

# Regional Resource Use for Agricultural Production in California, 1961-65 and 1980

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The purpose of this study is to evaluate the regional resource use for agricultural production in California in 1961-65 and 1980. A spatial allocation model is used to determine location patterns under alternative projections of demand levels, urban expansion, feed grain production, and water pricing. For this analysis, land areas with moderate to high agricultural production potential, accounting for some 19.6 million acres of the State's 100 million acres, are delineated into 95 homogeneous production areas having similar soil and climatic conditions. Crop yields and nonland production costs are determined for each area in 1961-65 and are projected to 1980. Urban, public, and semiagricultural land uses are estimated for these periods. Commodity coverage includes 15 field crops and vegetable groups that account for about 72 per cent of the harvested acreage in California. All orchard and certain vegetable crops are specified as to location and production level, but are not determined within the location model.

The study provides information on regional land use based on an "optimum" location pattern. Data are provided on irrigated acreage and water requirements associated with these cropping patterns. Particular attention is directed to analysis of the agriculture of California in 1980 under alternative specifications of demand for products, levels of urban expansion, and West Side San Joaquin Valley water pricing. The model provides the basis for further analysis of the impact of change on California agriculture.

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# CONTENTS

Introduction . . . . .	1
The Problem . . . . .	1
Some Relevant Questions . . . . .	2
Objectives of the Study . . . . .	3
Framework of Economic Analysis . . . . .	4
General Considerations . . . . .	4
Location of Production . . . . .	5
Location Model for California . . . . .	6
Linear Programming Allocation Model . . . . .	8
Homogeneous Production Areas . . . . .	11
Resource Variables . . . . .	11
A Note on Aggregation Bias . . . . .	12
General Soils Map . . . . .	13
Plantclimate Zones . . . . .	16
Homogeneous Production Areas . . . . .	17
Conditional Projections of Urban and Public Land Use . . . . .	19
Urban Land Requirements . . . . .	19
Public Land Uses . . . . .	24
Impact of Urban Expansion on the Agricultural Land Base . . . . .	25
Conditional Projections of Demand . . . . .	27
U. S. Production, Consumption, and Trade, 1980 . . . . .	27
Orchard Crops and Excluded Vegetables . . . . .	28
Major Vegetable and Field Crops . . . . .	29
Feed and Livestock Projections . . . . .	35
Conditional Projections of Yields and Production Costs . . . . .	37
Yield Trends and Projections . . . . .	37
Nonland Cost Projections for Included Crops . . . . .	39
Allocation Model Restraints . . . . .	40
Structure of Alternative Models . . . . .	40
Demand Restraints for Included Crops . . . . .	41
Land Restraints . . . . .	41
Rotation Restraints . . . . .	46
Water Availability . . . . .	46
Summary of Model Restraints . . . . .	47
1961-65 Regional Resource Use . . . . .	48
State and Regional Resource Use . . . . .	48
Harvested Crop Acreage . . . . .	54
Production Cost, Resource Rent, and Product Price . . . . .	56

1980 Regional Resource Use . . . . .	59
Highlights of the Preliminary 1980 Models . . . . .	59
Best 1980 Projections Models . . . . .	62
Summary of Projections Models . . . . .	75
Application of Allocation Models to Particular Resource	
Use Problems . . . . .	76
West Side San Joaquin Valley Water Pricing . . . . .	76
High Rate of Urban Expansion . . . . .	80
Summary and Conclusions . . . . .	83
Base-Period Model . . . . .	83
1980 Models . . . . .	85
Appendix A: Maps of Homogeneous Production Areas . . . . .	88
Appendix B: Land, Irrigated Acreage, Rotation, and	
Demand Restraints . . . . .	97
Appendix C: Study Crop Acreage, Actual and Estimated	
Model Requirements . . . . .	104
Acknowledgments . . . . .	114
Literature Cited . . . . .	115

# REGIONAL RESOURCE USE FOR AGRICULTURAL PRODUCTION IN CALIFORNIA, 1961-65 AND 1980<sup>1</sup>

## INTRODUCTION

### The Problem

AGRICULTURE IN CALIFORNIA is a complex, dynamic industry. Many of the forces which have prompted constant adjustment and change in the past will continue to shape the structure of agriculture in the future; these forces include population and income growth, urban expansion and sprawl, technological changes both in agriculture and in related industries, foreign market developments, shifting consumer preferences, and governmental programs. Although per-capita use of all farm products is expected to change little, there may be significant changes in diet, relative prices, and resource use and organization in agriculture.

**Competition for land resources.** A favorable climate and abundant rich soil make California a particularly attractive environment for people as well as for agriculture. With net in-migration to California averaging 340,000 persons per year in the past decade, total population has increased at an annual rate of approximately 528,000 persons (California Department of Finance, 1967, pp. 1-3). Industry has expanded rapidly necessitating the growth of public and private services incidental to this expansion. All this growth requires space and increases the demand for land. To accommodate the influx of people and in-

dustry, about 54,000 acres of land per year have been converted to urban uses from agricultural and other uses during the past ten years. The value of land based on capitalized earnings from traditional agricultural use is substantially below its value for subdivisions, shopping centers, or industrial plants. Therefore, as industry and people move in, agriculture moves out.

Total population in California is projected to be 26.4 million by 1980, which represents an annual increase of 512,000 persons from the 1965 estimate of 18.7 million. This projected rate of population growth is slightly lower than during the previous decade. However, the rate of land conversion to accommodate this continued urban and industrial expansion is projected at 61,000 acres per year, a somewhat higher rate than before. It is estimated that 90 per cent of this acreage will be taken from agricultural land.

**Increasing demand for agricultural products.** The same forces of expansion which reduce the land base supporting agriculture in California also increase the demand for agricultural products in California and in the United States. As the population grows, so do aggregate requirements for food and fiber. With a rising income level, more living space per person is demanded, and con-

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sumer preferences shift for particular types of food. This shifting of consumer preferences is expected to increase per-capita requirements for many of the foods in which California specializes. For example, two of California's most important crop groups are fruits and vegetables. Daly and Egbert (1966a, p. 5), project that the national per-capita consumption of these commodities in 1980 will be 6 per cent higher than the average for the period 1959-61.

Crop production in California has increased significantly in the past 15 years with no net increase in gross land resources used. However, from 1940 to 1954 the average of cropland harvested increased 27 per cent (U. S. Bureau of the Census, 1967, p. 14). Technological developments, improved varieties of crops, better management practices, and increased use of other resources (e.g., fertilizer) have generally allowed per-acre yield levels to increase as rapidly as gross output levels. Since 1945 the per-acre yield of some commodities in California has increased as much as 200 per cent. The rate of increase has been significantly lower for other crops, but yield levels of all commodities are higher now than they were 20 years ago.

**Maintaining the agricultural land base.** Although gross-land inputs to agriculture have not changed much, the patterns of specific land use and crop production have changed significantly under the pressures of urban expansion. To offset the decreases in cropland because of urban and industrial expansion, farmers have developed unused land for production. Possibly more important have been the effects of governmentally financed conservation and irrigation developments. With water the limiting resource in many areas, water projects have made possible the conversion of idle land into productive farms; e.g., the California Water Project on the west side of the San Joaquin Valley may bring as much as a million acres of idle land into production by 1990

(Kirkpatrick, 1966). Another project, which will increase the acreage of irrigated land on the west side of the Sacramento Valley, is the construction of the Tehama-Colusa Canal. Plans are also being considered for the construction of a major drain down the center of the San Joaquin Valley which would expand the possibilities for permanent reclamation of soils with heavy salt concentrations. On a smaller scale, other projects, both public and private, are helping to maintain or expand the cropland base.

### Some Relevant Questions

The future of California agriculture is constantly in the forefront of policy decisions by government and in the plans of individual farmers, land investors, and industry. Legislators and directors of government agencies ask, "How much new land will be needed to maintain California's current share of the nation's food and fiber market? How cheaply must water be made available if new land is to be brought into production? How can urban and industrial expansion be directed to minimize adverse effects on agricultural production? What impact do acreage allotments and other government programs have on economic efficiency in production? What policies and projects should be carried out to keep agriculture a viable force in California's economy?" Farmers planning for growth want to know which cropping patterns will likely maximize profit. Processors need sound production projections to make decisions such as where to locate plants, what size to construct, and how much expansion to allow for.

No one can exactly predict future changes in demand, technology, production, and prices of farm products. However, because farmers, processors, legislators, and administrators are forced daily to make decisions on the basis of future expectations, economic projection becomes a primary function of re-

searchers whose aim it is to aid such people to make rational decisions.

Various types of projections relating to California agricultural production have been made within the university system, government, and private industry. However, these projections have primarily concentrated on single resource or product categories. Projections of location and activity of specific commodities, conversion of agricultural land to nonagricultural purposes (e.g., California Conservation Needs Committee, 1961), and water demands in specific areas (e.g., California Department of Water Resources, 1957, 1960, 1965), have been made. These various sets of projections have been developed for the most part independently, based on very different assumptions, and have been made without adequate consideration of the interrelationships among them. One set of projections, by Dean and McCorkle (1961), included all major crop and livestock groups as well as the major resources in California. However, the projections are related primarily to State output of crop groups and to regional requirements for major resources in the production of the total bundle of agricultural commodities. The need now exists for a more extensive and current set of projections to aid in industrial and governmental planning.

### Objectives of the Study

The ultimate objective of this study is to provide a set of California agricultural projections which are:

- for an intermediate time period (e.g., projection date of 1980)
- comprehensive in coverage of major products, primary resources, and geographic areas within the State
- detailed in specific crop groups by area of the State, and
- internally consistent.

However, because many years of research are required before analysis of all the important variables shaping Cal-

ifornia agriculture can be completed and applied in detail to all major resources and products, the scope and methods used in this study are carefully limited.

**Research focus.** The basic assumptions and framework of this study must be formulated soundly to allow other studies to be built upon them so as to achieve the ultimate objective through additive research. The detailed projections of this study focus on location of field and vegetable crop production within the State. Estimates of resource requirements focus on land and water. Gross projections of orchard and vineyard crops and minor field crops and vegetables, though not covered in detail, are included to project total resource requirements. To project product prices and total input costs, the cost of resources other than land and water also are estimated.

The practical orientation of this research is to inventory land resources by major production area, determine the gross requirements for all urban uses and crops not receiving detailed attention, and then to project the locations and requirements for the major study crops subject to the residual resource constraints. Water resources are also inventoried in areas where they may restrict production before the land resources become limiting. All other resources (e.g., fertilizer, machinery, etc.) are assumed available in unlimited supply at specified unit costs.

**Specific objectives.** The impact of the natural resource endowments on the location of California's field and vegetable crop production are analyzed with all other variables set at exogenously determined levels or unit costs. Rather than predicting the equilibrium conditions, the research conclusions take the form: if X, then Y. That is, if the set of exogenous variables, X, were to occur as specified, then it is projected that the set of endogenous variables, Y, should also occur. These are, therefore, condi-

tional projections. The following questions have been answered for the target year 1980:

1. Will California have the productive capacity to produce its current share of the nation's food and fiber market?
2. Can California produce the share of national output projected by recent trends?
3. What will be the locational structure of field- and vegetable-crop production which will maximize profits to producers if they supply the share projected by recent trends? How does it compare to the optimal 1961-65 locational pattern estimated by a similar model for that period?
4. What will be the imputed farm price of each commodity if perfect competition prevails? How will it compare with current price?
5. What will be the imputed rents on land and water resources, where restricting, under perfect competition?
6. What will be the requirements for water and irrigated land in each region of the State in 1980 as compared to the present?

7. How will the feed-grain production be distributed among the various feed grains if total net energy is produced at least cost?
8. At what maximum price of water will all alluvial soil on the west side of San Joaquin Valley come into production?
9. What impact would alternative rates of urban expansion have on resource requirements and optimum cropping patterns?

The emphasis of the study thus is on projections of resource use in 1980; however, analysis of the average 1961-65 period provides a useful basis of comparison for analysis of change. The study provides estimates of location of production in California, based on comparative advantage of production, by areas that are homogeneous with respect to soil and climatic conditions. Urban land use also is estimated for these areas. It should be emphasized that, although detailed area projections are reported, the basic purpose is to provide aggregate guides for resource needs for the agricultural industry rather than for the individual farmer in a specific area.

## FRAMEWORK OF ECONOMIC ANALYSIS

### General Considerations

This report uses an approach of comparative statics; that is, an analysis is made of the base period (1961-65) resource use under given model specifications. Changes in specifications for 1980 are then determined by side-analysis, such as the effect of urbanization on availability of land, the demand for agricultural products from California, yield and cost estimates, and availability of irrigation water by region within the State. With such information, analyses are made for 1980 to answer the questions raised in the introduction as to the availability of land for agricul-

tural production, the water requirements for production, and the resource and product prices associated with these production levels.

Major attention is centered on location of production within California, with detailed specification of production areas having similar soil and climatic characteristics. Thus, we explicitly treat comparative advantage among subareas within the State. The competitive position of California with respect to other regions of the country is taken as given for the base period analysis. For 1980, demand for California production is based on United States demand levels



and on estimates of the share of production that will be produced in California. Thus, although recognition is given to possible changes in interregional competition between the base period and 1980, it was not feasible to include in the model the production and resource conditions in regions outside California. Before turning to the particulars of this study, it is useful to review the general location framework from which our model is derived.

## Location of Production

Agricultural economists have a particular interest in location and spatial-equilibrium theory because of the extensive nature of production of many crops, the importance of transportation costs, and the need for a framework for analyzing the competitive position of regions. In location analysis, von Thunen (1930) provided a basic theoretical development in his analysis of agricultural production patterns as influenced by transportation costs for various commodities, and the resulting patterns of land rents.

Further developments in location analysis and in general equilibrium models including dimensions of space and form are noted briefly. Weber (1928) studied the effects of raw material prices, wages, and transportation costs on the location of particular industries. Hoover (1937) is credited by Lefebvre (1958) for combining the notions of Weber with contemporary theory of the firm. Other important contributions include those by Lösch (1954) and Isard (1956) in broadening the scope of location models toward more general equilibrium constructs. Contributions were also provided by neoclassical economists, such as Enke (1951), Samuelson (1952), and Beckmann and Marschak (1955), by the introduction of transportation costs into interregional analysis, and the suggested use of programming models for analysis. Lefebvre (1958) developed a more general analysis pre-

sented in an activity analysis framework. Takayama and Judge (1964b) reformulated Samuelson's formulation as a quadratic programming problem. There have been numerous applications of this theory to both plant location and production location problems in agriculture. Bressler and R. A. King (1970) provide a most useful framework for analyzing markets, prices, and interregional trade, with particular reference to agricultural products.

Theoretically, we have the necessary framework for the analysis of agricultural production and processing under competitive conditions and for determining static equilibrium among the various regions of the country. The basic determinants of location include the regional endowment of resources such as land and water; the production and cost relations for final commodities, such as lettuce, and for intermediate commodities, such as feed grains used in livestock and poultry production; the transportation, processing, and storage cost functions connecting markets in space, form, and time; and the demand functions for commodities. Consideration must be given to the specific type of resources, and the time period of analysis, since labor may be "fixed" by region in the short run, but mobile in the long run. Of importance to California is the fact that water available in the northern counties can be transported to the southern counties with construction of water diversion schemes. Thus, care must be given to the interpretation of the nature of the model specifications for our static "time-slice" spatial equilibrium analysis.

A complete model would include both the agricultural and nonagricultural sectors of the economy. The first simplification is that we analyze agricultural production and processing with other sectors taken as given with respect to location and prices. Second, there are a fixed number of discrete location

points at which production or consumption may take place, rather than a continuous plane of locational possibilities. Third, each region is endowed with a given set of productive factors at a given point in time. Fourth, production can take place at any region using available resources or transportable intermediate commodities (Lefebvre, 1958, pp. 111-12; Takayama and Judge, 1964a; and King, 1965, pp. 36-38). Fifth, production functions are defined for all commodities, but coefficients may differ by region. Input-output relationships are defined as linear and homogeneous of degree one, but alternative production processes may be defined for each commodity in each region.<sup>2</sup> Sixth, transportation costs are taken as given and independent of the quantity shipped.<sup>3</sup> Seventh, perfect competition is specified under which no firm can affect the market price by adjusting its output. Eighth, regional demand functions are known for all final commodities.

With the above model specification, it is theoretically possible to obtain

equilibrium levels of production, consumption, and prices, by region;

the associated flows of final and intermediate commodities among regions;

and the imputed prices or rents to the fixed resources.

The general nature of activity analysis models applicable to agricultural production and processing plant location is summarized by King (1965). A survey of published research relating to agriculture is given by Weinschenck *et al.* (1969).

## Location Model for California

This section describes the general characteristics of the model in terms of

four categories; namely, the *resource availability*, the *demand* for commodities, *production and cost relations*, and *particular restraints* of the model. The development of particular coefficients for the base-period model and the analysis of change between 1961-65 and 1980 is discussed in detail later.

**Resource availability.** Because California soils and climatic conditions differ considerably, particular attention is given to the delineation of regions that are homogeneous with respect to these characteristics. The model specifies 115 homogeneous production regions within the State, comprising some 19.6 million acres of land with a potential for agricultural production. Methods used in delineating these regions are discussed in the next section, *Homogeneous Production Areas*.

