe and Easter suggest that the total cost of land retirement and price support for publicly-served irrigated land could have been as high as $350 million in 1964. (25, pp. V-14 to V-20). It is in this sense that two public investments that cancel each other arise; one to develop irrigation which increases output, then supply control programs which reduce output. However, even considering public funds involved per se for agriculture over the past 40 years, these investments for irrigation may be less important than other public involvements which initially result in augmented farm output then provide direct payments

to farmers for idling land to reduce output. For example, the public invests heavily in research and education to promote improved practices and greater input use in the 31 states east of the Missouri River which depend mainly on rainfall. Then, to offset successful effects in increased productivity it implements the complex of supply control, price support and demand-augmenting programs previously mentioned. Data are not available to show how much the public must pay through commercial farm policies to offset the increased output resulting from a dollar of public investment in (a) irrigation projects on the one hand and (b) general agricultural development (research, education, credit facilities, subsidized nonwater inputs, etc.), on the other. Through programs that increase productivity in the one case and that restrain supply and bolster prices in the other case, farmers have been able to improve efficiency, reduce the real cost of food to consumers and simultaneously retain some of the benefits through their contribution to technological and economic development.

Public investments in irrigation and general agricultural development thus relate similarly where both have a positive net benefit/cost ratio or marginal payoff to society. There is no logical basis for sorting one out more than the other for restraint. More important for this study are the prospective demands for water in nonfarm uses relative to future food demand and the real price of food. This study indicates clearly that the availability and productivity of natural resources for agriculture are sufficiently large that some water could be shifted to municipal and industrial uses, should economic development and water demand in western states specify it, by 2000. Land now immobilized through federal supply control programs can be substituted for water so diverted and the productivity and supply capacity of American agriculture will remain high. In fact, from the results of this study, even with some reduced water use for agriculture, the supply capacity still could be so great relative to domestic demand in 2000 that problems of food more nearly will revolve around low prices and incomes of farm producers, rather than around high real prices and strained budget outlays for consumers. Currently, American families spend only 17 percent of their disposable income for food. Since the greatest proportion of this expenditure is for the packaging, processing, freezing and other services incorporated with food after it leaves the farm, the food product in the farm form leaving the agricultural producer absorbs less than 7 percent of the American consumer's disposable income. The percentage could be considerably lower by the year 2000 as per capita incomes increase and the large agricultural capacity identified in this study is attained even with some diversion of water from agriculture.

The discussion above has been of federal irrigation projects which have positive net benefit/cost ratios or marginal payoffs. Given the total supply or productive capacity projected for agriculture in this study, the implementation of federal irrigation projects that do not have positive net payoffs, or that have high opportunity costs in the returns foregone in other uses, should not be implemented in behalf of national agriculture.

The potential water supplies so implemented could more readily be economically justified for municipal and industrial uses with population and economic growth at particular locations, than in agriculture which is part of a national supply complex with the prospect that large production capacity in 2000 is more likely to cause surplus potential than domestic food shortages.

Distribution and Compensation

Should population and economic activity grow beyond projected levels for 2000 at particular locations, causing nonfarm uses of water to have a greater value productivity than farm uses, diversion of water supplies from agriculture for these purposes would have distributive impacts on income and employment of rural communities using water from publicly developed projects or through water rights of historic origin. Incomes of farmers and communities from which these water supplies and rights were withdrawn would suffer economic losses and communities and urban centers realizing a larger water supply for municipal and industrial uses would gain in economic activity and employment generated. In terms of equity, the diversion of income and capital values from one location and economic group to another or the potential diversion of water from agricultural to municipal and industrial uses is of the same sort as a revision of public irrigation and commercial farm policies, as outlined previously, that benefit one group at the expense of another.

In areas of long-established water rights and publicly-developed irrigation projects, these water supplies made available to farmers have become property with capitalized values based on greater streams of income over time. Also, the greater volume of trade and employment generated in these communities from water inputs and increased agricultural output serves as the base of definite capital values in the nonfarm sector of the rural communities involved. The value placed on these property rights and the nonfarm capital values are economic quantities justified in terms of public laws and investments and the economic outlook and forecast information available in past periods to farm and nonfarm investors in the particular water supply regions. To erode these income streams and capital values through a transfer of water to other locations and uses would not per se guarantee an increase in aggregative societal welfare due to the income loss required for one sector to bring gain to another sector. Inability to make quantitative comparisons of the relative magnitude of utility and welfare gains and losses prohibits any such simple arithmetic.

However, means do exist for transfers which guarantee that the sector from which water supplies are diverted does not sacrifice for the gains of the recipient sector. Various forms of compensation can be used to guarantee a positive-sum outcome over both the losses of the farm and nonfarm enterprises in regions from which water is diverted and the gains in the other locations and uses to which it is transferred. This compensation would need to cover the discounted value of future income which erodes as

water supplies and rights are withdrawn. A basic amount involved is the expected decline in asset values associated with reduced availability of water and withdrawal of rights in irrigated regions. But other social values and losses also are implied. These include social costs attached to reduced employment, population thinning and the decay of community facilities as the economic base resting on water is withdrawn.

Pricing and Quality of Water

This study provides quantitative results which can serve a partial basis for farm compensation associated with reduced water use. The shadow prices attached to water and land under different variants of the programming model serve in this manner (Appendix G). With further analysis, the reduction in shadow prices associated with a shift from the current structure of water uses and returns in agriculture could be compared, area by area and region by region, with that resulting from a pattern needed to provide future municipal and industrial transfers. Capitalized, these decrements in shadow prices approximate the capital values for which farmers, now benefiting from water supplies and rights supplied through public investments and legal institutions, should be compensated. The magnitudes so represented do not, however, reflect compensation appropriate for the nonfarm sector of rural communities where economic activity is reduced or population shifts and decay of local institutions induce social costs.

Supposing implementation of appropriate compensation means to safeguard against welfare reductions in these communities, alternatives also exist through which water can be diverted from agriculture and increased in supply to municipal and industrial uses at indicated locations of water scarcity in 2000. An abrupt procedure, of course, would be that of legislating outright withdrawal of water rights from farmers in the water supply region of relevance. Another procedure with greater economic justification is a pricing system orienting water use toward the highest value alternatives in municipal, industrial and farm uses. This pricing mechanism also could allow the public to recover fully its investment in water supply development so that both (a) those who benefit from its value productivity eventually pay the associated costs and (b) the public capital so restored can be invested repeatedly in further augmentations of water quality and quantity where they have positive net benefit/cost ratios exceeding other public alternatives.

Assuming a 300 million population without government program restraints, instituting a water pricing system and increasing the price from $15.00 to $22.50 per acre foot of irrigation water would reduce total irrigated land (and hence water use) in the 17 Western States by 5.5 million acres. Concurrently, 3.1 million additional acres of annual crops (including corn and sorghum silages) would be grown on nonirrigated land. Also, 3.5 million additional acres of all hays and pasture would be grown on nonirrigated land. Increasing the water price further, from $22.50 to $30.00, would

reduce total irrigated acreage by an additional 4.8 million acres and increase all crops grown on nonirrigated land by 3.7 million acres. In comparisons between the lowest price, $15.00, and the highest price, $30.00, for water, the acreage of annual crops (including corn and sorghum silages) grown on irrigated land would decline by 72.4 percent. Hence, the pricing of water not only would alter its allocation among agricultural, municipal and industrial uses but also would bring about reallocations within agriculture. Water could still be used for irrigation but its concentration would be on high value crops. Much less would be employed for lower-return uses such as pasture and hay production. For example, of the total water consumed by all crops with a water price of $15.00, about 70 percent is consumed by hay and pasture. With a water price of $30.00, hay and pasture consume about 50 percent of the total. As identified by this study, water supplies not only are large enough to allow ready attainment of projected food demand at reasonable real costs but also to allow some diversion of water to municipal and industrial uses at the scattered scarcity locations based on projections for 2000. Pricing and compensation means prevail whereby these reallocations can be attained with gains to some population and locational groups without sacrifice to others.