Not all of this land is available for production, however, and estimates are made of (a) urban use; (b) public use; and (c) semiagricultural use. Estimates are made for the base period *urban use* of land by homogeneous production areas, and, also, for projected increases in urban use to 1980. The effect of alternative levels of urban expansion are explored in the 1980 model analyses. *Public land use* includes such categories as public roads, military reservations, and parks. Public land use in homogeneous production areas was estimated at 0.8 million acres in 1964, and this level was also specified for the 1980 analyses. *Semiagricultural land use* includes farmsteads, farm roads, canals, feedlots, typical acreage of crop failure, and forced idle land. Estimates for this category were made for the base period and for 1980. In the base period, 4.1 million acres are estimated for urban, public, and, semiagricultural uses in homoge-

<sup>2</sup> The assumption of constant returns to scale can be relaxed somewhat by using different per-unit costs of production in alternative model runs. The new per-unit production costs could simulate different farm sizes.

<sup>3</sup> This assumption is made for the sake of simplicity. Agricultural demands on transportation during the peak season are undoubtedly enough to affect the unit cost. However, this assumption is not nearly so unreasonable in this case with only agricultural production variable as if an equilibrium for the entire economy were the objective of the study.

neous production areas, leaving 15.5 million acres for agricultural production. Estimates of nonagricultural land use in the base period and for 1980 are presented in the section, *Conditional Projections of Urban and Public Land Use*; however, a higher level of urban expansion is considered in a subsequent section.

Water availability restricts production in certain regions of the State, such as the coastal valleys of Santa Barbara County, the coastal terraces of San Mateo and Santa Cruz counties, the high elevation mountain counties, and the desert areas of Antelope and Owens valleys. The amount of irrigated acreage provides the effective restraint on production rather than total available acreage for these areas. In other regions, it is expected that water development projects will provide adequate irrigation water by 1980 so that irrigated acreage as such is not specified as a restraint to production. Discussion of water restraints is given in the section on *Allocation Model Restraints*. Regional differences in water cost are introduced in the coefficients of typical costs of producing commodities in the various homogeneous production areas.

**Demand for commodities.** For the base-period analysis, California production is taken as given. No explicit analyses are undertaken as to possible non-equilibrium situations for particular commodities in the production and trade between California and other regions of the country. Although such an analysis might be desirable, it was impossible if primary emphasis were to be given to regions within California. Basically, we treat all of California as one region in terms of prices facing producers; that is, the farm price is equal in each homogeneous producing area.

Projections for 1980 are based on a study of United States demand for agricultural commodities by Daly and Egbert (1966a, b), with some modifications and extensions for particular com-

modities. A detailed explanation of these projections and methods is given in the section, *Conditional Projections of Demand*. In brief, two alternative estimates are obtained for the demand for California production in 1980, with both based on United States demand levels in that year. The first specifies California production to equal its share of the 1961-65 United States production. If California produced 50 per cent of United States production in the base period, we specify that it will produce 50 per cent of the 1980 level United States production. The second method is based on an analysis of the change, if any, in the share of United States production produced in California. With an estimate of this projected share, California production is estimated at this specified percentage of 1980 United States production. There are exceptions to this approach, mainly in the analysis of the feed-livestock sector where an attempt is made to account for inter-regional competition in the production of poultry and livestock and the inter-regional flow of feed grains that characterizes California's industry.

**Production, yield, and cost relations.** This study gives primary emphasis to the location of crop production by subregions in the State. Livestock production is specified for the State to allow estimates of the derived demand for feed grains and other concentrates and roughages that may be produced in California or shipped in from other regions. The crops explicitly included in the regional allocation model account for 72 per cent of the harvested acreage in 1961-65.

Orchard crops and certain vegetables, aggregating to some 1.7 million acres in 1961-65, are treated differently than the included commodities. It is assumed that the high-value orchard crops are located optimally in the base period, and locations are considered to be predetermined. Thus, acreage devoted to these crops (plus irrigated pasture and non-

alfalfa hay acreage) is estimated by homogeneous production areas and then deducted from the available land supply for each region. For the State, these excluded commodities accounted for 3.2 million acres. For 1980, estimates were made, both for the demand and the yield levels for the excluded crops, providing estimates of the required acreage for this production. It was specified that the high-value orchard crops would remain in current locations except where forced out by urban expansion. In cases where location shifts are required, production would take place in areas with similar climatic regions of the State. A more detailed explanation of these excluded commodities is given in the section on *Allocation Model Restraints*.

Per-acre yield and cost of production (excluding land cost) data are developed for the various commodities in the various homogeneous production areas. The base-period data were taken from published yield and cost information adjusted to the study regions based on the judgment of resource and crop production experts. Projected yields for 1980 are based on analysis of trends plus advice on probable changes in technology from production experts. Nonland costs of production per acre are projected to increase by 23 per cent by 1980 and the base-period costs are adjusted accordingly for the 1980 analyses. The yield and cost data are more fully discussed in the section on *Conditional Projections of Yield and Production Costs* and in a report by Shumway and Stults (1970).

All producers in a given homogeneous producing area with similar soil and climatic conditions are assumed to have identical yield and nonland production costs for each commodity. This results in a unique nonland cost and yield estimate for a particular production process in a given production area. Costs and yields, of course, vary by area. The production function for each commod-

ity is linear and homogeneous with constant returns to scale. In such a formulation, the supply function for the area is perfectly elastic at the given nonland cost level unless resources are limiting; then, the imputed values to the fixed resources would provide an additional cost element. A perfectly competitive model is assumed in which all producers are assumed to maximize profits. The distribution of output among farms in a given production area is not determinant under such a formulation. Total production, by area, is limited by the particular resource mix of that region, its comparative advantage with other areas, and the level of demand for all commodities.

**Particular restraints of model.** We have discussed the major restraints in the problem of allocation of production to various areas of the State. For a particular period, the demand for every commodity is assumed "given" and perfectly inelastic. Total production in each area is limited only by the net acreage available to the model crops. However, production of irrigated crops in an area may be limited by water available for irrigation. Further, production of a particular commodity may be limited by a specified crop rotation requirement. And, finally, because of particular production conditions that may affect either quality or season of maturity, certain restraints are placed on either minimum or maximum quantities that may be produced in a given region. The particular restraints are discussed more fully in the subsequent section on *Allocation Model Restraints*.

## Linear Programming Allocation Model

An activity analysis framework for the solution of the problem of location among all regions in the country, although theoretically appealing, is not feasible in this study. Rather than specifying demand functions as such, we have obtained estimates for quanti-

ties produced in California for both the base period and for 1980. With production levels specified, our problem is to determine the comparative advantage of regions within California based on given cost and yield data. The basic approach is similar to that used by Egbert and Heady (1961, 1963) in analyzing regional adjustments in grain production in the United States. These authors show (1963, p. 12) that, with demand predetermined and ignoring transfer costs, it is possible to specify the problem in terms of minimizing costs of production subject to certain restraints, rather than in terms of profit maximization.

The linear programming model used in this study is outlined below. The essential characteristics of the model, then, include fixed levels of demand for each commodity, given yield and non-land costs of production levels, given levels of the land resource available by area, and certain restraints as to the amount of irrigated acreage, crop rotation requirements, and particular production limitations as to season and region of production.<sup>4</sup> This model may be stated mathematically as follows:

Minimize total nonland cost of production, or

$$\sum_{i=1}^r \sum_{j=1}^s \sum_{k=1}^t C_{ij}^k X_{ij}^k \quad (1)$$

subject to:

Output

$$\begin{aligned} \sum_{j=1}^s \sum_{k=1}^t A_{1j}^k X_{1j}^k &\geq D_1, \\ &\vdots \\ \sum_{j=1}^s \sum_{k=1}^t A_{rj}^k X_{rj}^k &\geq D_r, \\ \sum_{j=1}^s \sum_{k=a}^d A_{hj}^k X_{hj}^k &\geq D_m^a, \\ \sum_{j=1}^s \sum_{k=q}^h A_{nj}^k X_{nj}^k &\geq D_n^q, \end{aligned} \quad (2)$$

Production area acreage

$$\begin{aligned} \sum_{i=1}^r \sum_{j=1}^s X_{ij}^1 &\leq L^1, \\ &\vdots \\ \sum_{i=1}^r \sum_{j=1}^s X_{ij}^t &\leq L^t, \end{aligned} \quad (3)$$

Irrigated acreage

$$\begin{aligned} \sum_{i=1}^r \sum_{j=1}^{s-2} X_{ij}^1 &\leq I^1, \\ &\vdots \\ \sum_{i=1}^r \sum_{j=1}^{s-2} X_{ij}^t &\leq I^t, \end{aligned} \quad (4)$$

<sup>4</sup> Specific seasonal requirements of lettuce and melons are incorporated in the demand equations. Additional limitations on regions of production are imposed as follows: (a) The lower quality of potatoes produced on peat soils in the otherwise high-yielding San Joaquin Delta area restricts its disposition to the seed market. Acreage in this area is restrained at a maximum of 10,000 acres in all models. (b) There are important varietal differences in at least two commodities produced in different parts of the State. Dry beans produced in the Central Valley are generally of a different variety than those produced along the coast. Likewise, the type of potato produced in the mountain valleys faces a somewhat different demand market than other potatoes produced. The unit cost of producing dry beans in the Central Valley and potatoes in the mountain valleys is higher than in some other areas. However, because of the peculiarities of the product in the specific areas mentioned, production would likely not shift to other areas in an optimal pattern. Because a product price differential between regions has been assumed away in the development of these models, minimum output restraints will be imposed on the production of dry beans and potatoes in the Central Valley and mountain valleys, respectively.

Individual crop acreage (rotation requirements)<sup>5</sup>

$$\begin{aligned} X_{11}^1 &\leq R_{11}^1, \\ &\vdots \\ X_{rs}^t &\leq R_{rs}^t, \end{aligned} \quad (5)$$

Nonnegative input usage

$$X_{ij}^k \geq 0; \quad (6)$$

where

$C_{ij}^k$  is cost of producing one acre of commodity  $i$  by process  $j$  in production area  $k$ ,

$X_{ij}^k$  is acreage of commodity  $i$  produced by process  $j$  in area  $k$ ,

$D_i$  is minimum output of commodity  $i$  grown in California,

$D_m^a$  is minimum output of dry beans grown in the Central Valley,

$D_n^g$  is minimum output of potatoes grown in the mountain valleys,

$A_{ij}^k$  is yield of commodity  $i$  grown by process  $j$  on one acre in area  $k$ ,

$L^k$  is maximum acreage of cropland for model crops in area  $k$ ,

$I^k$  is maximum irrigated acreage available for model crops in area  $k$  ( $I^k \leq L^k$ ),

$R_{ij}^k$  is maximum acreage of commodity  $i$  grown by process  $j$  in area  $k$  due to rotational requirement ( $R_{ij}^k \leq L^k$ ),

$a, \dots, d$  are Central Valley areas,

$g, \dots, h$  are mountain valley areas,

$m$  is dry beans,

$n$  is potatoes,

1,  $\dots$ ,  $s-2$  are irrigated production processes,

$r, s, t$  are upper limits on commodity, process, and area numbers, respectively.

The dual problem of that specified above is:

Maximize returns to fixed resources

$$\sum_{i=1}^r \sum_{j=1}^s \sum_{k=1}^t (U_i D_i + V^k L^k + W^k I^k + Y_{ij}^k R_{ij}^k), \quad (7)$$

subject to the restriction that the imputed value per acre of output less rents to fixed resources is equal to or less than per-acre nonland costs; or

$$A_{ij}^k U_i - V^k - W^k - Y_{ij}^k \leq C_{ij}^k, \quad (8)$$

and that imputed product price and resource rents are nonnegative; or

$$U_i, V^k, W^k, Y_{ij}^k \geq 0. \quad (9)$$

The additional notation required is as follows:

$U_i$  is imputed price of commodity  $i$ ,  
 $V^k$  is imputed rent to an acre of land in production area  $k$ ,

$W^k$  is imputed rent to an irrigated acre in production area  $k$ ,

$Y_{ij}^k$  is imputed rent to an acre of the individual crop restraint of commodity  $i$  produced by process  $j$  in production area  $k$ .

<sup>5</sup> Also quality restraint on potatoes in the San Joaquin Delta.

The format of the dual problem portrays the equilibrium relation between resource and product prices. When the system is in equilibrium, the product

value per acre in a particular area is equal to nonland costs per acre plus all rents to fixed resources.

## HOMOGENEOUS PRODUCTION AREAS

### Resource Variables

A homogeneous production area (HPA) refers, in this study, to spatial units having a degree of internal homogeneity in the natural resource endowment—soil, climate, and water. The underlying concept of such a delineation is to group productive units which face similar production relationships, costs, and prices in order to minimize aggregation bias. By stratifying the data according to resource endowment, attention is focused on spatial differences in nontransferable factors affecting yields and production costs.

It is desirable to follow such administrative boundaries as county lines in the delineation of areal units because most data are collected using administrative units as a base, and results can be understood most easily if they relate to familiar boundaries. However, a typical county in California is an extremely heterogeneous production area. Most counties include valleys and mountains, shallow soils and very deep soils, and areas with surplus and deficit water supply. For example, San Diego County has land in four major plantelimate zones, ranging from marine dominated coastal valleys to the desert, and soil conditions which vary just as widely. Reliance on county boundaries results in the delineation of production areas which are so heterogeneous that one may be but slightly less justified in considering the entire State to be one HPA. Although the practical problems associated with data collection and reporting of results are increased markedly, county boundaries will have to be ignored if realistic HPAs are to be specified.

The first goal in this study is to obtain the most reasonable spatial aggregation of productive units for which a single set of production conditions could apply. Soil productivity and climatic conditions are hypothesized to be the key natural resource variables affecting agricultural production. These are the factors of production which, in the long run, are least susceptible to change. Although soil productivity and microclimate can be modified to some extent by production practices, rents do accrue to specific land units because of the inherent natural-resource endowment. Other factors of production, such as labor, equipment, and managerial ability, are more flexible over space and time.

In addition, there are aspects of the market situation which are directly associated with individual land units over relatively long time periods. The major one is distance from the market. Depending on the time horizon of the study, the location of processing plants may be relatively inflexible. Although these factors are not emphasized in defining HPAs in this study, any variable which can be stratified spatially may be incorporated conceptually into the criteria for delineating homogeneous production areas. The shorter the time horizon of the study the more variables must be assessed in obtaining realistic HPAs.

Similarity in soil and climate are sought in the delineation of HPAs through the analysis of general soil maps and plantelimate studies. It is for these areas that land, rotation, and water restraints and cost and yield estimates are relevant.

In the following subsection, the method used to delineate HPAs is de-

fended as a means of effectively limiting aggregation bias. The remainder of the section will then be devoted to a discussion of (1) the soil categories, (2) the climate zones, and (3) the combination of the two in identifying HPAs for this study.

### A Note on Aggregation Bias

Day (1963), Miller (1966), Lee (1966), and others, including Sheehy and McAlexander (1965), Frick and Andrews (1965), and Barker and Stanton (1965), have dealt with the problem of aggregation bias in agricultural models. This bias may be experienced in any macro model which utilizes benchmark- or average-unit data. In a production model, the effect is to estimate aggregate supply at a higher level, for any given price, than it would be if a linear model had been solved for each production unit in the aggregation. Day suggests three sufficient conditions which, if met by all production units, would prevent aggregation bias in a macro supply problem: (1) identical input-output matrices, (2) proportionate variation in the net returns vectors, and (3) proportionate variation in the restraint vectors. The method of aggregation used in this study is analyzed here in light of these criteria.

By delineating HPAs according to similar soil and climate, we have grouped together farms with similar input-output matrices. Those with very different coefficients of output are separated into different areas.

The unit price vector for nonrestrictive resources is probably similar for all the farmers in a given HPA. Farms within most HPAs are reasonably closely situated, so the competitive environment in the resource market should be similar for most farmers. Although

some economies of scale are possible in agriculture, most of the State's production comes from farms which are large enough to take advantage of major economies of size.<sup>6</sup> In a perfectly competitive environment, product price equals marginal cost. Therefore, not only should the net returns vector of one farmer be proportional to that of another in the same HPA, but in many cases they may be equal.

Because of the methods used in specifying restraints in this study, nonproportionality in the restraint vectors is not expected to be a significant source of aggregation bias. Specifically, land is the only restricting resource to production in all HPAs. In those areas where water is expected to restrict irrigated production before land becomes limiting, the restraint is not imposed on total water available; instead, it is imposed on total land that can be irrigated. In all other areas, the irrigation restraint is omitted. In each area where a specific irrigation restraint is imposed, it is based on actual past irrigated acreage. Therefore, the possibility of overestimating supply in these areas, if water is not uniformly available on all farms, is minimized. Finally, the rotation restraints are estimated as a function of land available. Because they never exceed the total land restraint, it is not necessary that the rotation requirement be uniformly distributed throughout the HPA in order to avoid aggregation bias. It may be possible that another resource, not assumed to be restricting in this analysis (e.g., capital, labor, or machinery), actually limits production or alters the cropping pattern on particular farms in the target year. However, other studies of California cropping systems have concluded that these resources are not normally restricting in actual prac-

<sup>6</sup> In several economies of size studies conducted on California field crop farms by Dean and Carter (1960), Moore (1965), and Faris and Armstrong (1963), it has been observed that few additional internal economies are possible as farms become larger than 600-1,000 acres. The 1964 Census of Agriculture reports that two-thirds of field crop output in California is produced on farms larger than 700 acres (U. S. Bureau of the Census, 1967, pp. 94-105).



tice. It has been pointed out by Dean and Carter (1961) that adequate credit facilities are available, labor can be hired, and excess machine capacity often exists in relation to the amount of land available.<sup>7</sup> Therefore, the problem boils down to the natural resource endowment being the primary restriction on production, and nonproportionality in the restraint vectors should not be a serious cause of aggregation bias.

It is concluded that Day's sufficient conditions for avoiding bias in aggregation are satisfied reasonably well by the method of grouping production units used in this study. While some bias is inevitable, it should be minimal. Certainly, it will be far less important than had very dissimilar production units been grouped (e.g., by following county boundaries).