Agricultural Policies and the Environment

With 280 million population in 2000, attempts to improve the quality of the environment would not place undue stress or strain on the productive capacity of agriculture. With a ban on the use of insecticides in corn and cotton production (Model E), the use of cropland and hayland would increase by about 3 million acres. Land irrigated and, hence, total water consumed also would increase slightly. Farm prices would rise only slightly.

With nearly 656 million acres of fragile lands removed from crop production (Model F), cropland and hayland used would increase by about 30 million acres. Total irrigated acreage would remain unchanged but total water consumed would increase slightly. In general, with fragile lands removed, farm prices would rise about 12 percent over the comparable prices with fragile lands still in production. Government costs of removing these fragile lands from production would not be great, since a large amount of this land already is owned by the government.

Thus, policies adopted to improve the quality of the environment would lead to higher farm incomes. Not all areas of the country, however, would gain from such policies. With a ban on insecticides in corn and cotton production, farmers in areas of the nation susceptible to severe damage from insects would be forced out of production. In areas of the nation where the insect population was very low or nonexistent, production of either corn or cotton or substitutes for these crops would increase. Businesses in rural communities would be similarly affected. It would decline in areas that cease, reduce or extensify production and increase in areas with higher levels of agricultural production.

Removal of fragile lands from crop production would have a bigger impact on agricultural land and water use and farm prices than a ban on insecticides in corn and cotton production. Currently, most of the fragile lands in this nation are used for extensive types of crops such as dryland pasture and dryland wild hay. Thus, those areas with agriculture structured around these crops would face the most severe adjustment problems with these lands removed from production, especially farmers in areas of the nation depending on grazing from public lands. Other areas of the nation would gain as additional cropland and hayland were brought into production to replace the output from these fragile lands. Some areas of the nation would reduce acreages of annual crops and increase acreages of forage or more extensive crops.

The negative effects, however, of such a program both in those areas that suffer losses and nationwide are potentially less than under alternative types of programs. A program to remove fragile lands from crop production would reduce wind and water erosion and have other positive effects on the environment. Siltation of streams and reservoirs could be reduced, the air would be cleaner, etc. Those areas with large amounts of fragile lands already are structured around an extensive agriculture and adjustments would be less than if these same areas were structured around an intensive agriculture. Conceptually some of this fragile land could be devoted to recreation, trees or other uses. Hence, certain areas would not be faced with elimination of all economic activity and certain areas might even experience a gain.

The supply capacity of agriculture would be reduced by such a program, but a considerable slack still would exist. With such a program, however, farm prices and incomes would be higher than if these lands were to remain in production at the implied demand level. And since the government already owns a large amount of the fragile lands in the nation, the government costs of the program would be less than for alternative types of price support and supply control programs.

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VIII. APPENDICES

Appendix A. Exogenous Crop Production

Projections of the national demand for fruits, nuts and vegetables are based on a 1967 study done in California (12). This study also provides projections of the acreage, yields and production levels for California in 2000. The difference of the projected California production from (12) and the projected national production level is allocated to the other states based on the proportion their production was of the total U. S. production of fruits and vegetables over the period 1967-1969:

$$Q_{ij2000} = \sum_{k=67}^{69} \frac{Q_{ijk}}{\sum_{j=1}^{48} Q_{ijk}} \left[Q_{i,0,2000} - Q_{i,48,2000}\right] \qquad (A.1)$$

$i = 1,\ldots,13$[1]
$j = 0,\ldots,48$
$k = 67, 68, 69$

where

- i is the index over the 13 specialty crops;
- j is the index over the states with $j = 0$ for the U. S. total and $j = 48$ for California;
- k is the index over time in years after 1900; and
- Q_{ijk} is the quantity of the ith specialty crops produced (or projected) in the jth state for the kth year.

Yields are estimated by increasing the average of the 1959 and 1964 yields in each state by the same proportion as the California yields are projected to increase by the year 2000 (12):

$$Y_{ij2000} = \frac{Y_{ij59} + Y_{ij64}}{2} \left(1 + \frac{Y_{i48,2000} - \bar{Y}_{i48}}{\bar{Y}_{i48}}\right) \qquad (A.2)$$

$i = 1,\ldots,13$
$j = 1,\ldots,47$

where

- Y_{ijk} is the average yield of the ith specialty crop in the jth state in the kth year as reported in the Census of Agriculture (184, 186); and
- $\bar{Y}_{i48}$ is the 1961-1965 average yield of the ith specialty crop in California (12).

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[1]The specialty crops include potatoes, rice, tomatoes, lettuce, sweet corn, carrots, onions, melons, cabbage, other vegetables, lemons and grapes, citrus and deciduous fruits and nuts.

The acreage in each state is then calculated as

$$A_{ij2000} = Q_{ij2000}/Y_{ij2000} \tag{A.3}$$

$i = 1,\ldots,13$
$j = 1,\ldots,47$

where A_{ijk} is the total acreage of bearing plants of the ith specialty crop in the jth state in 2000. The irrigated acreage is calculated with an adjustment to account for the acreage of nonbearing fruits and vegetables as based on the ratio of the acres of bearing plants to the acres of nonbearing plants as reported in the California study (12). As the irrigated acreages of the exogenously-produced crops are used to adjust the water supplies available for the endogenously-produced crops, the acreages of nonbearing plants are adjusted to a bearing equivalent acreage using the assumption that a nonbearing acre of plants requires half the water of an acre of bearing plants:

$$IA_{ij2000} = A_{ij2000}\left(1 + .5\,\frac{NBA_{i,48,2000}}{BA_{i,48,2000}}\right)\frac{IA_{ij64}}{A_{ij64}} \tag{A.4}$$

$i = 11, 12, 13$
$j = 1,\ldots,48$

where

IA_{ij64}	is the bearing and nonbearing irrigated acreage of the ith specialty crop in the jth state in 1964 as reported in the Census of Agriculture (186);
$BA_{i,48,2000}$	is the projected acreage of bearing plants of the ith specialty crop in California in the year 2000;
$NBA_{i,48,2000}$	is the projected acreage of nonbearing plants of the ith specialty crop in California in the year 2000;
IA_{ij2000}	is the projected fruit bearing equivalent irrigated acres of the ith specialty crop in the jth state in 2000; and
A_{ij64}	is the total bearing and nonbearing acreage of the ith specialty crop in the jth state in 1964 as reported in the 1964 Census of Agriculture (186).

Using this procedure, there would be no adjustment for nonbearing acres for the annual specialty crops.

The acreages of each specialty crop are then allocated to the producing areas based on the county proportions of the state acreages in 1964 using

the following relationship:

$$IAP_{i,n,2000} = \sum_{m \in n} IA_{im64} \frac{IA_{ij2000}}{IA_{ij1964}} \tag{A.5}$$

$i = 1,\ldots,13$
$j = 1,\ldots,48$
$m = 1,\ldots,3067$
$n = 1,\ldots,223$

where

IA_{im64}	is the irrigated acreage of the ith specialty crop in the mth county in 1964 (186);
IA_{ijk}	is the irrigated acreage of the ith specialty crop in the jth state in the kth year; and
IAP_{in2000}	is the projected irrigated acreage of the ith specialty crop in the nth producing area in 2000.

The amount of irrigation water consumed by each of the specialty crops is calculated as

$$WW_{ir} = \sum_{n \in r} (IAP_{in2000})(W_{in}) \tag{A.6}$$

$i = 1,\ldots,13$
$r = 1,\ldots,51$
$n = 1,\ldots,223$

where

W_{in}	is the per acre consumptive use of water by the ith specialty crop in the nth producing area;
IAP_{in2000}	is as defined above; and
WW_{ir}	is the projected total consumption of irrigation water by the ith specialty crop in the rth water supply region in 2000.

The total irrigation water consumption of the specialty crops is the sum of the use by the individual crops:

$$WW_r = \sum_{i=1}^{13} WW_{ir} \tag{A.7}$$

$r = 1,\ldots,51$

where

WW_r is the projected total specialty crop consumption of water in the rth water supply region in 2000.

The total specialty crop water use levels deplete the water supply available to the endogenous activities by the amounts calculated and shown in Heady, Madsen, Nicol and Hargrove (21a).

Appendix B. Crop Yields

A time series of dryland and irrigated yields by state or county from which the projection of the crop yields in 2000 can be made is not available. The Census of Agriculture is the only source of dryland and irrigated yields by county. By combining these county data with a long time series of state average yields[1] a projected yield is obtained for each of the 14 crops[2] using the following producedure.

Estimates of the portion of the acreage irrigated by state, ρ, are obtained from the 1949, 1954, 1959 and 1964 Census of Agriculture. These values are then interpolated to give a series of 16 observations. Ratios to state average yields of the county dryland yield, λ_1, and county irrigated yield, λ_2, are calculated and interpolated for the 16 years 1949-1964.

The state dryland and irrigated yields are calculated as weighted averages of the county yields given in the census. These state yields are compared with the annual average state yields as follows:

$$SCYD_{jkt} = (b_{1jk})(SERS_{jkt}) + e_{1jkt} \qquad (B.1)$$

and

$$SCYI_{jkt} = (b_{2jk})(SERS_{jkt}) + e_{2jkt} \qquad (B.2)$$

$j = 1,\ldots,14$
$k = 1,\ldots,48$
$t = 1949, 1954, 1959, 1964$

where

$SCYD_{jkt}$ is the dryland yield of the jth crop in the kth state for the tth year from the census;

$SCYI_{jkt}$ is the irrigated yield of the jth crop in the kth state for the tth year from the census;

$SERS_{jkt}$ is the annual average state yield of the jth crop in the kth state for the tth year;

b_{1jk} and b_{2jk} are least-squares estimates of the relationships of $SCYD_{jkt}$ to $SERS_{jkt}$ and $SCYI_{jkt}$ to $SERS_{jkt}$ for all t; and

e_{1jkt} and e_{2jkt} are error terms assumed to be normally distributed with means of zero.

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[1]The sources for this data are listed in Part III in the "crop yields" section.

[2]Yields are determined for corn, corn silage, sorghum, sorghum silage, wheat silage, wheat oats, barley, soybeans, alfalfa, clover-timothy, wild hay, cotton, sugar beets and other hay.

For each of the 14 crops a fifty-year yield trend is estimated.

$$SERSY_{jkt} = \alpha_{jk} + \beta_{jk}\, t \qquad (B.3)$$

$j = 1,\ldots,14$
$k = 1,\ldots,48$
$t = 1,\ldots$

where

$SERSY_{jkt}$	is the predicted yield of the jth crop in the kth state in the tth year;
α_{jk} and β_{jk}	are least-squares regression coefficients for the jth crop in the kth state estimated from the 50 years of annual yield data; and
t	is time after 1900.

From the estimates of b_{1jk}, b_{2jk}, α_{jk}, β_{jk} and ρ_{jk} projected dryland and irrigated yields are calculated and weighted into a projected state average yield:

$$YLD_{jkt} = \rho_{jkt} b_{2jk} SERSY_{jkt} + (1-\rho_{jkt})\, b_{1jk} SERSY_{jkt} \qquad (B.4)$$

$j = 1,\ldots,14$
$k = 1,\ldots,48$
$t = 49, 50,\ldots,64$

where YLD_{jkt} is an estimate of the total yield for the jth crop in the kth state in the tth year. The estimate of the total yield in each state for each year (YLD_{jkt}) is compared to the predicted total yield as estimated from the annual data ($SERSY_{jkt}$):

$$\eta_{jkt} = YLD_{jkt}/SERSY_{jkt} \qquad (B.5)$$

$j = s.,,,.14$
$k = 1,\ldots,48$
$t = 49,50,\ldots,64$

where η_{jkt} is the ratio of the two yields for the jth crop in the kth state in the tenth year. Using η_{jkt} as an adjustment factor, adjusted state dryland and irrigated yields are projected for the 16 years:

$$SAYD_{jkt} = (1/\eta_{jkt})(b_{1jk} SERSY_{jkt}) \quad (B.6)$$

and

$$SAYI_{jkt} = (1/\eta_{jkt})(b_{2jk} SERSY_{jkt}) \quad (B.7)$$

$j = 1,\ldots,18$
$k = 1,\ldots,48$
$t = 49,50,\ldots,64$

where $SAYD_{jkt}$ and $SAYI_{jkt}$ are the adjusted projected dryland and irrigated yields of the jth crop in the kth state in the tth year. From these adjusted state yields county yields are projected:

$$CAYD_{jpt} = SAYD_{jkt}\lambda_{1jpt} \quad \text{for each } p \in k \quad (B.8)$$

and

$$CAYI_{jpt} = SAYI_{jkt}\lambda_{2jpt} \quad \text{for each } p \in k \quad (B.9)$$

$j = 1,\ldots,14$
$p = 1,\ldots,3067$
$t = 49,50,\ldots,64$
$k = 1,\ldots,48$

where

λ_{1jpt} and λ_{2jpt} are the ratios of dryland and irrigated county yields to the state yield of the jth crop in the pth county in the tth year; and

$CAYD_{jpt}$ and $CAYI_{jpt}$ are the dryland and irrigated adjusted county yields for the jth crop in the pth county in the tth year.

The 16 year series of yields for dryland and irrigated production of crop j are generated in each producing area by:

$$PAYD_{ijt} = \sum_{p \in i} CAYD_{jpt}\, ACD_{jpt} / \sum_{p \in i} ACD_{jpt} \quad (B.10)$$

and

$$PAYI_{ijt} = \sum_{p \in i} CAYI_{jpt} ACI_{jpt} / \sum_{p \in i} ACI_{jpt} \quad (B.11)$$

$i = 1,\ldots,223$
$j = 1,\ldots,14$
$p = 1,\ldots,3067$
$t = 49,50,\ldots,64$

where

ACD_{jpt}	is the dryland acreage of the jth crop in the pth county in the tth year as interpolated from the data in the four Census of Agriculture (180, 182, 184, 186);
ACI_{jpt}	is the irrigated acreage of the jth crop in the pth county in the tth year as interpolated from the data in the four Census of Agriculture (180, 182, 184, 186);
$PAYD_{ijt}$	is the dryland yield of the jth crop in the ith producing area in the tth year; and
$PAYI_{ijt}$	is the irrigated yield of the jth crop in the ith producing area in the tth year.