## General Soils Map

Soil surveys have been completed in varying detail during the past half century on virtually all privately owned land in California. These surveys have been conducted on an area by area basis and have typically concentrated on microclassification of soils by soil series.

Storie and Weir (1953) depicted the general soil geography of the entire state. They based their report on an analysis of then current detailed and reconnaissance soil surveys and grouped individual soils into 18 major categories. They rated each category according to its "... general land use suitability for commercial timber, grazing, nonirrigated field and truck crops, and irrigated field and truck crops." Subsequently, additional work was done on the general soil map, the number of categories was expanded, and the map, acreage, land use suitability, and Storie-

Index rating were developed by Storie for each county, in an unpublished manuscript, "Soil Resources of California: County Inventory of Soil Resources," 1957.

The Soil Conservation Service has recently been authorized to prepare general soil reports for each county in California. Although the maps are much more detailed than Storie's and would therefore be more accurate for some of the inventory work undertaken in this study, these reports were not available for all counties when this study was begun. A limitation to the use of the SCS general soils reports even now is that the soil categories are not uniform for all counties. Each county SCS unit possessed a degree of autonomy in the specification of soil categories; hence, these categories cannot be readily fit together into a consistent soil map for the entire State.

Storie's unpublished manuscript has been used in this study as the basic reference for delineating soils of different agricultural productive capacity. Based upon recommendations by Storie and of Eugene Begg and Gordon Huntington, soils specialists in the Department of Soils and Plant Nutrition at Davis, Storie's soil classes were grouped into 13 agricultural soil categories: four alluvial (numbered 01, 02, 03, and 05), five basin (11-15), and four terrace soils (21-24). A description of typical soils in each category can be found in table 1.

Soils 01-03 are recent alluvial fan and flood plain soils of medium texture; 05 is wind-modified sandy soil; 11 consists of the organic soils; 12 is salt-free basin clay soil; 13 is clay soil with moderate-to-strong salt concentrations; 14 is basin rim soil reclaimed of salts; 15 is unreclaimed basin rim soil; 21 is terrace loam

<sup>7</sup> In addition, it is anticipated that managerial talent and acreage allotments will not alter the optimal production pattern on individual farms. The rationale for this expectation is that (1) it should be possible to purchase adequate managerial talent if not already available on specific farms; and (2) even if the current allotment programs are continued, allotments can be transferred from one HPA to another, through land sales or rentals, so that acreage allotments are not a real restraint to production on individual units.

TABLE 1  
TYPICAL CHARACTERISTICS OF SOIL CLASSES

Soil characteristic	Alluvial fan and flood plain soil number				
	01	02	03	05	
Typical soil series.....	Yolo Hanford Soquel	Sorrento Hesperia	Panoche Gila Surprise	Delhi Marina Coachella	
Depth.....	Very deep	Very deep	Very deep	Very deep	
Profile development.....	Without	Without	Without	Without	
Textures: surface.....	Medium-moderately coarse	Medium-moderately coarse	Medium-moderately coarse	Coarse	
subsoil.....	Medium-moderately coarse	Medium-moderately coarse	Medium-stratified	Coarse	
Drainage.....	Moderately well-well	Well	Well	Somewhat excessive	
Salts or alkali.....	Free	Free-slight	Free-moderate	Free-moderate	
Reaction: surface.....	Slightly acid	Neutral	Moderately alkaline	Varied	
subsoil.....	Slightly alkaline	Moderately alkaline	Moderately alkaline	Varied	
Lime present? surface.....	No	No	Yes	Varied	
subsoil.....	No	Yes	Yes	Varied	
Storie Index rating.....	85-100	85-100	70-100	35-55	
Occurrence.....	Medium-high rainfall zones	Moderately low rainfall zones	Low rainfall zones	General	
Comments.....			Higher saline concentrations are in desert.	Higher saline concentrations are in desert.	
	Basin soil number				
	11	12	13	14	15
	Egbert	Sacramento Tulare Pit	Levis Willows	Fresno Traver	Fresno Traver Lahanton
	Very deep	Very deep	Very deep	Moderately deep-deep	Moderately deep-deep
	Without	Without	Without-minimal	Minimal-medial	Minimal-medial
	Texture: surface.....	Organic medium	Moderately fine-fine	Medium-moderately coarse	Medium-moderately coarse
	subsoil.....	Organic	Fine-stratified	Moderately fine-medium	Moderately fine-medium
	Drainage.....	Poor	Somewhat poor-poor	Moderately well	Somewhat poor
	Salts or alkali.....	Free	Free-slight	Free-slight	Moderate-strong
	Reaction: surface.....	Moderately acid	Varied	Slightly alkaline	Moderately alkaline
subsoil.....	Slightly acid	Moderately alkaline	Moderately alkaline	Moderately alkaline	
Lime present? surface.....	No	No	Yes	Yes	
subsoil.....	No	Yes	Yes	Yes	
Storie Index rating.....	60-80	40-60	5-25	40-80	10-30
Occurrence.....	San Joaquin Delta	General	General	San Joaquin Valley	Arid valleys
Comments.....		Basin clays	Soil 12, but with saline-alkali problems	Basin rim soils, reclaimed of salts	Unreclaimed soil 14
	Terrace soil number				
	21	22	23	24	
	Ramona Tehama Rohnerville	Porterville Denverton	Huerhuero Hillgate Bieber	San Joaquin Redding	
	Deep	Deep	Shallow	Shallow	
	Medial	Without	Maximal	Maximal	
	Texture: surface.....	Medium-moderately coarse	Fine	Medium-moderately coarse	
	subsoil.....	Moderately fine	Fine	Fine	
	Drainage.....	Moderately well	Well	Moderately well	
	Salts or alkali.....	Free	Free	Free	
	Reaction: surface.....	Moderately acid	Neutral	Moderately acid	
subsoil.....	Slightly acid	Moderately alkaline	Slightly acid		
Lime present? surface.....	No	No	No		
subsoil.....	No	Yes	No		
Storie Index rating.....	50-80	40-60	35-50		
Occurrence.....	General	Central Valley and South Coast	General except desert and mountain valleys		
Comments.....		Clay terrace soils	Claypan Hardpan		

soil with medial profile development; 22 is terrace clay soil; 23 is claypan soil; and 24 is soil underlain with hardpan.

While Storie's manuscript was used as the primary source of data, other information, both published and unpublished, has been utilized for refinements on acreages, boundaries, and classification. The U. S. Soil Conservation Service (1968) general soil reports were used for Napa, Solano, Sonoma, Stanislaus, Yolo and Yuba counties. The general soil maps published in recent soil surveys were used for Glenn County (Begg, 1965), Tehama County (Gowans, 1967), and for a portion of Alameda County (Welch, *et al.*, 1966). A reconnaissance soil survey by Gowans and Lindt (1965) was used for Sutter County. Alan Carlton, soils specialist in the Department of Soils and Nutrition at Davis, modified the map for San Joaquin County from more recent data. Begg and Huntington recommended modification in several other counties. County farm advisors and agricultural commissioners provided estimates of the acreage of land classified by Storie as saline-alkaline which has since been reclaimed of salts. They also suggested a few alterations in delineations and acreages.

## Plantclimate Zones

Climate is one, and perhaps the most important, of the fundamental determinants of what plants can be grown in a given area. The word climate encompasses such variables as annual rainfall, its seasonal distribution, light, temperature, humidity, and air movement.

In recent years extensive research has been undertaken at the University of California to determine which of the climatic variables most affect plant growth and to delineate major zones within which crop adaptability is similar. It has been observed that in all the principal farming areas of California temperature is the major climate factor which controls plant growth. Rainfall is

less important, except where the seasonal distribution causes plant damage or where it is so sparse that the cost of irrigation water becomes prohibitive.

Kimball and Brooks (1959) published a preliminary mapping of 16 plantclimate zones in California in which areas with similar effective day and night temperatures were grouped. Although effective day and night temperature is only one measure of climate, the important factors which combine to determine temperature also greatly affect other climatic measures. The chief factors which determine temperature in different parts of California include distance from the equator, elevation, influence of the Pacific Ocean, influence of the continental air mass, mountain ranges, and local terrain (Editors of *Sunset Magazine*, 1967, p. 8). Several of these factors also affect rainfall, humidity, and light intensity. Therefore, by directly introducing temperature as the key variable in delineating plantclimate zones, other climatic measures were indirectly accounted for because of the degree of correlation between them.

A revision of the plantclimate map was published by the Editors of *Sunset Magazine* (1967, pp. 17-27). It divided California into 19 zones for the benefit of the home gardener. In consultation with Kimball, and his successor, DeWayne E. Gilbert, the basic plantclimate delineation published in *Sunset* was followed in this project. Certain revisions prompted by the specific crops in the study and additional research findings since the preparation of the map were recommended. In general, the changes consisted of grouping the minor thermal belts with their valley floor counterparts, splitting the Central Valley laterally in two additional places, splitting the north coastal climates laterally, and separating the San Joaquin Delta from the coastal climates. This set of modifications resulted in the delineation of 19 plantclimate zones which

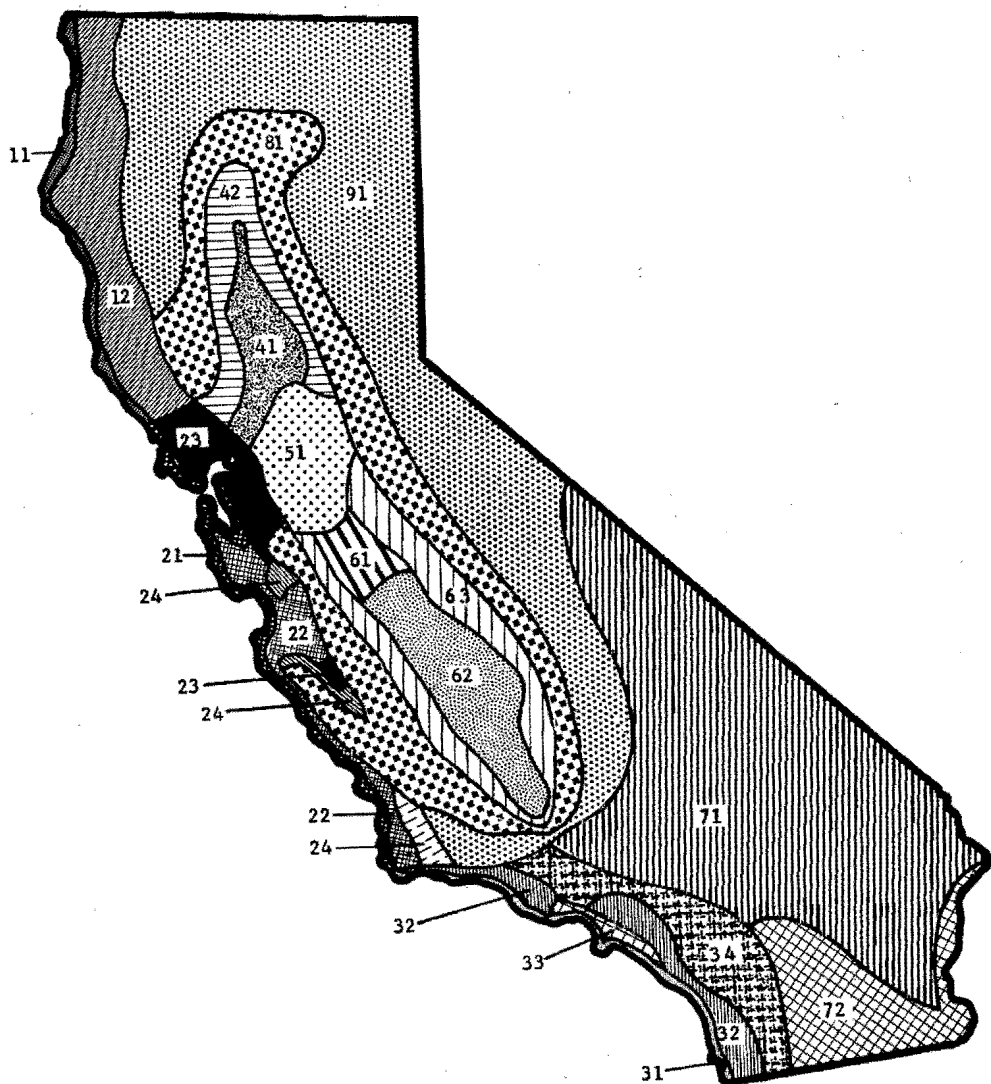


Fig. 1. Plantclimatic zones.

are shown in figure 1 and described briefly in table 2.

For purposes of presenting the findings of this study, the 19 climates have been grouped into nine regions (identified by the first digit of the climate code) which, with one exception, follow plant-climate boundaries. The one exception is that climate zone 24 is the same as 51,

but was separated from 51 in order to keep the regions contiguous. Hence, there are 20, rather than 19, climates listed.

### Homogeneous Production Areas

An overlay of the climate zones on the soil map results in the delineation of 115 different soil-climate combinations,

TABLE 2  
DESCRIPTION OF CALIFORNIA PLANTCLIMATE ZONES

Zone	Description
11	Marine influence completely dominates this North Coastal climate. Sunshine intensity is markedly reduced by fog. Humidity is the highest of any of the climates. Typical mean daily maximum temperature in August, the hottest month, is 61° F; typical mean daily minimum in January, the coldest month, is 41° F.
12	This climate zone consists of the cold winter valley floors along the North Coast. Humidity is high. Typical mean daily maximum temperature in July is 84° F; typical mean daily minimum in January is 33° F.
21	Marine influence dominates this Central Coastal climate 98 per cent of the time. There are virtually no frosts. Typical mean daily maximum temperatures in September range from 67° to 72° F; typical mean daily minimum in January is 42° F. Fog reduces sunshine intensity. Humidity is high.
22	This Central Coastal climate is dominated by the ocean 85 per cent of the time. It has regular summer afternoon winds. Humidity is high. Winters are colder and summers are warmer than in zone 21.
23	The temperatures in these cold winter basins along the Central Coast are moderated by occasional marine influence. Humidity is relatively high. Record low temperatures range from 11° to 22° F in different parts of the climate.
24	See zone 51.
31	This mild South Coastal climate is almost completely marine dominated. Humidity is high. Record low temperatures range from 20° to 33° F in different parts; record highs average 105° F.
32	This climate consists of air-drained thermal belts surrounding the South Coastal cold winter basins. Marine domination varies throughout the zone from occasional to 85 per cent of the time. Record lows range from 17° to 20° F.
33	Cold winter portions of the South Coast are included in this zone. Marine domination in this climate also varies from occasional to 85 per cent of the time. Record lows range from 14° to 24° F; record highs average 112° F.
34	This climate comprises Southern California's interior valleys and terraces. The continental air mass dominates the climate at least 85 per cent of the time. Humidity is low. Record lows range from 7° to 23° F; record highs average 115° F.
41	The Sacramento Valley floor is characterized by a long growing season of almost constant sunshine. The growing season is shorter, because of later spring and earlier fall rains, and the humidity higher than in the San Joaquin Valley (climates 61 and 62). Record lows for climates 41, 61, and 62 combined range from 13° to 18° F; record highs range from 104° to 116° F.
42	This climate is the thermal belt surrounding the Sacramento Valley. The cold air drains to the valley floor causing this climate to have milder winters. Record lows in climates 42 and 63 combined range from 15° to 21° F; record highs are similar to the valley floors. Other characteristics are similar to climate 41.
51	Occasional marine influence keeps winter temperatures higher and summer temperatures lower than they would otherwise be. While maximum and minimum temperatures are similar to climate 23, humidity is considerably lower. This climate consists of valley areas in the transitional zone, which is further inland than climates 22 or 23.
61	This climate is bordered by climates 51 on the north and 62 on the south. Humidity is higher than in climate 62, but it is still low. Rains are generally restricted to a six-month winter period.
62	This climate is characterized by the longest growing season and the lowest rainfall of the four zones which make up the Central Valley floor. Summer temperatures are generally slightly warmer.
63	The somewhat higher elevations which drain into climate zones 61 and 62 are grouped into this climate. This thermal belt is noted for substantially milder winters than its valley floor counterpart. In some areas, the temperature difference may be as high as 10° F at the same latitude.
71	The medium- to high-elevation deserts in Southern California comprise this climate. It is characterized by extremely wide temperature divergence between night and day and between winter and summer. Record lows range from 0° to 6° F; record highs range from 114° to 117° F. There are more than 110 days each year when the temperature exceeds 90° F and 80 nights when the temperature drops below 32° F.
72	This climate is identified by the lower elevation desert, particularly Imperial and Coachella valleys, with its extremely long growing season. Record lows range from 13° to 19° F; mean daily maximum temperatures in July range from 106° to 108° F.
81	This climate zone, otherwise referred to as the Digger Pine Belt, is made up of the middle elevations. Hot summers and pronounced winters give this zone well defined seasons without the severe winter cold of climate 91 or the high humidity of the coastal climates. Record lows range from -1° to 15° F.
91	Frosts can occur any day of the year in this high-elevation climate. The normal growing season ranges from 100 to 180 days. It is the coldest of California's climates.

which we shall refer to as homogeneous production areas.<sup>a</sup> Their locations are mapped in Appendix A, where each HPA is given a four-digit numeric label: the first two digits identify the soil and the last two identify the climate. The acreage of each HPA was determined by planimetering.