For the regions not included in the water supply regions the aggregate or total yield, $PAYT_{ijt}$ is calculated as

$$PAYT_{ijt} = \sum_{p\epsilon i} CAYD_{jpt}ACD_{jpt} + \sum_{p\epsilon i} CAYI_{jpt}ACI_{jpt} / \sum_{p\epsilon i} ACD_{jpt} + \sum_{p\epsilon i} ACI_{jpt} \tag{B.12}$$

$i = 1,\ldots,223$
$j = 1,\ldots,14$
$t = 49,50,\ldots,64$

where $PAYT_{ijt}$ is the aggregate yield for the jth crop in the ith producing area for the tth year. Least-squares estimates are obtained for the three series of 16 observations $PAYD_{ijt}$, $PAYI_{ijt}$ and $PAYT_{ijt}$ in each region with time as the independent variable:

$$YD_{ijt} = a_{1ij} + b_{1ij}t \tag{B.13}$$

$$YI_{ijt} = a_{2ij} + b_{2ij}t \tag{B.14}$$

and

$$YT_{ijt} = a_{3ij} + b_{3ij}t \tag{B.15}$$

$i = 1,\ldots,223$
$j = 1,\ldots,14$
$t = 1,\ldots$

where

a_{nij} and b_{nij}	are the regression coefficients for n = 1 = dryland, n = 2 = irrigated, n = 3 = total yield for the jth crop in the ith producing area as determined by least-squares;

YD_{ij}, YI_{ij} and YT_{ij} are the estimated dryland, irrigated and total yields for the jth crop in the ith producing area; and

t is time after 1900.

These equations are solved with t equal to 100 (the year 2000) for all i and j. The YT_{ij}'s are used as the yields for the crops in the producing areas which are not in water supply regions. For the producing areas which are within the water supply regions, YD_{ij} and YI_{ij} are used as the yields for the respective dryland and irrigated activities.

For the multiple crop activities, weights are generated giving the harvested acreages of the individual crops included as a portion of the combined harvested acreage of all the crops in the multiple cropping activity. The yields are calculated as

$$MYD_{ijm} = YD_{ij}\left(\sum_{p\epsilon i} ACD_{jp}\right) / \sum_{j\epsilon m} \sum_{p\epsilon i} ACD_{jp} \qquad (B.16)$$

$$MYI_{ijm} = YI_{ij}\left(\sum_{p\epsilon i} ACI_{jp}\right) / \sum_{j\epsilon m} \sum_{p\epsilon i} ACI_{jp} \qquad (B.17)$$

$$MYT_{ijm} = \left(YD_{ij} \sum_{p\epsilon i} ACD_{jp} + YI_{ij} \sum_{p\epsilon i} ACI_{jp}\right) / \sum_{j\epsilon m} \sum_{p\epsilon i} (ACD_{jp} + ACI_{jp}) \qquad (B.18)$$

i = 1,...,223
j = those crops included in multiple crop activity m
p = 1,...,3067 and is summed over the numbers included in producing area i
m = 1 for the corn grain-oats-corn silage activity, 2 for the sorghum grain-sorghum silage activity and 3 for the tame hay activity

where

MYD_{ijm} is the dryland yield of jth crop in the ith producing area for the mth multiple cropping activity;

MYI_{ijm} is the irrigated yield of the jth crop in the ith producing area for the mth multiple cropping activity; and

MYT_{ijm} is the total yield of the jth crop in the ith production area for the mth multiple cropping activity.

The weighted yields are used as the coefficients in the respective activities adding production to their appropriate rows. For the tame hay activity, where the activity includes crops adding to the same row, the individual yields are summed to give a combined yield of roughage.

Appendix C. Crop Costs

This appendix explains the derivation of crop costs for the 9 annual crops, tame hay and wild hay.[1] Costs used for sugar beets and pasture are explained in Part III of this report.

The crop costs are derived from work of Eyvindson (14) and consist of machinery costs, labor costs, fertilizer costs, pesticide costs and miscellaneous costs. Eyvindson estimated costs for each crop for three farm size groups, based on the acres of each crop per farm in the economic farm size classes as reported in the 1964 Census of Agriculture (186).[2] For the present study, these costs are aggregated to one farm size by weights reflecting the proportion of the acres of each crop in each of Eyvindson's farm size groups and producing areas (186).

To determine machinery costs and labor requirements for crops, Eyvindson first surveyed regional bulletins to determine the most common tillage practices used for each crop. He also determined the most common size of machinery used on each size of farm. Using these data and regional prices for machinery, he calculated machine costs per acre for each crop in each of the regions where the crop was grown as determined from the 1964 Census of Agriculture (186). He determined machinery costs for each of the crops under dryland and irrigated cultivation in each producing area where the repective activities were relevant. Eyvindson used a similar procedure to estimate the hours of labor used per acre for each of the crops.

For purposes of the present study, the hours of labor as estimated by Eyvindson are transformed into costs by multiplying by the average state farm wage rate in 1964 (173). In calculating the cost of labor, it is assumed that the farm owner will receive payment for labor equal to the wage paid to hired labor. Given that average labor requirements are used, no return to efficient management can be imputed without defining activities breaking down the farming practices of each management class.

For producing areas not included in a water supply region, fertilizer costs are calculated from Eyvindson's data. Since Eyvindson assumes all farm sizes use the same fertilizer application rates, no weighting of fertilizer costs by the different farm sizes is required. For producing areas in

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[1] The 9 crops are corn grain, corn silage, grain sorghum, sorghum silage, oats, barley, wheat, cotton and soybeans.

[2] These costs are available from the background work done by Eyvindson for his thesis (14).

a water supply region, fertilizer application rates are determined from fertilizer response work by Ibach and Adams (29). From this source, actual pounds of nitrogen, phosphorous and potassium applied per harvested dryland and irrigated acre in 1964 were determined for the relevant crops. The prices of the elemental fertilizers as estimated by Ibach (28) were used to calculate the fertilizer costs per harvested acre for the dryland and irrigated activities.

Pesticide costs, as calculated by Eyvindson (14), are assumed to be the same for the dryland and irrigated activities of a specific crop. Miscellaneous costs include costs of liming, grain drying and cotton ginning and are added to the costs of the relevant crops. Seed costs for cotton, silage and hay crops are also included as part of the miscellaneous costs of production. Seed requirements for other crops are subtracted from their projected yield.

Crop costs are projected to 2000 assuming nonlabor costs remain constant on a per unit of output basis between the calculated 1964 coefficients and the projected coefficients in 2000. In order to maintain this relationship, all nonlabor costs were increased by the ratio of the yields in 2000 to the average yield from the 1959 and 1964 Census of Agriculture (184, 186). The increase in nonlabor cost per acre will reflect the substitution of capital for labor and the continuing greater productivity of the marginal machine dollar when compared to the marginal labor dollar.

Labor as a part of real crop cost has been declining rapidly as farmers shift to new machinery and agronomic practices. To reflect a continuation of this trend, labor costs per acre for each of the crops are assumed to decline between 1970 and 2000 by the same proportion as they declined during the period 1948-50 to 1968-70.[3]

To transform the crop costs from Eyvindson 157 producing areas to the 223 producing areas used in the present study, each county in each of Eyvindson's producing areas is assumed to have the cost developed for that producing area. Costs in each county are then weighted together into the 223 producing areas as explained in Part III, "crop costs" section.

For the multiple crop activities (e.g., the corn grain-oats-corn silage activity) the aggregate cost for each activity is calculated by the weighting scheme used for the crop yield explained in Appendix B. Finally all costs are adjusted from the 1964 price base to 1970 dollars using the index of prices paid by farmers.

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[3]The percent of the 1964 labor hours required in 2000 is 35 percent for cotton, 55 percent for wheat, 40 percent for the feed grains and soybeans and 65 percent for the silages and hays.

Appendix D. Livestock Coefficients

The cost per unit of output, the feed requirements and the output level are determined for each of four livestock activities in each of the producing areas. The four livestock activities include hogs, beef cows, beef feeding and dairy. Eyvindson's data (14) are used as the basis for defining the initial coefficients for projecting the data for each activity. Eyvindson defined six different methods of producing fed beef. Four of these activities were based on feeding calves from weaning until fat and the other two were based on placing animals on feed after they had been grown out in a yearling activity. No data are available indicating the proportions of animals fed under each system, and size restraints on the programming model prevented the inclusion of more than one beef feeding activity per area. The beef feeding activity selected feeds a high roughage ration to the feeder during the early feeding period and a larger proportion of concentrates as the weight of the feeder increases.

Weights are determined to combine Eyvindson's data from the three farm sizes. The weights for hogs are based on the number of hogs marketed by economic farm class. The weights for beef cows are based on the number of beef cows on hand as of January 1, 1964, for each of the economic farm classes. The weights for dairy cows are based on the number of dairy cows on the farm on January 1, 1964, for each of the economic farm classes.[1] Weights are calculated for the beef feeding activity based on the number of steers and heifers on hand on January 1 not needed for replacement as calculated from the number of steers, heifers and cows reported on the farm by the economic farm classes (186). From these weighted coefficients, it is apparent that the Midwest and East Coast producing areas would not be competitive due to the greater proportion of smaller and less efficient feedlots in these areas. Over time those areas that give way to a technological advantage will alter their practices to remain competitive or they will change to the production of other products for which they have the comparative advantage. In order to allow some shift in the technology of feed beef production it is assumed that by the year 2000 all areas will be feeding cattle in lots equivalent to those of Eyvindson's farm size one (his larger size operations).

After weighting Eyvindson's data into aggregate coefficients, except for beef feeding, the cost of production is adjusted to reflect labor costs and interest charges on capital required for production:

$$FC_{ij} = \sum_{m \epsilon i} (C_{jm} + L_{jm} W_m)(1 + r_m) \qquad \text{(D.1)}$$

$i = 1, \ldots, 157$
$j = 1, \ldots, 4$
$m = 1, \ldots, 3067$

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[1] The weights were determined from economic farm class data in the 1964 Census of Agriculture (186).

where

C_{jm} is the cost per unit of the jth livestock activity in the mth county included in the ith Eyvindson producing area;

L_{jm} is the hours of labor required per unit of the jth livestock activity in the mth county included in the ith Eyvindson producing area;

W_m is the wage rate per hour in the mth county as determined from the state wage rates (173);

r_m is the interest charge on productive capital in the mth county as determined from the interest rate charged on productive capital in the respective state (114); and

FC_{ij} is the final cost of the jth livestock activity in the ith Eyvindson producing area.

For added details on livestock coefficients, see Heady, Madsen, Nicol and Hargrove (21a).

Appendix E. Commodity Transportation

The availabilities and demands for commodities are defined by consuming region. This implies that there is no spatial differentiation among commodities produced or demanded in various producing areas within a consuming region. Among consuming regions, however, cost of transporting commodities is specified.

Consuming regions are defined using dual criteria: first, the central city is a major metropolitan area, and second, the central city is a transportation center. Fox (15) defined 24 such regions which are modified such that 27 consuming regions are defined as shown in Figure E.1. The precise boundaries of the consuming regions are determined by the boundaries of the producing areas included.

Transportation routes are defined between each pair of contiguous consuming regions. The model, then, is basically one of transshipment. Some heavily used routes between non-contiguous regions also exist, however, and transportation routes are defined to represent some of them. The routes used are shown in Heady, Madsen, Nicol and Hargrove (21a). Over each route two activities are defined for each commodity--one activity for shipment in each direction.