After the projected 1980 acreage of land in urban, public, semiagricultural and nonmodel crop use was calculated, 20 HPAs, including one entire climate zone, were deleted from the model because of insignificant residual acreage. The residual acreage of a deleted HPA was added to that of the next most similar HPA. A minimum of 10,000 residual acres was established as the primary guideline for keeping an HPA in the

model. In addition, HPAs with 10,000–20,000 acres which are very similar to another with a much larger acreage were grouped, and HPAs with nearly 10,000 acres which are greatly different from all other HPAs were retained in the model. Using the primary guideline as the only criteria, 19 HPAs would have been excluded. By applying the supplementary rules, three more HPAs were deleted and two of the 19 were retained to leave a total of 95 in the model. The identification of the specific HPAs that were grouped is given in Appendix table B-1. The climate zone dropped was zone 33 which had a projected 1980 acreage of less than 13,000 acres.

## CONDITIONAL PROJECTIONS OF URBAN AND PUBLIC LAND USE

Urbanization is one of the major factors affecting the location of agricultural production in California. To evaluate the impact of urban expansion on agriculture, it is necessary to distinguish land conversion according to soil type and climatic characteristics. This section develops estimates of current and 1980 land use for urban and public use, by homogeneous production area. Public use includes such categories as public roads, military reservations, and parks. These estimates for 1980 are referred to as conditional projections since they depend on accuracy of forecasts of population growth and the extent of intensive versus extensive land use for urban development.

### Urban Land Requirements

Estimates of current urban land use in California vary from 2.0 million acres (Ruth and Krushkhov, 1966, pp. 46, 48)

to 2.4 million acres (California Conservation Needs Committee, 1961), and to a preliminary as yet unpublished 1968 estimate by the California Conservation Needs Committee of 3.4 million acres. Projections of requirements during the next decade range from 0.7 to more than 1.0 million acres (Ruth and Krushkhov, 1966, p. 48). To adequately assess the impact of urban expansion on agriculture within the context of this study, such projections must be disaggregated in terms of homogeneous production areas.

Urban economists have developed a number of theories for explaining the process of urban agglomeration and expansion (Alonso, 1964; Rao, 1965; and Ruth and Krushkhov, 1966). While some emphasize transitions within the urban sector, others concentrate directly on the issue of expansion onto nonurban land. From the theories of urban expan-

<sup>a</sup> Although no additional delineations were made along irrigation water isocost lines, the cost of water in the San Joaquin Valley was indirectly taken into account when soils 01, 02, and 03 were retained as separate entities in the model. The productive capacity of these soils is similar for most crops; hence, they could be reasonably grouped together on this basis alone. But the natural geophysical boundaries between these soils separate them equally well according to the cost of irrigation water.

sion, a few points stand out which are of value in quantifying urban land requirements by HPA. Three urban economists, Ruth and Krushkhov (1966, p. 17), and Rao (1965, p. 21), agree that the primary variable determining total new land required is the rate of population growth.

Ruth and Krushkhov (1966), further theorize that, in the absence of a comprehensive urban development plan, the two variables which most affect specific land developed are its slope and proximity to the urban fringe. The value of land for agricultural use appears in previous studies not to be a statistically significant variable in determining which land is developed for urban use. Therefore, acreage losses because of urban expansion can be projected without consideration of any resultant agricultural adjustments.

**Population growth.** With net immigration to California averaging 340,000 persons per year in the past decade, total population has increased at an annual rate of approximately 528,000 persons (California Department of Finance, 1967, p. 103). Anticipating that net in-migration will decline gradually to about 300,000 persons annually, and that birth and mortality rates will drop slightly to correspond to the U. S. Bureau of Census (1966) fertility series D,<sup>9</sup> population is projected to be 26.4 million by 1980 (table 3). This estimate represents an annual increase of about 512,000 persons from the 1965 estimate of 18.7 million.

Approximately 94 per cent of this additional population is expected to settle in 25 counties.<sup>10</sup> These counties are illustrated in figure 2. Sixty per cent of the

population increase will be in the Southern California Metropolitan Region (Los Angeles, Ventura, Orange, San Bernardino, Riverside, Santa Barbara, and San Diego counties); 24 per cent in the Bay Area Metropolitan Region (San Francisco, San Mateo, Santa Clara, Alameda, Contra Costa, Solano, Napa, Sonoma, and Marin counties); and 10 per cent in the Sacramento-Stockton Area (Sacramento, San Joaquin, Yolo, El Dorado, and Placer counties), the Fresno Area (Fresno County), the Bakersfield Area (Kern County), and Monterey and Santa Cruz counties. These urban areas are located, almost exclusively, in the best agricultural regions of California (the Central and South Coast and the Central Valley).

**Urban land requirements in urban counties.** Ruth and Krushkhov (1966), for their comprehensive study of urban land expansion in these 25 counties between 1950 and 1964, used research procedures that included measurement from aerial photographs of actual developed land for the two points of time, analysis of a host of general and local explanatory variables, testing of several alternative equations, and projection of urban land requirements for the period 1965-75 in 188 urban submarkets.

Ruth and Krushkhov found the most important determinant of new land required per additional person during the period 1950-64 to be the rate of population growth. Two equations expressing the relationship between these two variables, in the absence of controlled patterns of expansion, were estimated for primary and for extensive land uses in each county. Primary land use include single and multiple family residential

<sup>9</sup> Series D is the lowest of the fertility rates used in the U. S. Bureau of the Census projections. Series B was the fertility level used most frequently by researchers until a few years ago. Series C is currently thought to be the most relevant for the United States. However, in 1966 and the early part of 1967, actual performance in California fell somewhere between C and D (California Department of Finance, 1967, p. 1). Reliance on Series D in these projections is based on the assumption that the fertility rate will continue to decline.

<sup>10</sup> This figure represents a slight increase in the relative concentration in these 25 counties. In 1965, 92 per cent of the State population resided in these counties, with 58 per cent in the Southern California Metropolitan Region, 23 per cent in the Bay Area Metropolitan Region, and 11 per cent in the remaining nine urban counties.

TABLE 3  
TOTAL POPULATION OF  
CALIFORNIA COUNTIES, 1960 AND  
1965, WITH PRELIMINARY  
PROJECTIONS FOR 1980

County	Estimated*		Projected*
	July 1, 1960	July 1, 1965	July 1, 1980
Alameda.....	912,600	1,032,600	1,367,291
Alpine.....	400	400	400
Amador.....	10,000	11,000	18,300
Butte.....	83,200	98,200	127,100
Calaveras.....	10,400	11,500	14,900
Colusa.....	12,200	12,600	11,800
Contra Costa.....	413,200	509,600	836,860
Del Norte.....	17,800	18,300	18,800
El Dorado.....	29,900	43,400	83,715
Fresno.....	368,500	408,200	525,508
Glenn.....	17,400	18,800	21,400
Humboldt.....	104,900	105,200	117,200
Imperial.....	73,000	77,000	90,400
Inyo.....	11,700	14,100	20,800
Kern.....	294,900	330,600	426,723
Kings.....	50,500	67,000	80,600
Lake.....	13,900	17,200	24,100
Lassen.....	13,600	16,900	19,700
Los Angeles.....	6,071,900	6,868,300	8,604,359
Madera.....	40,700	44,300	53,900
Marin.....	148,600	188,600	318,081
Mariposa.....	5,100	6,000	7,400
Mendocino.....	51,000	51,200	54,500
Merced.....	90,900	107,100	151,400
Modoc.....	8,300	8,000	8,700
Mono.....	2,500	4,300	7,800
Monterey.....	195,300	221,600	312,347
Napa.....	66,400	75,700	98,308
Nevada.....	21,200	25,100	28,800
Orange.....	719,500	1,152,300	2,364,585
Placer.....	57,500	72,500	117,241
Plumas.....	11,900	12,300	14,400
Riverside.....	311,700	413,200	774,767
Sacramento.....	510,300	611,900	853,472
San Benito.....	15,500	17,200	21,200
San Bernardino.....	509,000	637,200	1,023,114
San Diego.....	1,049,000	1,197,200	1,681,766
San Francisco.....	741,500	743,100	724,128
San Joaquin.....	251,700	273,600	333,835
San Luis Obispo.....	81,900	100,500	144,500
San Mateo.....	449,100	526,900	749,184
Santa Barbara.....	173,600	243,000	363,628
Santa Clara.....	658,700	893,800	1,553,853
Santa Cruz.....	85,100	104,800	173,098
Shasta.....	60,400	74,700	115,100
Sierra.....	2,200	2,400	2,500
Siskiyou.....	33,000	34,300	37,500
Solano.....	137,100	159,800	236,951
Sonoma.....	148,800	179,500	261,078
Stanislaus.....	158,300	176,000	219,900
Sutter.....	33,700	39,000	51,700
Tehama.....	25,500	28,300	33,700
Trinity.....	9,600	8,800	11,500
Tulare.....	169,400	187,200	249,500
Tuolumne.....	14,500	18,100	28,300
Ventura.....	203,100	302,700	641,501
Yolo.....	66,400	78,900	113,207
Yuba.....	35,100	43,400	81,600
The State.....	15,863,000	18,726,000	26,406,000

\* California Department of Finance (1967, p. 3).

units, commercial, industrial, stock-yards, docks, and related developments. Extensive urban patterns consist of highways, airports, cemeteries, schools, railroad yards, residential estates, parks, and similarly used land.

The primary urban equation is:

$$\log_e \Delta L = -4.51767 + .802238 \log_e \Delta P, \quad (10)$$

and the extensive equation is

$$\log_e \Delta L = -5.76868 + .791069 \log_e \Delta P, \quad (11)$$

where

$\Delta L$  is urban land increase in 10 years in hundreds of acres, and

$\Delta P$  is county population increase in 10 years.

The density of new persons per additional acre of land, which was estimated by summing these equations, varies from 3.5 for an annual county population increase of 300 persons to 11.6 for an increase of 120,000 persons. These equations may be used to predict additional land required in the absence of any pattern controls. However, the actual county projections derived by Ruth and Krushkhov deviated about this "median" projection path when pattern variables were analyzed. With the inclusion of four pattern variables<sup>11</sup> into the equations,  $R^2$  values of .994 for the primary urban category and .974 for the extensive category were obtained.

**Extension of Ruth-Krushkhov projections to 1980.** The only independent variable in the Ruth-Krushkhov prediction equation for which county estimates are available for 1980 is the projected population growth. In the absence of data for the pattern variables,

<sup>11</sup> The authors do not explain precisely what these pattern variables are.



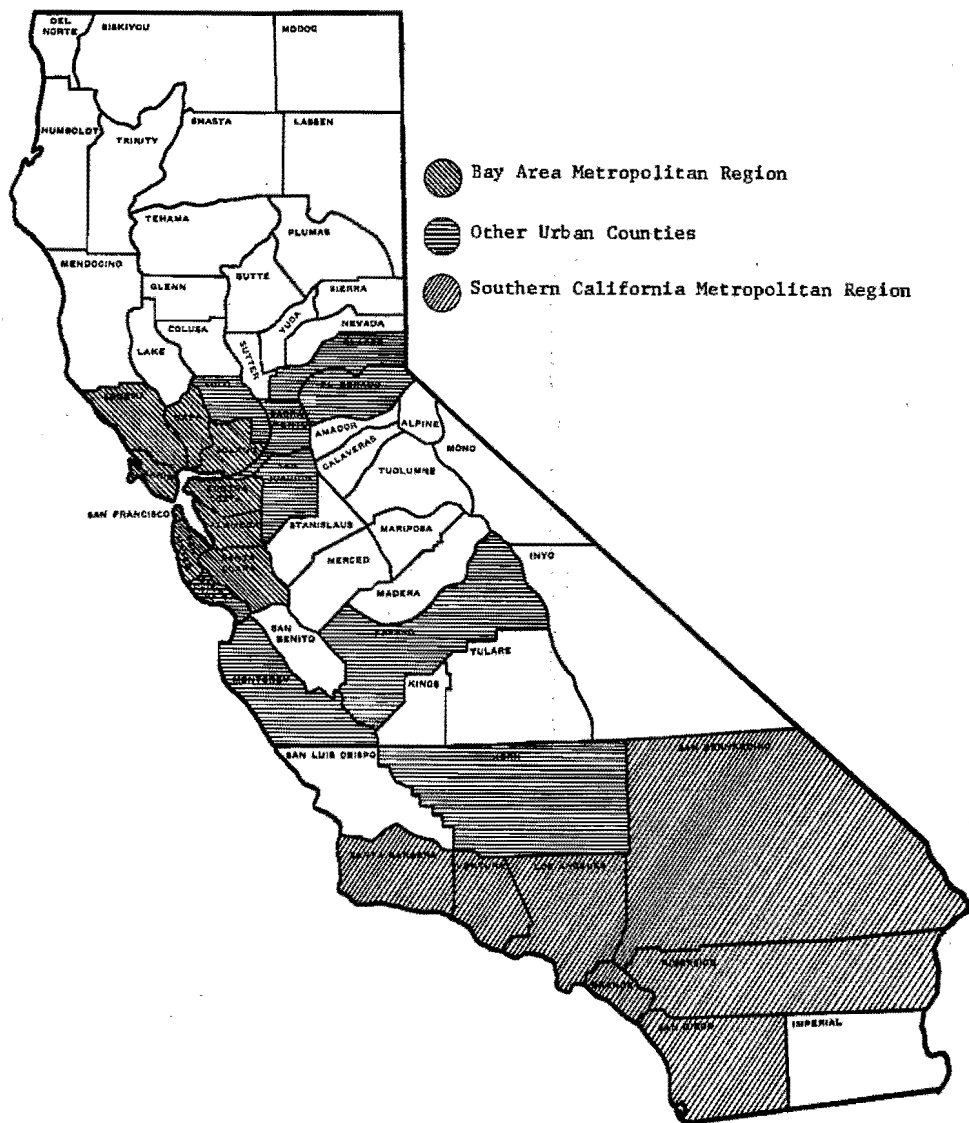


Fig. 2. Urban counties in California.

the two-variable equations, in which urban land requirement is a function of population growth only, were consolidated and expanded for a 15-year projection period in this study. The equation derived is:

$$\log_e \Delta L' = .26007 + .78845 \log_e \Delta P', \quad (12)$$

where

$\Delta L'$  is primary and extensive urban land increase in 15 years in acres, and

$\Delta P'$  is county population increases in 15 years.

The urban land requirements, 1965-80, estimated from the above equation,

TABLE 4

## PROJECTIONS FOR 25 URBAN COUNTIES OF CALIFORNIA, 1965 TO 1975 AND 1965 TO 1980

Method	Population growth		Urban land requirements	Marginal population density
	Total	Average annual		
	<i>persons</i>		<i>acres</i>	<i>persons/acre</i>
Ruth-Krushkhov 1965-75.....	5,526,963*	552,696	615,660†	9.0
Extension to 1965-80.....	7,279,300	485,287	830,086	8.8
Ratio: 1965-80/1965-75.....			1,348	

\* Ruth and Krushkhov (1966, p. 21), based on preliminary figures of the Department of Finance.

† Ruth and Krushkhov (1966, p. 3), corrected sum.

were summed over all urban counties. The average population density for new land in the 25 counties was slightly below the density for the 1965-75 period (see table 4). The lower density in the 15-year period is due to a projected annual *rate* of population growth lower than in the 10-year period.

The relative distribution of the 1965-80 projected population growth among counties, as estimated by the California Department of Finance (1967), is not exactly the same as that for 1965-75, but it is reasonably similar. At least, the degree of variation is not as great between these two population distributions as between the two 1965-75 urban land distributions among counties projected from (1) the population growth variable only and (2) the five independent variables. Therefore, instead of applying the 1965-80 land requirements projected from the two-variable equation to each county, only the 25-county total figure was used directly. This figure was then distributed among counties in the same proportion as the 1965-75 distribution by Ruth and Krushkhov. The validity of such a procedure rests on two basic assumptions: (1) projected population growth in the State will be

distributed among counties in the 1975-80 period relatively the same as in the 1965-75 period (see table 1 for the 1980 county population projections), and (2) pattern variables in each county will have the same relative effect on urban land required per person between 1975-80 as between 1965-75. The 1965-80 urban land requirement for each county was subsequently distributed among individual urban submarkets in proportion to the 1965-75 period.<sup>12</sup>

**Disaggregation of urban projections among HPAs.** The urban submarkets are the smallest geographic units for which urban projections have been made. Since the urban submarket and HPA boundaries do not coincide, the following assumptions are introduced in order to generalize submarket projections to HPAs:

1. All urban units within a submarket encroach additional land at the same rate (e.g., 3 per cent per annum) regardless of the absolute level of current urban acreage.
2. All urban expansion is contiguous to existing urban units.
3. The relative propensity to develop is the same in all directions.

<sup>12</sup> Only exception: when all of the developable land within five miles of the urban fringe would be exceeded. In this case, the working assumption of Ruth and Krushkhov (1966, Appendix C-3) that virtually all development would occur within these boundaries in a decade was respected for the 15-year period, also. Hence, these submarkets were filled to their stated limit and the residual was allocated proportionately among the other submarkets in the county.

These assumptions tie the expansion projection procedure employed in this study most directly to the concentric expansion model of classical urban development theory.<sup>18</sup> Warren Farrell (1968, p. 13) emphasizes that two alternative expansion models, which he labels "scattered" and "radial," are more representative of California's typical urban development patterns than the concentric model. He hastens to add, however, that the concentric model is "... still frequently used when land requirements must be estimated for future population levels ... (because it) is the easiest to work with mathematically."

**Urban land requirements in nonurban counties.** Detailed urban land projections are unavailable for California counties not in the Ruth-Krushkhov (1966) study. However, population has been estimated for 1960 and 1965 and projected to 1980 by the California Department of Finance (1967, p. 3) for these counties, also.<sup>14</sup> In addition, the 1960 population and estimated acreage in individual cities, unincorporated towns, and counties have been published by the U. S. Bureau of the Census (1965).