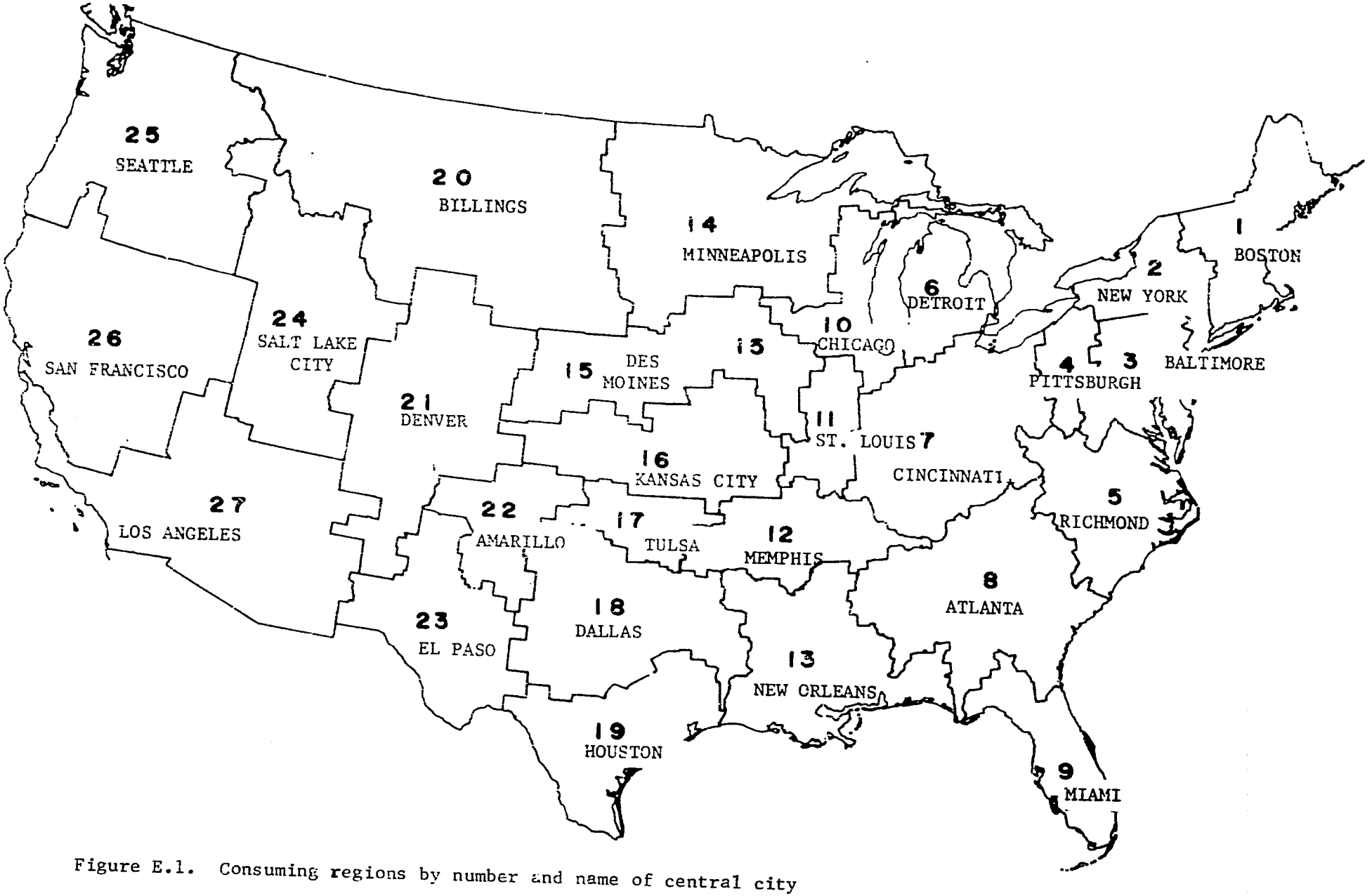

Figure E.1. Consuming regions by number and name of central city

Appendix F. Demand Analysis

The per capita direct demands for corn-sorghum, barley-oats, wheat and sugar beets are based on the average 1967 to 1969 use of each. The corn-sorghum demand is based on the corn and sorghum use for milling, brewing and cereals. Similar uses are considered when calculating the demand for the barley oats commodity and wheat. The per capita consumption level of cotton is claculated using the average decline over the past 30 years and projecting to 2000 on this basis. The average sugar beet production per capita over the 1967 to 1969 period is used as a proxy for the demand for sugar. This procedure is used since a large proportion of the sugar consumed in the nation is imported from countries producing sugarcane and to assume some increase in the proportion of total sugar from sugar beets is not warranted when compared to past trends in the sugar market.

Per capita consumption levels of beef, pork broilers are determined from the price-quantity equations developed by Waugh (222). These equations were inverted to give:

$$Q_B = 43.7809 - 0.7697\ P_B + 0.2786\ P_P + 0.1076\ P_{Br} + 0.0336\ Y \qquad (F.1)$$

$$Q_P = 90.1111 - 0.2786\ P_B - 0.9612\ P_P + 0.0728\ P_{Br} + 0.0032\ Y \qquad (F.2)$$

$$Q_{Br} = 32.0623 + 0.1076\ P_B + 0.0728\ P_P - 0.4485\ P_{Br} + 0.0023\ Y \qquad (F.3)$$

where

Q_B is the beef consumed in pounds per capita in 2000 on a carcass weight basis;

Q_P is the pork consumed in pounds per capita in 2000 on a carcass basis;

Q_{Br} is the broilers consumed in pounds per capita in 2000 on a ready to cook basis;

P_B is the expected price of beef in 2000[1];

P_P is the expected price of pork in 2000[1];

P_{Br} is the expected price of broilers in 2000[1]; and

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[1]Prices are an index with 1957 to 1959 = 100.

Y is the projected per capita disposable income in 2000[2].

Using the prices assumed to prevail in 2000 and the appropriate level of disposable income the equations are solved for the per capita consumption levels for the respective quantities (Table 3.8).

The per capita consumptions of turkeys, mild, eggs and lamb and mutton are claculated from equations F.4 - F.7:

$$Q_T = e^{2.40871} P_T^{-0.43835} P_B^{0.19729} t^{0.21801} \quad (F.4)$$

$$Q_M = e^{6.6301-0.019T} \quad (F.5)$$

$$Q_E = e^{6.00183-0.01264T} \quad (F.6)$$

$$Q_L = e^{5.57087} P_L^{-1.9916} P_B^{0.57397} Y^{0.36813} t^{-0.13775} \quad (F.7)$$

where

Q_T is the turkey consumed in pounds per capita in 2000 on a ready to cook basis;

Q_M is the dairy products consumed in pounds per capita in 2000 on a whole milk equivalent basis;

Q_E is the number of eggs consumed per capita in 2000;

Q_L is the lamb and mutton consumed in pounds per capita in 2000 on a carcass weight basis;

e is the base of the natural logarithm;

P_T is the expected price of turkeys in 2000[3];

P_B is the expected price of beef in 2000[3];

t is time in years after 1947;

P_L is the expected price of lamb and mutton in 2000[3]; and

Y is the projected per capita income in 2000.

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[2]The income used is the disposable per capita income projected by the Office of Business Economics (196) with the additional restraint that no area will have a disposable income greater than $4,000 in 1957 to 1959 dollars ($5,400 in 1970 prices).

[3]See footnote 1.

The per capita consumption levels of turkeys, broilers, lamb and mutton, sugar beets and eggs, (Table 3.8) are multiplied by the projected population and adjusted for foreign trade to give the lower bounds on the national production activities for the respective commodities. The per capita demands for beef, pork and milk are used in the producing area population activities to create a demand in the consuming region equal to the sum of all the producing areas' population times per capita consumption for the commodity in each consuming region.

Appendix G. Average Crop Yields and Shadow Prices of Land and Water in 2000

Table G.1. Average dryland and irrigated yields of annual crops, hay and pasture in the United States in 2000.

Crop	Unit	Model A		Model A1	
		Dryland yield	Irrigated yield	Dryland yield	Irrigated yield
Corn grain	bu./acre	112.0	121.0	112.6	124.0
Corn silage	ton/acre	19.1	32.9	19.7	32.4
Grain sorghum	bu./acre	73.4	121.5	72.7	120.7
Sorghum silage	ton/acre	15.6	28.4	15.6	28.4
Wheat	bu./acre	40.0	107.6	40.4	98.3
Oats	bu./acre	69.0	82.0	69.0	89.2
Barley	bu./acre	60.0	85.7	61.2	76.2
Soybeans	bu./acre	37.6	30.6	37.2	30.6
Sugar beets	ton/acre	27.2	48.1	27.2	48.1
Cotton	bale/acre	2.2	4.2	2.2	4.5
Tame hay	ton/acre	2.5	5.1	2.5	6.1
Wild hay	ton/acre	1.1	1.7	1.1	1.8
Imp. & cropland pasture[1]	ton/acre	1.4	2.6	1.4	2.8
Other pasture[1]	ton/acre	0.1	0	0.1	0

[1]Tons of hay equivalent. Other pasture includes unimproved permanent pasture, woodland pasture and public grazing lands.

Model A2		Model A3		Model B	
Dryland yield	Irrigated yield	Dryland yield	Irrigated yield	Dryland yield	Irrigated yield
113.1	122.9	112.8	119.3	115.9	124.6
19.9	34.9	20.2	34.7	21.4	32.9
70.3	117.9	80.4	119.5	76.7	121.3
15.9	23.4	16.2	23.6	15.8	28.4
41.0	112.5	41.3	118.2	40.6	110.7
70.1	94.7	68.5	83.1	68.7	87.5
64.4	63.1	64.7	0	56.9	80.0
36.5	30.6	36.4	30.6	37.4	0
27.2	48.1	27.2	48.1	27.2	0
2.2	4.5	2.1	4.4	2.1	4.5
2.5	6.1	2.5	7.1	2.9	5.3
1.1	2.0	1.1	2.6	1.0	1.7
1.4	3.1	1.4	3.7	1.4	2.6
0.1	0	0.1	0	0.1	0

Table G.1. (Continued).

Crop	Unit	Model C Dryland yield	Model C Irrigated yield	Model D Dryland yield	Model D Irrigated yield
Corn grain	bu./acre	109.5	114.7	107.8	124.6
Corn silage	ton/acre	16.2	35.1	16.0	32.6
Grain sorghum	bu./acre	70.5	118.5	76.9	127.4
Sorghum silage	ton/acre	15.7	27.1	17.0	30.2
Wheat	bu./acre	39.1	93.0	39.6	93.0
Oats	bu./acre	66.7	81.5	67.0	91.4
Barley	bu./acre	59.7	85.8	57.4	87.0
Soybeans	bu./acre	37.2	42.7	36.3	43.1
Sugar beets	ton/acre	19.2	33.7	27.2	40.8
Cotton	bale/acre	1.8	3.0	2.1	3.0
Tame hay	ton/acre	2.4	4.3	2.5	5.0
Wild hay	ton/acre	1.1	1.7	1.1	1.7
Imp. & cropland pasture[1]	ton/acre	1.4	2.6	1.4	2.6
Other pasture[1]	ton/acre	0.1	0	0.1	0

Model E		Model F	
Dryland yield	Irrigated yield	Dryland yield	Irrigated yield
111.6	117.4	113.6	127.3
20.7	34.1	19.4	33.7
79.7	129.4	80.9	136.7
15.6	24.1	15.7	29.8
40.6	104.8	43.1	107.8
65.3	82.8	65.7	82.5
56.6	82.4	62.6	81.3
37.2	0	37.8	31.3
31.9	47.2	27.5	47.9
1.9	3.7	2.1	4.4
2.8	5.2	2.6	5.3
1.0	1.7	1.1	2.1
1.4	2.6	1.7	3.9
0.1	0	0.2	0

Table G.2. Shadow prices of water in selected water supply regions under the 9 alternative policy models in 2000.

Water supply region	Model A	Model A1	Model A2	Model A3	Model B	Model C	Model D
	(dollars per acre foot consumed)						
8	3.74	0	0	0	0	7.89	6.26
15	35.78	0	0	0	0	30.32	44.40
16	63.78	58.28	58.00	58.00	58.32	58.32	72.40
17	13.78	15.28	0	0	0	0	22.40
18	19.58	20.36	23.76	0	11.97	28.26	42.67
19	35.08	38.28	43.36	44.31	25.74	71.50	56.54
20	35.08	38.28	43.36	44.31	25.74	71.50	56.54
21	19.40	21.68	25.30	30.00	12.74	45.34	34.68
22	9.50	0	0	0	5.83	18.47	15.44
23	2.58	0	0	0	2.08	2.58	2.58
25	2.58	15.00	22.50	30.00	2.58	2.58	2.58
26	19.58	20.36	23.76	30.00	11.97	28.26	42.67
27	19.58	20.36	23.62	0	11.95	37.45	42.32
31	0	0	0	0	0	24.40	10.31
32	16.86	18.09	22.50	30.00	11.45	30.70	26.63
35	8.87	15.00	22.50	0	8.87	30.75	16.66
36	8.87	15.00	22.50	0	8.87	0	16.66
37	3.07	15.00	22.50	30.00	3.07	3.07	0
40	9.50	15.00	22.50	30.00	0	18.00	15.45
41	15.64	15.24	0	0	11.20	0	34.54
42	61.35	63.72	68.29	70.77	47.58	112.24	98.50
47	0	0	0	0	0	2.18	10.03
48	0	0	0	0	0	0	16.13
49	52.42	54.51	58.53	60.69	40.37	74.43	74.32
51	100.00	100.00	100.00	100.00	0	0	100.00

Table G.2. (Continued).

Water supply region	Model E	Model F
	(dollars per acre foot consumed)	
8	0	0
15	0	30.32
16	58.32	58.32
17	0	0
18	17.98	17.26
19	26.26	34.42
20	26.26	34.42
21	13.23	18.02
22	6.63	9.01
23	2.17	2.58
25	2.58	2.58
26	17.98	17.26
27	14.95	16.64
31	0	5.90
32	12.05	18.39
35	0	12.25
36	8.87	10.70
37	0	0
40	6.23	9.00
41	12.35	4.47
42	48.37	59.43
47	0	0
48	0	0
49	41.17	54.78
51	0	0

Table G.3. Shadow prices of alternative land uses in the 18 river basins with C population level, present water prices, trend technology and a free market in 2000 (Model A).

River basin	Dryland hayland	Dryland cropland	Irrigated hayland	Irrigated cropland
	(dollars per acre)			
United States	14.36	25.38	26.01	40.12
New England	0	29.12	-	-
M. Atlantic	0	9.84	-	-
S. Atlantic-Gulf	7.65	11.93	-	-
Great Lakes	16.62	29.72	-	-
Ohio	7.66	29.17	-	-
Tennessee	5.39	21.35	-	-
U. Mississippi	20.86	39.23	-	-
L. Mississippi	11.64	26.40	-	-
S.-Red-Rainy	12.79	14.76	-	-
Missouri	14.50	21.14	25.46	51.36
Ark.-White-Red	9.86	19.51	12.72	52.15
Texas-Gulf	7.46	21.50	12.81	11.70
Rio Grande	10.72	24.73	26.34	36.58
U. Colorado	23.38	15.87	22.56	31.65
L. Colorado	0	0	15.10	5.73
Great Basin	8.25	14.15	6.54	15.46
Col.-N. Pacific	14.83	31.03	32.48	54.24
Cal.-S. Pacific	1.41	31.34	31.27	41.90

Table G.4. Shadow prices of alternative land uses in the 18 river basins with C population level, $15.00 water prices, trend technology and a free market in 2000 (Model A1).

River basin	Dryland hayland	Dryland cropland	Irrigated hayland	Irrigated cropland
	(dollars per acre)			
United States	16.37	27.87	18.85	36.80
New England	0	30.87	-	-
M. Atlantic	1.80	11.65	-	-
S. Atlantic-Gulf	8.08	13.55	-	-
Great Lakes	19.39	32.65	-	-
Ohio	10.09	31.77	-	-
Tennessee	7.52	26.39	-	-
U. Mississippi	23.80	42.56	-	-
L. Mississippi	14.05	29.86	-	-
S.-Red-Rainy	14.74	16.81	-	-
Missouri	16.04	23.45	16.69	46.72
Ark.-White-Red	11.67	21.79	11.54	54.14
Texas-Gulf	9.11	23.02	12.67	12.16
Rio Grande	13.28	26.45	30.29	30.88
U. Colorado	25.93	17.89	26.36	21.28
L. Colorado	0	0	13.35	5.45
Great Basin	11.68	14.19	7.96	13.53
Col.-N. Pacific	15.29	32.09	18.39	36.17
Cal.-S. Pacific	3.63	31.31	23.55	44.29

Table G.5. Shadow prices of alternative land uses in the 18 river basins with C population level, $22.50 water prices, trend technology and a free market in 2000 (Model A2).

River basin	Dryland hayland	Dryland cropland	Irrigated hayland	Irrigated cropland
	(dollars per acre)			
United States	20.34	32.95	19.31	37.21
New England	0	31.00	-	-
M. Atlantic	0.99	16.58	-	-
S. Atlantic-Gulf	11.47	16.90	-	-
Great Lakes	24.50	38.72	-	-
Ohio	14.54	38.03	-	-
Tennessee	11.46	30.32	-	-
U. Mississippi	29.15	49.36	-	-
L. Mississippi	18.45	36.18	-	-
S.-Red-Rainy	18.77	21.29	-	-
Missouri	19.90	27.98	18.83	47.19
Ark.-White-Red	15.28	26.05	13.11	54.97
Texas-Gulf	12.36	26.06	14.40	13.79
Rio Grande	18.32	29.31	32.43	27.94
U. Colorado	30.84	22.04	30.24	20.91
L. Colorado	0	0	9.19	10.62
Great Basin	16.49	16.38	10.93	14.80
Col.-N. Pacific	18.22	37.43	16.30	34.43
Cal.-S. Pacific	9.16	34.24	25.43	43.73

Table G.6. Shadow prices of alternative land uses in the 18 river basins with C population level, $30.00 water prices, trend technology and a free market in 2000 (Model A3).