The following assumptions provide the framework for updating to 1965 and projecting to 1980 urban land requirements in the nonurban counties and in the area outside of urban submarkets in the urban counties:

1. Population and acreage within city limits, or general boundaries or unincorporated towns, reported by the U. S. Bureau of the Census (1965), are reasonable estimates of actual 1960 urban population and acreage in built-up uses.
2. Population in 1965 and 1980 are distributed among urban and rural sectors in the same proportion as in 1960.

3. Urban population in 1965 and 1980 are distributed among towns (incorporated and unincorporated) in the same proportion as in 1960.
4. The urban density of persons per unit of land in each town in 1965 and 1980 are the same as in 1960.
5. Urban expansion is contiguous to existing towns.
6. The propensity to expand on land is uniform in all directions.

**Urban projections.** Urban land in 1964 (or, 1965 for the nonurban counties), urban land requirements, 1965-80, and projected 1980 urban land for the State are given in table 5 for urban and nonurban counties. HPA urban acreage in 1964 and 1965-80 urban requirements are identified in Appendix table B-1.

## Public Land Uses

The term "public land use" refers to *all* lands in public ownership which are committed to uses not classified as urban, nor directly related to agricultural production. This category includes parks, national forests, military bases, Indian reservations, wildlife refuges, and public roads outside of towns and urban submarkets.

Acreage in parks, national forests, military bases, Indian reservations, and wildlife refuges were measured with a planimeter for each HPA from 1966 county maps prepared by the California Division of Highways. The acreage of land in these uses is assumed to remain constant through 1980. A major reason for this assumption is that decisions for expansion or contraction of such lands are made through the political processes, frequently involve large units of land, and are not amenable to effective prediction with economic models.

The current mileage in public roads outside of cities is published for each

<sup>18</sup> One important difference should be noted. The second assumption implies that the relative shape of the urban unit will tend to remain constant rather than becoming concentric.

<sup>14</sup> It is estimated that the proportion of the State's populace which resides within the nonurban counties is now less than 10 per cent and will decrease slightly by 1980.

TABLE 5  
CALIFORNIA URBAN LAND REQUIREMENTS

Item	Urban acreage, 1964*	Urban land requirements, 1965-80	Urban acreage, projected 1980
	1,000 acres		
Urban counties.....	1,862	857†	2,719
Urban land in HPAs.....	1,457	683	2,140
Urban land not in HPAs.....	405	174	579
Nonurban counties.....	202	61	263
Urban land in HPAs.....	158	49	207
Urban land not in HPAs.....	44	12	56
State total.....	2,064	918	2,982
Urban land in HPAs.....	1,615	732	2,347
Urban land not in HPAs.....	449	186	635

\* Urban acreages for the nonurban counties and area outside urban submarkets in the urban counties are for 1965.

† This figure is higher than the urban county projection recorded in table 4; urban land requirements outside the urban submarkets are also included in this figure.

county in the California Statistical Abstract (1967, p. 160). The mileage is classified according to State or county maintenance. Estimated average acreage per mile by type of road in California was secured verbally from Thomas E. Whaley, supervising highway engineer, California Division of Highways. Projected 1980 mileage of State highways was also obtained from the same source. Although a 15-per cent increase in State highway mileage between 1966 and 1980 is projected, the additional acreage required in any HPA is not substantial. Therefore, only the current acreage of roads and other land uses in the "public land" category is recorded in table 6 and Appendix table B-1. The 1966 estimate of public land in all HPAs in the State is 803,500 acres.

### Impact of Urban Expansion on the Agricultural Land Base

The acreage of land in urban uses is projected to increase by 917,000 acres between 1965 and 1980. Of this total, 80 per cent will come from agricultural land. This projection represents a slight increase in the concentration of urban land in the agricultural production areas.

A land-use tabulation of 1964 urban,

public, and agricultural land and projected 1965-80 urban requirements is reported for each HPA in the State in Appendix table B-1. For summary purposes, these production areas are combined into three groups on the basis of agricultural adaptability. Soils 01-03 in the Central Valley and in the Central and South Coast (Regions 2-6) are the most adaptable to a large variety of crops and are designated "prime" agricultural land. Although not as flexible for the variety of commodities as is prime land, high yields of many crops are also obtained from soils 11 and 12, and from portions of the Desert Region. This second group is designated "good" agricultural land. The remaining agricultural areas are extremely varied, but are grouped together in the "other" category. A summary land-use table for these broad groups is recorded in table 6.

Although only one-third of the land inventoried in the HPAs is prime agricultural land, almost 60 per cent of current urban acreage and 55 per cent of projected urban requirements are on such land. It is projected that more than 20 per cent of the prime agricultural land in California will be urbanized by 1980. In comparison, only 4 per cent of

TABLE 6  
CALIFORNIA LAND USE SUMMARY BY MAJOR AGRICULTURAL LAND  
GROUP, 1964 AND PROJECTED 1980

Agricultural land group	Total acreage	Urban land, 1964	Public land, 1964	Gross acreage for agriculture, 1964	Urban requirements, 1965-80	Gross acreage for agriculture proj. 1980
1,000 acres						
Prime*	6,893.6	936.9	144.5	5,312.2	391.7	4,920.5
Good†	2,847.6	120.1	81.1	2,646.4	59.4	2,588.0
Other‡	10,883.7	558.2	578.2	9,247.3	282.0	8,965.2
Total¶	19,624.9	1,615.2	803.8	17,205.8	732.1	16,473.7

\* Soils 01, 02, and 03 in the Central and South Coast and the Central Valley (Regions 2-6). See figure 3 (p. 33) for California production regions.

† Soils 11 and 12 in Regions 2-6 and soil 03 in the Desert climate 72.

‡ Includes all remaining HPAs.

¶ Computed from unrounded data.

the good land and 8 per cent of other agricultural land is projected for urban uses by that date. Although it is expected that urban pressures on prime land will continue to be heavy, the proportion of the urban requirement which is met by land of lower quality should increase slightly. Because the best agricultural land is more intensively cultivated than land of poorer quality, the current patterns of urban expansion have a more dramatic impact on agricultural production than if the expansion were spread more evenly on all types of agricultural land. However, even with the prime land providing more than a proportionate share of future urban land requirements, California agricultural output should suffer no reduction in the near future because of urban encroachment, as will be noted in later sections of this report. With additional land being developed for agriculture through the California Water Project and with more efficient use of existing resources, agricultural production will likely increase during the next few decades. The major impact will be on certain specialty crops whose production is restricted to small coastal areas and on regional shifts in the production of other crops currently grown near the urban fringe.

If the planning horizon is extended, eventual reductions in aggregate agricultural output seem inevitable from a continually expanding urban sector. For example, if the urban projections between 1965 and 1980 prove to be representative of uncontrolled urban expansion in California during each 15-year period to the year 2100, more than two-thirds of the prime agricultural land will be in urban uses by that date. Before the year 2200, no prime land will be left for agriculture. Without some external controls directing urban growth onto less productive land or extensive technological advancements increasing agricultural yields on low quality land, the long-range outlook for agriculture in California is a position of diminishing total output.

In summary, heavy urban pressures are expected to continue in the next decade. The urban sector will compete successfully against agriculture for significant quantities of the best agricultural land. Although some crops will undoubtedly be phased out or their production markedly decreased, overall output should increase considerably. But in the long run, continued and un-directed urban expansion may result in important reductions in California's agricultural producing capacity.

## CONDITIONAL PROJECTIONS OF DEMAND

For the 1980 location models, demand projections are required for California crop and livestock products. Most of these commodities are produced, not only in California, but in other regions of the country, and some are important in international trade. Thus, the demand for California output must be related to supply conditions in other regions. The report by Daly and Egbert (1966a) provides estimates for major agricultural commodities of 1980 production, imports, exports, and domestic use levels for the United States. Building on this report, Farrell (1969) developed 1980 estimates for certain major commodities for California. Following the procedures used in the report by Dean and McCorkle (1961), Farrell assumed that certain shares of U. S. output would be supplied by California. The present study required more detailed projections of many of the individual commodities and an analysis of the feed-livestock requirements for 1980. In addition, population experts have recently revised downward their expectations as to the level of the 1980 United States population, requiring a shift from the Bureau of the Census Series B projections (245 million) to Series C (235 million), and thus the Daly-Egbert and Farrell estimates were revised accordingly.

This section presents the framework and the specific conditional projections of demand for California products in 1980. These projections are based on certain specifications as to population growth, increases in real income, international trade, consumer preferences among various commodities, and inter-regional competition between California and other regions of the country. Two alternative assumptions are introduced for many crops as to the share of U. S. output that may be supplied by California. Although the projections do provide a reasonable basis for evaluating

the impact of changing demand conditions on the resource base of California agriculture, no claim is made that these estimates are accurate forecasts of 1980 production.

This presentation includes: (1) a discussion of the assumptions underlying the United States production and consumption estimates; (2) estimates for orchard crops and certain vegetables that were excluded from the formal allocation model, but for which acreage requirements were subtracted from available land supply; (3) major vegetable crops, including consideration of such factors as seasonal and varietal demand; (4) field crops other than feed grains and hay; and (5) feed grain and hay projections based on estimates of livestock and poultry production and levels of feed grain inshipments into California. For all commodities, point estimates, rather than demand functions, are projected for 1980. The allocation model determines cost-minimizing locations of production given the specified levels of demand. A more general model would incorporate demand and supply functions, but this step is beyond the scope of this report.

### U. S. Production, Consumption and Trade, 1980

The report by Daly and Egbert (1966a) provides projections for major commodities to 1980 that are based partly on formal statistical models and partly on trends and a knowledge of factors influencing these trends. The basic assumptions underlying their projections are:

1. U. S. population will reach 245 million by 1980 (U. S. Bureau of the Census Series B estimate);
2. Per-capita consumption in the United States will continue to change generally according to recent trends;

TABLE 7  
PROJECTED DEMAND FOR CALIFORNIA ORCHARD CROPS AND EXCLUDED  
VEGETABLES, 1980

Commodity	U. S. production			California			
	Average 1961-65*	Projected 1980		Production, Average 1961-65	Share of U. S. output		1980 Pro- duction to meet pro- jected share of U. S. output†
		Index‡	Level		Average 1961-65	Projected 1980	
	1,000 tons	1961-65 = 100	1,000 tons		per cent		1,000 tons
Orchard crops							
Deciduous.....	6,654	134	8,673	2,125	31.9	31.9	2,769
Citrus.....	7,535	161	12,216	1,772¶	23.5	23.5	2,873
Semitropical.....	192	120	230	178	92.9	92.9	214
Grapes.....	3,591	120	4,348	3,250	90.8	90.8	3,946
Tree nuts.....	266	125	333	139	52.1	65.7	218
Excluded vegetables....	9,090	142	12,699	1,470¶	16.2	16.2	2,066

\* U. S. Department of Agriculture (1968).

† Projections are based on Farrell (1969, p. 13) but are adjusted downward (approximately 4 per cent) to account for change from Series B to Series C population levels as given in U. S. Economic Research Service and Forest Service (1967a).

‡ Computed from unrounded data.

¶ California Crop and Livestock Reporting Service (1966, 1968).

3. Prices of farm products will be approximately the same as in recent years;
4. Net exports will continue to change by the same quantities as during the 1950-60 decade;
5. Per-capita disposable income will show an annual gain of approximately 2.3 per cent.

The Daly-Egbert output projections, modified to the lower Series C population estimate of 235 million,<sup>15</sup> are used in this study for potatoes, excluded vegetables (as a single category), and each of the field crops.

Using assumptions similar to the Daly-Egbert projections, Farrell (1969, p. 13) has estimated 1980 demand for the U. S. production of orchard crops. These projections are also modified to the Series C population estimate for purposes of this study.

Demand for U. S. production of individual vegetables, except potatoes, in 1980 is projected in this study based on the following assumptions:

1. U. S. population will reach 235 million by 1980 (Series C population estimate);
2. Per-capita consumption of individual vegetables will continue to shift according to general trends of the past two decades;
3. Net export demand will change in the same proportion as domestic demand.

## Orchard Crops and Excluded Vegetables

The production of orchard crops and certain vegetables was not included in the location models. However, it was necessary to estimate both demand and yield for these crops to determine the 1980 acreage required for production. The estimated 1980 California production of these crops required to meet the State's projected share of United States output is given in table 7. The method of projection is obvious from the table. The United States level of production in 1980 was estimated by Farrell (1969)

<sup>15</sup> Factors have been derived by the U. S. Economic Research Service and Forest Service (1967a and 1967b, Appendix table A-1) to convert a modified set of 1980 U. S. output projections from Series B to Series C population estimates. This same set of factors is used in this study to convert the Daly-Egbert (1966a and 1966b) and Farrell (1969) projections.

and adjusted in this study by factors provided by the U. S. Economic Research Service and Forest Service (1967a) to reflect the lower population estimates of the U. S. Bureau of the Census Series C level of 235 million.

California production in 1961-65 is expressed as a percentage of United States production. These percentages are applied to the United States 1980 level of production for all groups except tree nuts. California's share of this group is expected to increase rapidly because of recent heavy plantings of new trees. Bearing and nonbearing acreage in 1967 had risen to 356,000 acres, up nearly 22 per cent from the average 1961-65 acreage (California Crop and Livestock Reporting Service, 1968). The share of the United States citrus crop supplied by California has decreased substantially over the past three decades. However, this decline has begun to taper off recently which, together with a large current acreage of nonbearing trees and industry expectations of continued heavy plantings, suggests that California may hold its own in the citrus market through 1980. A strong upward or downward trend in the share of the other crop groups supplied by California is less apparent.

### **Major Vegetable and Field Crops, Excluding Feed Grains and Hay**

Two alternative sets of California demand projections are developed for these crops. Both are based on the same U. S. output projections, but differ as to the assumed share to be supplied by California.

The first projection specifies that California producers will continue to supply the same share of United States output as in average 1961-65. Because California's share in the production of some commodities has changed rather steadily over a period of one or more decades, the second set of projections specifies that these trends will continue to 1980. California's projected share in

1980 is estimated from time series data on market share with the time variable expressed (1) in actual units from the base period, and (2) in logarithms. A minimum of 10 and a maximum of 37 years of annual data were used in each equation. If both trend coefficients were significantly different from zero at the 5-per cent level, the equation providing the highest degree of explained variance was used in the projections. If neither trend coefficient was statistically significant, California's projected share was specified at the average 1961-65 share.

**Vegetable projections.** The two alternative estimates of vegetable production for selected vegetable commodities is shown in table 8, which indicates the methods used in making these projections. For these items, it was necessary to make independent estimates of 1980 per-capita consumption levels, and these were based on trends over the past decade. In addition, seasonal demand estimates were made for lettuce and melons. Seasonal demand may be important in determining location of production especially for perishable vegetable crops sold on the fresh market. This factor may influence several crops in this study, but because lettuce and melons are sold almost entirely in fresh form, these commodities were given particular attention.

*Lettuce* is produced year-round in California. But whereas winter lettuce can be grown in one climate, only summer lettuce can be grown in another. Climates in which spring lettuce can be produced are generally suitable also for fall lettuce, but may not be well-suited for either summer or winter production. Hence, lettuce demand is separated into three seasons; fall-spring, summer, and winter. Approximately 34 per cent of California lettuce produced in 1961-65 was marketed in the spring and fall, 32 per cent in the summer, and 34 per cent in the winter. No strong trends in the share of California lettuce produced by



TABLE 8

PROJECTED DEMAND FOR CALIFORNIA VEGETABLES, 1980, BASED ON ESTIMATED SHARES OF PROJECTED U. S. DEMAND

Crop	U. S. per capita consumption		U. S. production			California production, average 1961-65*	California share of U. S. production		Projected California production, 1980	
	Average 1961-65*	Estimated 1980†	Average 1961-65*	Projected 1980			Average 1961-65	Projected 1980¶	1961-65 share	Projected share
				Index‡	Level					
	lbs		1,000 tons	1961-65 = 100	1,000 tons		per cent		1,000 tons	
Asparagus.....	1.79	1.50	181.5	105	191	95	52.3	52.3	100	100
Cole crops:										
Broccoli.....	1.18	1.22	114.3	130	149	85	74.2	90.2	110	134
Brussels sprouts.....	.37	.42	35.4	143	51	32	91.4	91.4	46	46
Cauliflower.....	1.37	1.00	127.1	91	116	77	60.7	84.7	70	98
Lettuce.....	20.94	23.60	1,946.7	141	2,746	1,141	58.6	58.6	1,609	1,609
Spring and fall.....	..§	..	..	..	..	386	..	..	544	544
Summer.....	..	..	..	..	..	367	..	..	518	518
Winter.....	..	..	..	..	..	388	..	..	547	547
Melons:										
Cantaloupes.....	8.38**	6.50**	633.9	98	621	348	54.9	54.9	341	341
Spring and fall.....	..	..	..	..	..	55	..	..	54	54
Summer.....	..	..	..	..	..	293	..	..	287	287
Honeydew melons.....	..	..	66.7	98	65	52	78.0	78.0	51	51
Spring.....	..	..	..	..	..	3	..	..	3	3
Summer.....	..	..	..	..	..	49	..	..	48	48
Watermelons.....	15.46	12.80	1,464.3	104	1,523	132	9.0	9.0	137	137
Spring.....	..	..	..	..	..	52	..	..	54	54
Summer.....	..	..	..	..	..	80	..	..	83	83
Tomatoes:										
Fresh market.....	12.30	11.50	1,033.3	116	1,199	302	29.2	29.2	351	351
Processing.....	45.25	56.00	4,551.6	155	7,055	2,694	59.2	62.2	4,177	4,386

\* U. S. Department of Agriculture (1968).

† Based on recent trends and tempered by judgment of commodity experts.