River basin	Dryland hayland	Dryland cropland	Irrigated hayland	Irrigated cropland
	(dollars per acre)			
United States	20.81	34.38	17.04	35.92
New England	0	31.89	-	-
M. Atlantic	1.37	17.88	-	-
S. Atlantic-Gulf	12.29	18.02	-	-
Great Lakes	25.62	40.26	-	-
Ohio	15.38	39.70	-	-
Tennessee	6.06	32.41	-	-
U. Mississippi	30.23	50.89	-	-
L. Mississippi	19.27	39.36	-	-
S.-Red-Rainy	19.54	22.20	-	-
Missouri	20.64	29.08	19.05	42.49
Ark.-White-Red	15.95	27.25	12.72	50.48
Texas-Gulf	12.95	27.04	14.48	14.41
Rio Grande	19.17	30.41	22.55	30.34
U. Colorado	31.68	22.73	31.07	22.41
L. Colorado	0	0	3.57	3.57
Great Basin	17.37	17.09	14.57	17.16
Col.-N. Pacific	18.45	40.13	14.47	33.67
Cal.-S. Pacific	10.16	36.11	13.64	45.08

Table G.7. Shadow prices of alternative land uses in the 18 river basins with D population level, present water prices, trend technology and a free market in 2000 (Model B).

River basin	Dryland hayland	Dryland cropland	Irrigated hayland	Irrigated cropland
	(dollars per acre)			
United States	8.84	14.34	17.17	27.10
New England	0	20.43	-	-
M. Atlantic	0	4.72	-	-
S. Atlantic-Gulf	15.42	4.71	-	-
Great Lakes	9.93	15.05	-	-
Ohio	2.56	14.23	-	-
Tennessee	2.93	10.81	-	-
U. Mississippi	10.73	22.50	-	-
L. Mississippi	3.78	13.19	-	-
S.-Red-Rainy	4.46	5.69	-	-
Missouri	10.90	13.03	15.58	34.63
Ark.-White-Red	5.01	9.75	18.91	36.56
Texas-Gulf	6.21	14.47	12.42	6.01
Rio Grande	7.62	14.50	15.95	28.11
U. Colorado	14.45	10.02	14.35	20.06
L. Colorado	0	0	16.49	8.68
Great Basin	0	7.69	1.14	8.64
Col.-N. Pacific	7.84	20.32	18.87	34.92
Cal.-S. Pacific	0	28.83	30.17	31.40

Table G.8. Shadow prices of alternative land uses in the 18 river basins with D population level, present water prices, trend technology and a free market with insecticide limitation in 2000 (Model E).

River basin	Dryland hayland	Dryland cropland	Irrigated hayland	Irrigated cropland
	(dollars per acre)			
United States	9.33	15.38	17.52	27.90
New England	0	20.34	0	0
M. Atlantic	0	4.82	0	0
S. Atlantic-Gulf	13.11	5.29	0	0
Great Lakes	10.45	15.68	0	0
Ohio	3.32	16.46	0	0
Tennessee	3.54	1.23	0	0
U. Mississippi	11.37	24.17	0	0
L. Mississippi	3.73	16.79	0	0
S.-Red-Rainy	5.01	6.49	0	0
Missouri	11.29	13.22	16.39	34.42
Ark.-White-Red	5.63	10.31	10.72	36.26
Texas-Gulf	6.93	14.92	13.39	6.54
Rio Grande	8.74	15.45	18.67	20.99
U. Colorado	15.62	11.14	15.61	20.58
L. Colorado	0	0	0	2.17
Great Basin	2.04	7.53	1.46	11.11
Col.-N. Pacific	8.24	22.29	19.88	38.35
Cal.-S. Pacific	0	30.44	24.77	35.60

Table G.9. Shadow prices of alternative land uses in the 18 river basins with D population level, present water prices, trend technology and a free market with fragile lands removed in 2000 (Model F).

River basin	Dryland hayland	Dryland cropland	Irrigated hayland	Irrigated cropland
	(dollars per acre)			
United States	13.47	23.40	26.76	43.32
New England	0	25.05	0	0
M. Atlantic	0	10.22	0	0
S. Atlantic-Gulf	7.29	12.10	0	0
Great Lakes	14.74	25.21	0	0
Ohio	7.28	25.13	0	0
Tennessee	7.32	17.94	0	0
U. Mississippi	19.63	35.19	0	0
L. Mississippi	10.71	23.37	0	0
S.-Red-Rainy	11.72	13.05	0	0
Missouri	13.73	19.84	24.10	57.84
Ark.-White-Red	8.62	17.30	12.73	63.33
Texas-Gulf	9.76	22.11	10.13	10.95
Rio Grande	13.37	8.55	24.18	40.08
U. Colorado	20.31	13.54	20.70	30.71
L. Colorado	0	15.01	14.57	8.18
Great Basin	7.41	11.63	6.40	18.32
Col.-N. Pacific	13.40	31.97	31.37	50.26
Cal.-S. Pacific	0	39.69	43.15	46.68

Table G.10. Shadow prices of alternative land uses in the 18 river basins with D population level, present water prices, trend technology and a 45 million acre land retirement program in 2000 (Model C).

River basin	Dryland hayland	Dryland cropland	Irrigated hayland	Irrigated cropland
	(dollars per acre)			
United States	44.80	42.23	76.52	53.59
New England	3.70	-18.63	-	-
M. Atlantic	12.86	22.96	-	-
S. Atlantic-Gulf	28.52	39.50	-	-
Great Lakes	59.22	47.62	-	-
Ohio	36.58	56.79	-	-
Tennessee	27.84	25.85	-	-
U. Mississippi	68.48	61.53	-	-
L. Mississippi	47.30	53.29	-	-
S.-Red-Rainy	51.92	13.38	-	-
Missouri	46.50	33.31	56.67	63.31
Ark.-White-Red	39.74	36.68	48.04	77.16
Texas-Gulf	30.96	22.07	47.91	22.78
Rio Grande	42.21	42.61	92.87	66.36
U. Colorado	67.33	-0.51	62.48	5.23
L. Colorado	0	-61.53	62.06	-16.13
Great Basin	48.23	0	33.57	-9.49
Col.-N. Pacific	37.92	47.92	84.63	65.58
Cal.-S. Pacific	21.79	21.55	122.37	55.81

Table G.11. Shadow prices of alternative land uses in the 18 river basins with B population level, present water prices, advanced technology and a free market in 2000 (Model D).

River basin	Dryland hayland	Dryland cropland	Irrigated hayland	Irrigated cropland
	(dollars per acre)			
United States	31.84	67.22	50.43	81.59
New England	0	53.01	-	-
M. Atlantic	7.63	59.71	-	-
S. Atlantic-Gulf	13.88	80.05	-	-
Great Lakes	45.21	76.28	-	-
Ohio	27.23	79.21	-	-
Tennessee	13.93	76.86	-	-
U. Mississippi	47.01	87.87	-	-
L. Mississippi	17.67	97.67	-	-
S.-Red-Rainy	33.65	42.46	-	-
Missouri	33.55	51.26	46.33	82.94
Ark.-White-Red	27.79	48.70	29.86	88.48
Texas-Gulf	23.06	47.98	35.76	40.61
Rio Grande	35.75	48.83	59.28	62.73
U. Colorado	47.08	35.72	49.41	70.77
L. Colorado	0	6.25	15.96	10.51
Great Basin	29.21	30.99	24.50	40.79
Col.-N. Pacific	27.90	80.39	65.19	135.89
Cal.-S. Pacific	20.73	69.22	51.03	93.82