‡ Based on estimated changes in per-capita consumption and a population increase of 25 per cent.

¶ Based on statistical analysis of California share of U. S. production for 1957-66 period. For commodities where the trend effect was not statistically significant at the

10 per cent level of significance, the 1961-65 share was used for projections to 1980.

§ Empty line indicates data not obtained.

|| Seasonal production as proportion of total obtained from California Crop and Livestock Reporting Service data (1966).

\*\* Includes honeydew melons.

season are discernible over the past decade. Therefore, the distribution among seasons is projected to remain constant to 1980.

The harvest for *melons* is limited to less than seven months. There are three major seasons for cantaloupes and two each for honeydew melons and watermelons. Production of the spring crop, in particular, is limited to the low desert valleys (climate 72). The fall cantaloupe crop also is produced in this climate zone. The demand for melons is separated into two seasons: fall-spring and summer. In the base period, approximately 16 per cent of the cantaloupes, 6 per cent of the honeydew melons, and 40 per cent of the watermelons were produced in the spring-fall season, with the remainder being harvested in the summer. These relative seasonal distributions are projected to prevail in 1980, also.

**Field crops, excluding feed grains and hay.** 1980 projections are given in table 9 for wheat, dry edible beans, potatoes, rice, sugar beets, safflower seed, alfalfa seed, and cotton. With the exceptions of dry edible beans, potatoes, and safflower seed, the methods described for projecting to 1980 apply without further comment. For dry edible beans and potatoes, it is important to specify demand by variety. For safflower seed, estimates were related to the demand for oilseeds as a group.

**Varietal demand.** Most of the demand estimates relate to all varieties of a particular commodity. However, just as there are important seasonal demand characteristics for lettuce and melons, there are important varietal aspects that affect production patterns of other crops, especially for dry beans and potatoes.

Many varieties of *dry edible beans* are produced in California, and a single yield estimate is not appropriate for all types in any area. The yield estimates developed in this study, as discussed in the following section, are, for example,

considerably higher in Region 2 (the Central Coast) than in Regions 4, 5, and 6 (regions of the Central Valley). (See figure 3, p. 33.) However, for bean varieties such as blackeye, pink, kidney, and baby lima, the yields obtained in the Central Valley are higher than in the Central Coast. These varieties will likely continue to be produced in the Central Valley proportionate to their current share (54 per cent) of total dry bean production. Thus, these varieties are specified separately in table 9.

**Potatoes** produced in Region 9 (mountain valleys) are predominantly the Russet-Burbank variety. This variety is a high-quality potato for fresh consumption and is projected to retain at least its current share (approximately 13 per cent) of total California potato production. The demand for this variety is specified separately in table 9.

The varieties discussed have a comparative growing advantage in the specified areas. However, because of a relatively high cost per unit in comparison to alternative varieties produced in other areas, no production would be assigned in these areas by a least-cost allocation model. To assure that, in the model solutions, minimum quantities of these crops are grown in the specified areas, separate demand estimates are established for these varieties.

**Safflower and related oil crops.** Cottonseed and safflower oil are the only important vegetable oils currently produced in California. The projection of cottonseed oil is directly related to the projected level of cotton production, shown in table 9, plus any change in the yield of oil. It is assumed that the yield of oil will remain constant to 1980. Next, it is assumed that California vegetable oil production will supply a given share of the 1980 United States demand for food fats and oils: 2.9 per cent, or 716 million pounds, in the constant share demand estimate and 3.9 per cent, or 961 million pounds, in the projected

TABLE 9

PROJECTED DEMAND FOR CALIFORNIA FIELD CROPS (INCLUDING POTATOES AND EXCLUDING FEED GRAINS AND HAY), 1980, BASED ON CONSTANT AND PROJECTED SHARE OF U. S. DEMAND

Crop	U. S. production		California production, average 1961-65*	California share of U. S. production		Projected California production 1980 based on:	
	Average 1961-65*	Projected 1980†		Average 1961-65*	Projected 1980	1961-65 share	Projected share
	1,000 tons			per cent		1,000 tons	
Wheat.....	36,460	56,459	263	0.72	0.53	407	299
Dry edible beans.....	938	1,159	164	17.48	15.18	203	176
Baby lima, kidney, blackeye, pink dry edible.....	..	..	89	..	..	110‡	95‡
Potatoes.....	13,026	15,994	1,518	11.14	11.14¶	1,782	1,782
Russet, Burbank.....	..	..	149	..	..	175§	175§
Rice, rough.....	3,399	4,154	705	22.49	22.49¶	934	934
Sugar beets.....	20,719	26,806	5,867	28.32	29.44	7,591	7,892
Safflower seed.....	308	..	245	..	..	678	880
	1,000 lbs					1,000 lbs	
Alfalfa seed.....	133,090	149,327**	46,036	34.59	26.47	51,057	39,527
	1,000 bales (500 lbs gross wt)					1,000 bales (500 lbs)	
Cotton.....	14,935	16,594	1,753	11.74	16.70	1,948	2,771
	million lbs					million lbs	
Basis of estimates of safflower:							
Food fats and oil.....	13,536	24,636	..	2.90	3.90	716	961
Cottonseed oil.....	1,937	2,152	..	11.62	16.52	250	355
Safflower oil.....	2.2††	..	..	..	..	466	606

\* U. S. Department of Agriculture (1968).

† Estimates, except where noted, are based on Daly-Egbert (1966a) as reported by Farrel (1969, p. 13), but are adjusted downward (approximately 4 per cent) to account for change from Series B to Series C population level as given by the U. S. Economic Research Service and Forest Service (1967a).

‡ Estimated minimum Central Valley production.

¶ Assumed equal to the 1961-65 average.

§ Estimated minimum Region 9 production (see figure 3, page 33).

|| Production in 1980 estimated from analysis of food fats and oils shown in the table. For example, from the constant share projection of fats and oils (716 mil. lbs.), cottonseed oil is subtracted (250 mil. lbs.) leaving a residual requirement of safflower or other oils (466 mil. lbs.). The safflower seed required to produce this oil is obtained by dividing the last figure by the yield of oil of 34.4 per cent (1961-64 average) and converting from pounds to tons (678,000 tons).

\*\* Assumed proportionate to the increase in hay production.

†† U. S. Department of Agriculture (1966).

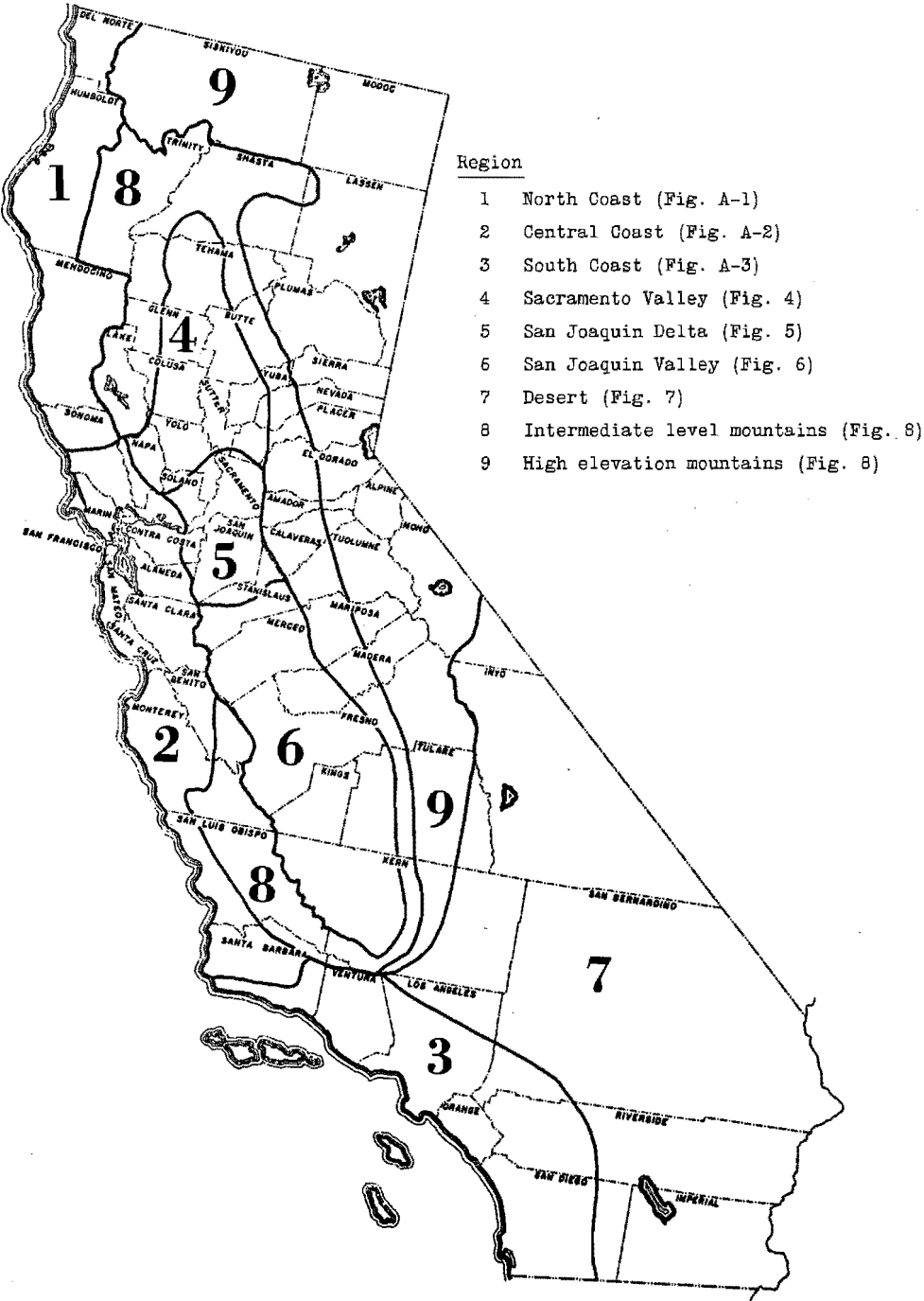


Fig. 3. California production regions. For details see figures in Appendix A.

TABLE 10  
CALIFORNIA FEED SUPPLY AND DISTRIBUTION, 1961-65 AVERAGE WITH PROJECTIONS TO 1980

Item	Feed grains	High protein byproducts	Other byproducts	Total concentrates	Hay	Silage*	Pasture
	1,000 tons						1,000 AUM's
<b>1961-1965</b>							
Beginning stocks.....	1,587.0	40.3	..	1,627.3	..	..	..
Production.....	2,573.4	623.2	1,282.4	4,429.0	7,410.6	1,557	27,629
Imports and inshipments.....	2,111.4	211.1	485.1	2,807.7	166.9	..	..
<b>TOTAL SUPPLY.....</b>	<b>6,271.8</b>	<b>874.6</b>	<b>1,717.5</b>	<b>8,864.0</b>	<b>7,577.5</b>	<b>1,557</b>	<b>27,629</b>
<b>Livestock feed:</b>							
Dairy cattle.....	615.8	185.3	683.2	1,484.3	5,363.0	1,557	6,966
Beef cattle.....	1,520.0	144.7	767.1	2,431.8	1,866.8	..	15,788
Sheep and lambs.....	0.6	..	0.5	1.2	16.4	..	4,875
Hogs.....	109.3	14.2	3.9	127.4	3.7	..	..
Poultry.....	1,843.6	527.8	257.5	2,629.0	..	..	..
Other (residual).....	168.8	2.6	2.8	174.1	100.8	..	..
<b>Total.....</b>	<b>4,258.1</b>	<b>874.6</b>	<b>1,715.0</b>	<b>6,847.8</b>	<b>7,350.7</b>	<b>1,557</b>	<b>27,629</b>
Ending stocks.....	1,449.6	..	..	1,449.6	..	..	..
Exports and outshipments.....	313.0	..	2.5	315.5	226.6	..	..
Seed.....	91.7	..	..	91.7	..	..	..
Food and industry.....	159.4	..	..	159.4	..	..	..
<b>TOTAL DISTRIBUTION.....</b>	<b>6,271.8</b>	<b>874.6</b>	<b>1,717.5</b>	<b>8,864.0</b>	<b>7,577.5</b>	<b>1,557</b>	<b>27,629</b>
<b>Projected 1980†</b>							
Production.....	3,450.0	‡	‡	‡	8,172.0	1,876	30,623
Imports and inshipments.....	1,878.1	‡	‡	‡	218.9	..	..
<b>TOTAL SUPPLY.....</b>	<b>5,328.1</b>	<b>981.9</b>	<b>1,943.8</b>	<b>8,843.9</b>	<b>8,390.9</b>	<b>1,876</b>	<b>30,623</b>
<b>Livestock feed:</b>							
Dairy cattle.....	877.4	203.9	751.7	1,633.0	5,898.9	2,876	7,658
Beef cattle.....	1,761.0	162.7	891.8	2,815.5	2,054.8	..	18,629
Sheep and lambs.....	0.5	..	0.5	1.0	14.5	..	4,336
Hogs.....	80.7	10.5	2.9	94.0	2.7	..	..
Poultry.....	2,075.6	602.3	291.9	2,969.8	..	..	..
Other (residual).....	168.8	2.6	2.8	174.3	193.2	..	..
<b>Total.....</b>	<b>4,764.0</b>	<b>982.0</b>	<b>1,941.6</b>	<b>7,687.6</b>	<b>8,164.1</b>	<b>1,876</b>	<b>30,623</b>
Exports and outshipments.....	313.0	..	2.5	315.5	226.8	..	..
Seed.....	91.7	..	..	91.7	..	..	..
Food and industry.....	159.4	..	..	159.4	..	..	..
<b>TOTAL DISTRIBUTION.....</b>	<b>5,328.1</b>	<b>982.0</b>	<b>1,944.1</b>	<b>8,254.2</b>	<b>8,390.9</b>	<b>7,876</b>	<b>30,623</b>

\* Entire State production of silage assumed fed to dairy cattle.

† Beginning and ending stocks are assumed to balance. Exports, seed, food, and industry uses are held at 1961-65 average levels. Feed grain total supply equals that reported in Dean *et al.* (1970); however, in that report production is 3,323,000 tons and

imports and inshipments is 2,005,100 tons. Similarly, hay and silage production projections are slightly lower based on revised estimates given in that report.

‡ Not projected individually.

Sources: Snider and King (1970) for 1961-65, and 1980 projections by authors.

share estimate. The latter share, like others in this group, is based on recent trends. With California cottonseed oil production projected, the remainder, 466 million pounds in the constant-share estimate and 606 million pounds in the projected-share estimate, of vegetable oil production is projected as safflower and related oils. Converting these values to tons of safflower seed, the 1980 constant-share estimate of 678,000 tons and the projected-share estimate of 880,000 tons are obtained.<sup>10</sup>

### Feed and Livestock Projections

California is a deficit state with respect to many livestock and poultry products and also for feed grains and by-product feeds. Projections of the future level of feed grain and production in California are complicated by questions as to the future level of demand for livestock products, changes in feed conversion efficiency, the level of inshipments of meat versus California production, and the level of net inshipments of feed versus California production. This study provides projections of the 1980 level of livestock and poultry feed grain and hay requirements and estimates of the amount likely to be produced in California.

**Feed grain and hay demand as a constant share of United States output.** Feed grain and hay production in 1980 were projected by two methods. The first was similar to that described for other crops; namely, to take the adjusted United States production projections for 1980, calculate California's 1961-65 share of United States production, and apply these percentages to the projected United States production level. This method is open to question because California feed grain produc-

tion is a small percentage of the United States total (1.74 per cent), and this method does not make explicit the assumptions as to changes in livestock numbers, changing feeding efficiency, and inshipment levels.

**Feed grain and hay production based on independent livestock projections.** The second method of obtaining projections of feed grain and hay production is based on projections of individual livestock numbers and feeding rates. Estimates were developed by Snider and King (1970) for the feed-livestock balance for California in the base period of 1961-65. Projections of livestock and poultry numbers in 1980 were developed from research studies of individual sectors, where available, and additional analysis of recent trends. A complete statement of these projections is available in a forthcoming report by Dean *et al.*, (1970) and thus only a brief statement of these estimates is given here. The feed supply and distribution for 1961-65 and 1980 are summarized in table 10.

**Dairy cattle** projections are based on Forker (1965) and Siebert (1967) with some modifications. Self-sufficiency in fluid milk production is projected to continue, but with some inshipments of certain manufactured products. It is assumed that population will increase to 26.4 million in California by 1980, but that consumption per capita will decrease by 3.6 per cent. Feed inputs required per cow are projected to remain constant. Because of a projected increase in milk production per cow, feed inputs per unit of milk are expected to decrease by 19 per cent, except for silage. With increased cow numbers, total feed grain and hay consumed by dairy animals will increase 10 per cent.

<sup>10</sup> Not all this expansion is likely to be safflower seed. Recent plantings of new sunflower seed varieties have produced favorable yields, and considerable expansion of these and related oil crops is expected. Because production and market characteristics of these crops are similar to those of safflower, their production will be included in the safflower projections.

The projection of *feedlot cattle marketings* in California is based on the projected increase in per-capita consumption, estimated by Daly and Egbert (1966b), plus studies of the competitive position of the California industry by Hopkin and Kramer (1965) and by King and Schrader (1963). In 1964, California feedlots supplied 52 per cent of the beef consumed in California, as estimated by Logan and King (1966). Because the feedlot industry depends primarily on inshipped feeder cattle as a source of supply, developments of feeding industries in other states make projections hazardous. In recent years slightly more than twice as many calves have been shipped into California as stockers and feeders than have been raised in the State. Increasing the number of calves produced on range appears unlikely in view of the competition for grazing areas. These factors, coupled with the fact that cattle ranching generally returns low profits, as discussed by Dean *et al.* (1966) and Ching (1967), would suggest only limited possibilities for expansion in range cattle numbers in the State. Thus, feedlot marketings are projected to increase by only 28 per cent over the base period.

*Sheep and hog numbers* are projected to decline, reflecting recent trends in these industries. Increased feeding efficiency is projected for hogs.

The *poultry industry* is composed of three distinct enterprises: egg production, turkey production, and broiler and fryer production. *Egg* production is based on the assumption of self-sufficiency to meet consumption needs in 1980. Numbers of layers are based on projected increases in eggs per bird from 225 in 1961-65 to 235 in 1980. Feed per poultry unit is held constant which implies increased efficiency per unit of production, given increased rates of lay per bird. *Broiler production* in California is expected to increase but not at a rate to maintain California's present share of United States produc-

tion. This assumes that the intense competition from the Southeast will continue to 1980. *Turkey production* in the United States is projected to increase by almost 90 per cent by 1980. California currently is the leading state in production, with 18 per cent of United States production. However, this percentage has been declining slightly in the past few years. A study by Bawden *et al.* (1966) suggests that, because of high-priced feed grains, California is at a disadvantage with the Midwest and South unless it can achieve offsetting efficiencies in production, processing, and transportation. The projection of California turkey numbers is based on the lower level of 15 per cent of United States production. Feed requirements are shown in table 10.

*California production of feed grains* is projected to increase from 2,541,000 tons in the average 1961-65 period to 3,450,000 tons in 1980. Net inshipments are projected to decrease slightly from 1,800,000 to 1,565,000 tons in 1980. The distribution of production, by grain, is shown in table 11. For 1980 the distribution of feed grain production in California is as follows: corn (10.7 per cent), grain sorghums (18.8 per cent), barley (67.3 per cent) and oats (3.2 per cent). The relative importance of individual grains is similar to the base period of 1961-65.

*California hay production* is projected to increase from 7,411,000 tons in 1961-65 to 8,172,000 tons in 1980 based on the hay requirements for the levels of livestock production projected in table 10. The alternative estimate, based on California hay production as a share of United States production, is 141,000 tons higher, as shown in table 11. The projection of alfalfa hay production is based on a percentage of all hay. In 1961-65 alfalfa production totaled 84 per cent of all hay production in California, and this is projected to increase to approximately 88 per cent in 1980.

TABLE 11

**PROJECTED DEMAND FOR CALIFORNIA FEED GRAINS, HAY, AND SILAGE,  
1980, BASED ON CONSTANT SHARE OF U. S. DEMAND AND CALIFORNIA  
LIVESTOCK PROJECTIONS**

Crop	U. S. production		California production, average 1961-65	California share of U. S. production, average 1961-65	Projected California pro- duction, 1980, based on:	
	Average 1961-65*	Projected 1980†			1961-65 share	Independent livestock projections‡
	1,000 tons			per cent	1,000 tons	
Feed grains:	147,053	221,390	2,541	1.74	3,854	3,450¶
Corn:	106,523	160,200	244	0.23	369	368
Grain sorghum:	15,355	23,200	481	3.13	728	649
Barley:	9,758	14,813	1,733	17.76	2,632	2,323
Oats:	15,417	23,172	98	.54	125	110
Hay, all:	120,113	134,767	7,411	0.17	8,313	8,172
Alfalfa:	..	..	0,225	..	7,313	7,172
Other:	..	..	1,186	..	1,000§	1,000§
Silage:	..	..	1,557	..	2,270	1,876
Corn:	..	..	1,305	..	1,903	1,573
Sorghum:	..	..	252	..	367	303

\* U. S. Department of Agriculture (1968).

† Estimates based on Daly and Egbert (1966b) as reported by Farrell (1969, p. 13), and adjusted from Series B to Series C population level. This estimate for total feed grains is about 11 per cent higher than that estimated by Dean *et al.*, (1970) based on slightly different assumptions concerning feed requirements and inshipments.

‡ See table 10 for projections of California feed supply and distribution based on projected numbers of livestock produced, feeding efficiency, and feed inshipments.

§ Proportion of individual feed grains in feed grain mix are projected to change slightly as indicated by recent trends.

|| Production of nonalfalfa hay is projected to continue in a downward trend from 1,186,000 tons average in 1961-65. Not based on a share of U. S. demand assumption, but on a preliminary California milk demand estimate 48 per cent higher than average 1961-65 (the same as anticipated increase in population).

## CONDITIONAL PROJECTIONS OF YIELDS AND PRODUCTION COSTS

The per-acre cost and yield estimates by HPA used in the location analyses, and additional detail concerning estimation and projection procedures are contained in Shumway and Stults (1970). General procedures are discussed briefly in this section.

Published data and the judgment of a group of resource and crop production experts provided the basis for determining average nonland cost and crop yield per acre in each HPA. *Relative* yields and nonland costs of the included crops among HPAs were determined chiefly by expert opinion, including farm advisors in nearly all counties, UC commodity, soils, climate, and irrigation specialists, and engineers of the California Department of Water Resources. The *absolute* levels were dic-

tated by published data; i.e., yield estimates by HPA were normalized to be consistent with published county and State yield data. The base area budget and standardized unit costs were adjusted by HPA to be consistent with county Agricultural Extension Service estimates.

### Yield Trends and Projections

Average yield per acre of all major crops in California has risen rapidly in the last several decades. Technological innovations, improved plant varieties, and better managerial skills have had a marked impact on yields. Given the current emphasis on research and adoption of new ideas, this upward surge is expected to continue, but at what rate?



**High-value excluded commodities.** Farrell (1969) has projected yield levels to continue to increase in each high-value crop group in California between average 1961-65 and 1980. To assess the yield estimates used by Farrell, a linear least squares yield trend, using 1930-66 annual yield data, was estimated for each important orchard and vineyard crop. Projected to 1980, the estimates thus derived are higher in all cases than those by Farrell. Perhaps the regression and Farrell estimates bracket the likely range in yields. For purposes of this study, an intermediate estimate for the orchard and vineyard yields is used, based on a simple average of Farrell's projection and that projected by the 1930-66 linear trend. The rate of yield increase between average 1961-65 and 1980 for excluded vegetables is the same as Farrell's estimate for all vegetables. Table 12 provides yield projections by commodity groups.

**Included commodities.** Two-point estimates for the 1980 yield of the representative commodity of each crop group included in the location analyses were

obtained by statistical estimation of time trends using (1) a linear equation

$$Y = a_1 + b_1 T, \quad (13)$$

and, (2) a logarithmic equation

$$\log_e Y = a_2 + b_2 \log_e T, \quad (14)$$

where  $T$  is year ( $T_{1945} = 1$ ) and  $Y$  is average California per-acre yield. Least squares estimates of  $Y$  were obtained for the year 1980. The estimated 1980 yields of each crop relative to average 1961-65 yield are reported in table 13.

Although "significant" measures of reliability were obtained from both equations for most crops, absolute confidence was not placed in either set of statistical estimates. Instead, these estimates were modified by the judgment of commodity specialists. Using the historical data and statistical estimates of trend as reference material in conferences with the specialists, the following question was asked for each commodity: "What do you consider will be the most likely level of average yield in Califor-

TABLE 12  
YIELD PER ACRE FOR CALIFORNIA ORCHARD CROPS AND EXCLUDED VEGETABLES, 1961-65 AVERAGE AND 1980

Commodity group	1961-1965 average*	1980 projection		
		Linear	By Farrell†	This study
	tons	1961-1965 = 100		
<b>Orchard crops:</b>				
Deciduous.....	6.80	126‡	110	118
Citrus.....	9.00	128	115	122
Semitropical.....	2.44	136	110	123
Grapes.....	7.30	126	120	123
Tree nuts.....	.63	133	115	124
<b>Excluded vegetables.....</b>	<b>6.65</b>	<b>¶</b>	<b>125</b>	<b>125</b>

\* Yield per bearing acre.

† Farrell (1969, p. 13).

‡ A high degree of confidence could not be placed in the linear trend for peaches and pears. Therefore, this figure is based on projection for these two crops averaged with a linear projection for the other deciduous fruits. The relationship of the nonlinear to the linear projection for these commodities is as follows:

Crop	Average yield, 1961-65 tons	Linear projection, 1980 tons	Nonlinear projection, 1980 tons
Peaches.....	11.43	18.10	14.00
Pears.....	8.92	13.88	12.50

¶ Not derived.

TABLE 13

## YIELD PER HARVESTED ACRE FOR CALIFORNIA FIELD CROPS AND VEGETABLES, 1961-65 AVERAGE AND PROJECTED 1980

Commodity	1961-1965 weighted average*		1980 linear projection	1980 logarithmic projection	1980 projection† by specialists
	unit	yield	yield index (1961-1965 = 100)		
Vegetable crops:					
Asparagus.....	cwt	29.8	107	91	111
Broccoli.....	cwt	63.4	122	99	122
Lettuce.....	cwt	197.2	129‡	108‡	129
Cantaloupes.....	cwt	136.4	122¶	109¶	115
Potatoes.....	cwt	209.8§	123	110	121
Tomatoes for processing.....	tons	18.7	141	121	160
Field crops:					
Corn for grain.....	bu	80.4	164	126	160
Barley.....	bu	50.4	135	105	136
Grain sorghum.....	bu	70.4	142	109	142
Alfalfa hay.....	tons	5.3	115	101	118
Dry beans.....	cwt	14.4	113	105	113
Rice.....	cwt	48.0	140	108	135
Safflower.....	cwt	19.8	152	131	141
Sugar beets.....	tons	20.5	115	108	115
Cotton.....	lbs	1,097.0	133	106	115

\* California Crop and Livestock Reporting Service (1966, 1967a).

† Values used for projecting yields in this study.

‡ Regression estimates from fall-lettuce data.

¶ Regression estimates from summer cantaloupe data.

§ All potatoes marketed—not just USDA #1.

|| Net cotton lint yield—does not include bags and ties.

nia in 1980?" The background assumptions for these yield projections were as follows:

1. Yield estimates to be based on probable adoption of known technology;
2. No continued major wars and no depression;
3. Target year 1980 will be a normal year with no unusual weather conditions, disease problems, and other unusual circumstances;
4. No shifts in production locations.<sup>17</sup>

The specialists' 1980 yield estimates are also recorded in table 13 and were used to project yields in this study. With three exceptions, their estimates coincide with either the linear or curvilinear regression estimates or fall somewhere between these two extremes.

<sup>17</sup> The importance of this last assumption is obvious: the objective was to estimate the increase in yield that could be expected within an HPA, not because of production shifting to another HPA with a superior or inferior soil-climate mix.

In the application of these estimates to HPA yields, it is assumed that (1) the yield of a given crop will increase by the same percentage in all HPAs, and (2) yields of all crops in a commodity group will increase at the same rate as the representative crop. Under these conditions, yield in each HPA will increase at the same rate as average state yield.

### Nonland Cost Projections for Included Crops

The unit price of all nonland agricultural inputs in the U. S. has increased 16.6 per cent during the 15-year period between 1945-49 and 1960-64 (U. S. Department of Agriculture, 1957, and U. S. Statistical Reporting Service, 1965). According to Farrell (1969, p. 6), "The [California] farm sector is

now (1965) producing nearly one-third greater output, with only 3 per cent more total inputs than in 1950." Because cropland used in California actually decreased during the period 1950-65, the increase in nonland inputs was more than 3 per cent. Provided (1) that a 5 per cent increase in physical nonland inputs between 1950 and 1965 was a reasonable estimate, (2) that nonland inputs between 1965 and 1980 will increase at the same rate, and (3) that unit costs (factor prices) will increase an average of 17 per cent, then total nonland production costs will increase by 23 per cent between 1965 and 1980.

## ALLOCATION MODEL RESTRAINTS

Earlier sections of this report were devoted to a discussion of HPA delineations, urban demand for land resources, and consumer demand for foods and fibers. Following an initial discussion of the alternative LP (linear programming) models used in the analysis, the remainder of this section will focus on the relevance of the above estimates in developing the model parameters. Additional procedures followed to complete the specification of the demand, land, water, and rotation restraints also are discussed.

### Structure of Alternative Models

Four specific LP models are developed for use in this study. One (Model 1961-65) is to determine optimum locations of production in the base period, 1961-65, in the absence of governmental programs. The demand levels, resources available for included crops after consideration of urban and excluded high-value crop requirements, and variable cost and yield parameters for the model crops are estimated for this period. The other three models

Although the unit costs of some inputs (e.g., labor) have been increasing at a more rapid rate than others, there is considerable opportunity for input substitution in agricultural production. Hence, the distortions caused by projecting all input costs to increase at the same rate between 1965 and 1980 may be little more than those caused by projecting the cost of individual categories independently based on historical trends. In summary, the nonland production costs for all crops in the 1980 projection models are assumed to be 23 per cent higher than in 1961-65.

(Models 1980A, 1980B, and 1980C) are for the projected year, 1980.

The differences among the 1980 models are designed to answer specific questions concerning the future of California's agricultural industry or to add greater realism to the analysis. The objective of each is the same as that of the base period model; that is, to minimize total nonland production costs subject to minimum output restraints and maximum area resource restraints. The cost and yield estimates, as projected to 1980, are the same in each of these models, as are the total land, irrigated acreage, and individual crop acreage restraints. Total land and individual crop restraints in 1980 are lower than in the base period because of additional requirements for urban and excluded cropland in 1980.

Actual 1961-65 California production of each included crop is used as the basis for the Model 1961-65 demand restraints.<sup>16</sup> The 1980 constant share demand projections are used in Model 1980A. The feed grain and alfalfa hay estimates based on projected livestock

<sup>16</sup> Production figures reported by the California Crop and Livestock Reporting Service (1966, 1967a) were used to develop the base period demand restraints. This data series was used, rather than those in the demand projections section, to be consistent with other data (yield and acreage) used for this model.

numbers and the projected share estimates of other crops are used in Model 1980B. Demand levels in Model 1980C are the same as in Model 1980B; however, substitution among feed grains is allowed in the selection of the least cost mix to meet total net energy requirements. A single feed grain restraint replaces the separate restraints for each feed grain category.

The specific crops included in the analysis are the same in each model. Those commodities which have sufficiently similar production requirements or demand structure are grouped and represented in discussion by the most important crop. No distinction is made between alternative marketing outlets, such as fresh and processing markets for vegetables. The crops included in the study represent 91 per cent of 1966 acreage and 83 per cent of 1966 value of production of field and vegetable crops (California Crop and Livestock Reporting Service, 1966, 1967a). The specific crops included in this part of the study, together with the representative crop of each group and the model crop activities, are identified by group in table 14.

## Demand Restraints for Included Crops

**Conversion of demand estimates to representative crop units.** For the crop groups represented in the linear program by a single commodity, one demand estimate for the entire group is obtained. It was assumed that relative yields of each of the crops in a group remain constant over HPAs and that they increase at the same rate over time. For the model solution accurately to reflect the acreage required for the group, demand for the nonrepresentative crops are converted into units of the representative crop in proportion to their average 1961–65 State yields. The

group output restraints are given in Appendix table B-4.

**Feed grain demand as a single restraint.** One alternative to demand projections by specified crop groups is analyzed in this study and incorporated into the demand restraints for Model 1980C. This alternative is to remove the minimum demand restraints from each of the individual feed grain groups, specify a single minimum feed grain demand, and solve for the minimum cost feed grain mix.

The yield and output estimates of the barley and sorghum groups used in Model 1980B are converted to corn equivalent net energy units. The relative net energy values used for conversion were derived by an average of estimates obtained for various classes of livestock and poultry weighted by the portion of 1961–65 feed grains fed to each class.<sup>19</sup> The average relative net energy values are 1.00, .96, and .93 for corn, sorghum and barley, respectively. The demand estimate in Model 1980B for each feed grain group is multiplied by its respective factor to convert to corn equivalents. The output requirement for individual feed grain groups is set at zero, except for the barley group. This last group includes the food grain, wheat, as well as feed grains, barley and oats. Its restraint, therefore, is set at the projected demand level for wheat multiplied by the relative 1961–65 yields of barley and wheat. These minimum demand restraints are given in Appendix table B-4.

## Land Restraints

Residual resource inventorying is used to estimate the HPA acreage restraints on model crop activities. Acreage estimates for land uses which normally return a higher marginal value product to land than the included crops

<sup>19</sup> Net energy values for ruminants are from Lofgreen and Garrett (1968, p. 25); for hogs from National Academy of Sciences (1968); and for poultry from a verbal estimate by Wilbur O. Wilson, Department of Poultry Husbandry, Davis. The breakdown of feed grains fed to each class, as given in table 10, is ruminants—54.2 per cent, poultry—43.2 per cent, hogs—2.6 per cent.

TABLE 14  
CROP GROUPS, REPRESENTATIVE CROPS, AND MODEL PRODUCTION  
PROCESSES

Study crop	Representative crop	Model crop activity (production process)
Vegetable crops:		
Asparagus	Asparagus	Asparagus
Cole crops:	Broccoli	Broccoli (single crop) Broccoli and fall or spring lettuce (double crop)
Broccoli		
Brussels sprouts		
Cauliflower		
Lettuce, spring and fall	Lettuce, spring and fall	Lettuce, fall or spring (single crop) Lettuce, fall and spring (double crop) Lettuce, fall or spring and summer (double crop)
Lettuce, summer	Lettuce, summer	Lettuce, summer (single crop)
Lettuce, winter	Lettuce, winter	Lettuce, winter (double crop)
Melons, spring and fall:	Cantaloupes, spring and fall	Cantaloupes, spring and fall
Cantaloupes		
Honeydew melons		
Watermelons		
Melons, summer:	Cantaloupes, summer	Cantaloupes, summer
Cantaloupes		
Honeydew melons		
Watermelons		
Potatoes	Potatoes	Potatoes
Tomatoes	Tomatoes, for processing	Tomatoes, for processing
For processing		
For fresh market		
Field crops		
Corn:	Corn for grain	Corn
For grain		
For silage		
Small grains:	Barley	Barley (fallow) Barley (nonirrigated) Barley (irrigated single crop) Barley and grain sorghum (irrigated, double crop)
Barley		
Oats		
Wheat		
Sorghums:	Sorghum for grain	Grain sorghum (single crop)
For grain		
For silage		
Alfalfa:	Alfalfa hay	Alfalfa hay
Hay		
Seed		
Dry beans	Dry beans	Dry beans
Rice	Rice	Rice
Safflower	Safflower	Safflower
Sugar beets	Sugar beets	Sugar beets
Cotton	Cotton	Cotton

are subtracted from the total inventoried acreage. Land uses for which acreage is to be deducted from the total include all urban, public, and semiagricultural uses, and production of orchard, vineyard, and excluded vegetable crops. Land required for each of these uses is exogeneously estimated and subtracted from the total HPA acreage. The residual is entered into the model as an upper acreage constraint on the sum of all model crop activities. These "net model" acreage restraints are given in Appendix table B-1.

The delineation and measurement of HPAs and the estimation of urban and public land requirements have been discussed. Attention is now focused on the estimation procedures for semiagricultural and excluded, high-value commodity land requirements.

**Semiagricultural demands.** The residual between the total land resources in each HPA and requirements for non-agricultural land uses is the gross acreage available for agriculture. Not all of the gross agricultural acreage can be used for the production of crops in any single year. Land is required for the farmstead, farm roads and lanes, feedlots, canals, and ponds. On a year-to-year basis, some acreage is lost from crop failure or ownership inflexibilities (such as estate transfer or operator illness). Because cost and yield data used in this study are representative for a harvested acre, it is necessary to deduct from gross agricultural land that acreage which will, on the average, not produce a crop in any given year.

No detailed survey of agricultural land in the above-stated uses is available by HPA. Hence, a State proxy variable was sought which could be applied generally to all HPAs. The 1964 Census of Agriculture for California (1967, p. 7)

reports that "Crop Failure" plus "Other Land"<sup>20</sup> accounts for 11 per cent of the total land available for agriculture. "Idle Cropland" accounts for nearly 5 per cent additional land.

The California Department of Water Resources estimates in their land use surveys that approximately 8 to 10 per cent of gross field crop acreage and 4 to 5 per cent of vegetable and orchard crop acreage is used for farmsteads, farm roads, and miscellaneous uses. This estimate was related to the authors of this report by Fred E. Stumpf, Associate Land and Water Use Analyst of the Department.

As an arbitrary standard in this study, 10 per cent of gross agricultural land in each HPA is assumed to be required for uses incidental to net agricultural production.

The base period and 1980 acreage estimates by homogeneous production area are given in Appendix table B-1.

**Orchard and vineyard crops and excluded vegetables.** The final step in deriving net model land restraints is to subtract from net agricultural land the acreage required for orchard, vineyard, and excluded vegetable crops. All land not required for these excluded crops or for any of the uses already inventoried is assumed to be available for the production of the included crops.<sup>21</sup>

The procedure described in this section consists of these major parts:

1. Inventory excluded crop acreage by HPA;
2. Update the inventory as necessary to a common base period (1965-66);
3. Project State acreage requirements to 1980;
4. Allocate 1980 State acreage among HPAs.

<sup>20</sup> The term includes the above-stated uses plus wasteland and excepting crop failure and ownership inflexibilities.

<sup>21</sup> In deriving the net model acreage restraints, requirements for pasture and range are not also subtracted from net agricultural land. Because of the low marginal value product of land in pasture and range, requirements for these uses will be allocated to land resources remaining after the optimal location patterns of the model crops are determined.

*Inventory of excluded crop acreage.* The California Department of Water Resources, in 1958, began a total inventory of land use throughout the State. Both agricultural and nonagricultural uses were inventoried, with considerable detail in the agricultural inventory. Sixty separate crop or crop groups were identified. The State was divided into study areas, and one or more of these areas have been inventoried every year. At the date of this writing, nearly all of the agricultural land in the State has been inventoried at least once.

The areal breakdown is quite detailed. Land use is identified geographically by major hydrologic area (e.g., a river basin), county, quadrangle (covering  $7\frac{1}{2}$  minutes of latitude and longitude), and service area (e.g., an irrigation district).

These data are summarized for this study by  $7\frac{1}{2}$  minute quads within most counties for the excluded high-value crops. For a few counties where quad data could not be obtained, the most detailed land use data available were used. A preliminary inventory by the Department of Water Resources for seven agricultural areas in Monterey County was used for that county. For four other counties where quad data were unavailable or unusable—Imperial, San Diego, Modoc, and Lassen—county totals were used.

*Updating to a common base period.* The allocation of excluded crops among HPAs derived from the Department of Water Resources survey was updated to a common base period to provide a reference for projecting. The base period selected is the average of the 1965 and 1966 crop years. The primary source of State excluded crop data for the base period is the California Crop and Livestock Reporting Service. Where available, county acreages for individual crops were obtained from the same

source; otherwise, Agricultural Commissioner reports were used.

Updating the inventory data is subject to the primary assumption that the allocation of excluded crops within a county at the time of the inventory was optimal. Hence, the acreage of excluded crops in each HPA within a county is scaled by the same factor.

The 1965-66 State acreage of each of the excluded crop groups is given in table 15. The acreage of all excluded crops in each HPA is given in Appendix table B-1.

*1980 projections of State requirements for excluded crops.* Based on projected increases in demand and per-acre yield (previously discussed), high-value crop acreage in 1980 is estimated to be 1,937,000 acres (table 15). This compares to an average of 1,710,000 acres in 1961-65 and an average of 1,768,000 acres in the 1965-66 crop years. Farrell's (1969, p. 13) 1980 projections for these crops total 1,957,000 acres.<sup>22</sup> An alternative set of projections using linear yield trends, constant share of U. S. output supplied by California, and U. S. output requirements based on Series C population estimates total 1,822,000 acres. The additional 115,000 acres projected in this study results from lower yield estimates and generally larger shares supplied by California.

*Allocation of 1980 excluded crop acreage among HPAs* is based on the following assumptions which are applicable to excluded crops as an aggregate:

1. Excluded crop acreage in counties which have no land in defined HPAs will remain the same as average 1965-66 acreage;

2. Location patterns within the rest of the State are optimal in the base period;

3. Urban expansion will be the major factor causing extensive shifting of acreage from one HPA to another, be-

<sup>22</sup> This estimate assumes that yield and share of U. S. market relative to 1961-65 average is the same for the excluded vegetables as for all vegetables.

TABLE 15

## CROPLAND UTILIZED FOR ORCHARD AND EXCLUDED VEGETABLE CROPS IN CALIFORNIA, 1965-66 AVERAGE, 1961-65 AVERAGE, AND PROJECTED 1980

Commodity group	Average 1965-66*	Average 1961-65†‡	Projected 1980 requirement‡§	1980 as percentage of average 1961-65
	1,000 acres			1961-65 = 100.
Orchard crops:				
Deciduous.....	390	397	452	113.9
Citrus.....	264	240	317	131.9
Semitropical.....	78	81	79	97.5
Grapes.....	488	478	466	97.5
Tree nuts.....	319	293	371	126.6
Excluded vegetables.....	229	221	252	118.8
Total.....	1,768	1,710	1,937	113.3

\* California Crop and Livestock Reporting Service (1966, 1967b).

† Farrell, (1969, p. 13).

‡ Includes bearing and nonbearing acreage.

§ Acreage requirement to meet specified share of projected U. S. output; ratio of bearing to nonbearing acreage assumed to equal average of 1961-65.

TABLE 16

## CROPLAND UTILIZED FOR ORCHARD AND EXCLUDED VEGETABLE CROPS BY COUNTY GROUPS IN CALIFORNIA, 1965-66 AVERAGE AND PROJECTED 1980

Commodity group	Average 1965-66 excluded crops				Projected 1980 excluded crops		
	State total	Counties with land in HPAs	Excluded counties	State total less county allocations*	State total	Counties with land in HPAs	Excluded counties
	1,000 acres						
Orchard and vineyard crops..	1,539†	1,531†	7†	0	1,685	1,678	7
Excluded vegetables							
Total acres.....	229‡	205¶	§	24	252	252	0
Acreage required  .....	163	146	0	17	180	180	0
Acreage excluded from net agricultural acreage							
Total acres.....		1,678				1,858	
Allocated to HPAs.....		1,674				1,853	

\* Residual of State acreage less that allocated to counties due to different sources of data.

† California Crop and Livestock Reporting Service (1967b). Computed from unrounded data.

‡ California Crop and Livestock Reporting Service (1966).

¶ California Crop and Livestock Reporting Service (1966) and County Agricultural Commissioners (1967).

§ Negligible.

|| Double cropping in 1965-66 was estimated at 57.34 per cent. The same percentage is assumed for 1980 projected acreage.

tween the time of the inventory and 1980;

4. A specific climate is more important than a specific soil to the production of excluded crops; and

5. The ratio of double-cropped to single-cropped vegetable acreage will remain the same as that estimated in the 1965-66 period.

Given the above assumptions, the



acreage of excluded crops in all HPAs will increase at the same rate. The ratio of 1980 to 1965-66 excluded crop acreage in counties having land in HPAs is 1.1073 ( $1,858 \div 1,678$ , see table 16).

In only five HPAs, all of which are in Southern California, did the estimates of additional urban land requirements limit the acreage of excluded crop expansion to less than the acreage thus estimated.<sup>28</sup> In none of the HPAs was the net agricultural acreage exceeded by more than 2,000 acres. In each case in which projected urban acreage limited the expansion of excluded crops, the excess requirement was transferred to most similar soil in the same climate.

**Summary of land restraints.** Two sets of upper limit parameters on total included crop acreage have been developed in this section. One is the base period land restraint, which is equal to total inventoried acreage less 1965 urban land, public land uses, semiagricultural requirements, and excluded crop acreage. The other is the 1980 projected land restraint, based on the same adjustment procedure. Restraints equal to the former will be used in Model 1961-65, and equal to the latter in each of the 1980 models.

The remainder of this section will focus on the development of parameters which restrict the acreage of particular crops in given areas.

## Rotation Restraints

Rotation is an important physical and economic cultural practice for many crops. However, it is often more important in the rotation cycle to take land out of the production of a specific crop for one or more years than it is to

plant to another specified commodity.

With many production possibilities open to most farmers, rotation practices in the State generally are flexible; hence, activities which involve a fixed rotation pattern were not built into the models. Instead, restraints were imposed on the maximum acreage in an HPA which could be planted to a particular cropping activity in a typical year if the same crop were to be grown in that area for several years in a row. The following questions were asked of commodity and plant pathology specialists at the University with respect to a typical HPA:

1. How many years in ten could crop X be grown on the same land without adverse effects on yields or quality if currently accepted management practices were used?

2. By how much, if any, would this estimate be reduced if a large contiguous area (e.g., 30,000 acres) were planted to this crop?

These estimates were converted to ratios and the rotation coefficients thus obtained are recorded in Appendix table B-3. Rotation restraints on individual crop activities are computed by multiplying net model acreage for any HPA by the rotation coefficient for that activity. Only one coefficient is recorded for each crop activity. No detailed survey was made of rotation requirements as a function of soil, climate, or secondary crop(s) in the rotation pattern.

## Water Availability

Gross annual rainfall in California is adequate to meet agricultural, industrial, and municipal requirements for many years to come. However, the spa-

<sup>28</sup> Although enough land is available in most of the HPAs technically to allow the projected expansion of excluded crops, there likely will be more transferring of acreage, particularly of orchard and vineyard crops, to HPAs without heavy urban pressures. Some of the fruit and nut crops to be removed by urban expansion undoubtedly will not relocate in the same vicinity to be removed again soon after the projection date of this study. Personal correspondence with heads of orchard and vineyard crop marketing and cooperative organization in 1968 indicates considerable shifting of orchard crops from Coastal valleys to the Central Valley.

tial and seasonal distribution of this rainfall is as varied as California's other natural resources. Two-thirds of the State's water supplies are in its northern third, while the greater requirements are in the central and southern portions (California State Water Resources Board, 1955, p. 25); and most of the rainfall occurs between October and April, while the bulk of the crop production takes place in the other six months.

Local storage of surface water plus pumping of groundwater supplies is adequate to meet water requirements at low cost in some areas of the State. In other parts, either overdraft pumping of groundwater or importation of surface water is necessary to meet the existing demand for water. When water must be imported long distances or a pumping overdraft occurs for many years, the cost of water may become prohibitive for agricultural purposes. Water is a physically limiting resource for agriculture in only a few areas of the State; but in several areas, cost effectively limits its use for certain crops.

The areas designated by Department of Water Resources engineers, Louis R. Mitchell and Helen Peters, as having water resources in limited supply to agriculture, and without prospects of importing additional water by 1980, include the coastal valleys of Santa Barbara County; the coastal terraces of San Mateo and Santa Cruz counties; the high-elevation mountain counties—Mono, Sierra, Plumas, Lassen, Modoc, and Siskiyou; and the intermediate-level desert—Antelope and Owens valleys. The limited water supply will likely prevent an expansion of irrigated agriculture in these areas. Most recent irrigated acreage data available, typically 1964, was used to estimate irrigation restraints in these areas. The HPAs for which restraints on irrigated acreage are imposed at less than net-model acreage, by region, include:

Central Coast (Region 2)	Desert (Region 7)	Mountain Valleys (Regions 8 & 9)
0222	0171	1381
0224	0371	0191
2121	2471	0391
2122		1291
2124		2391

The same irrigated acreage restraints are used in the 1961–65 model and in each of the 1980 models. See Appendix table B-3 for the restraint values.

In all other areas of the State, this study estimates, adequate water supplies exist or can be made available to irrigate net model acreage. It is recognized that the cost of additional water to expand agricultural production may be more expensive than that currently used. Insofar as such estimates could be obtained, this information was taken into account in the development of typical water cost figures in the preceding section.

### Summary of Model Restraints

This section discusses four types of model parameters. One type specifies the minimum quantity of each crop group which must be produced to satisfy demand. The other three limit the acreage of all or part of the crop activities in specific areas. One or more of these parameter types vary between alternative models.

With these parameters specified as model restraints and the per-acre yield and nonland production costs estimated, the parameter estimation for the linear programming models is complete. The nonland cost estimates provides objective function coefficients, and the per-acre yield estimates provide the nonzero coefficients in the demand rows. All other coefficients in the matrices have values of zero or one since the resource restraints and the activities are each specified in acre units. The following sections focus on the insights gleaned from the allocation model analyses.

## 1961-65 REGIONAL RESOURCE USE

Although this report focuses on production in 1980, there are two important reasons for analysis of production in a base period of 1961-65:

1. To make comparisons of the differences in resource use, harvested crop acreage, and location of production between the "actual" and the linear programming solution, with (a) given levels of State output, (b) model yields by HPA normalized to the State average for the same period, and (c) model costs representative of actual costs; and
2. To provide a base-period optimal solution with which to compare the effects of urban expansion, increasing cost and yield, and a changing demand for agricultural products to 1980.<sup>24</sup>

Specifically, this approach should facilitate separation in the discussion of the 1980 model solutions between (1) the effects of changing parameters over time by comparing model results in 1961-65 and 1980; and (2) the changes in production patterns from actual 1961-65 levels to model production patterns in 1980 that include effects in (1) plus possible inefficient locations at present.

The first purpose should be clearly distinguished from testing the validity of the model. The model is normative; its value is not measured by how closely it approximates the real world. Possible explanations which might cause the model solution to differ from the actual include the following: (1) resources are

not optimally allocated in the base period; (2) farmers do not have the single objective of maximizing profits; (3) relevant variables have been omitted; (4) the data collected are incorrect or inadequate; (5) there is a nonlinear relation among variables over the relevant range; or (6) the model is too aggregative—i.e., variation in cost and yield within an HPA, or seasonal or special markets may be more important than assumed in the model development.<sup>25</sup>

Comparisons of actual 1961-65 and LP solutions are presented in three major sections. First, the optimal land- and water-resource use patterns are compared to the actual patterns. Second, the optimal harvested acreage of each crop and its regional distribution are contrasted with actual acreage estimates. In the final section, derived-model total product value and imputed product prices are compared with actual value and prices.

### State and Regional Resource Use

**Land use pattern.** Nearly 20 million acres in California are estimated to have potential for commercial agricultural production. In the base period, approximately 12 per cent of this acreage is required for urban and extra-urban purposes, 9 per cent is reserved for semi-agricultural uses, 16 per cent is for crops not in the allocation model (consisting of irrigated pasture and nonalfalfa hay as well as orchard and excluded vegetable crops), and 25 per

<sup>24</sup> The term "optimal" is applied to each model solution discussed in this report. Each solution is optimal in the sense that for the output, cost, yield, and acreage parameters specified in the model it is the one for which total costs are at a minimum (and aggregate producer profits are estimated to be at a maximum). None of the solutions is presented as an optimum in the sense that the model parameters also are derived under conditions which meet some measure of optimality.

<sup>25</sup> The farm price for a given commodity is assumed to be equal in all regions of the State. Thus, some deviations of model production from actual patterns are due to current locations of processing plants (e.g., sugar refineries), feeding areas, and markets for commodities which cause farm prices in one area to differ somewhat from those in another.

cent is used for included crops. An estimated 28 per cent of the inventoried acreage was used only for range. In the model solution, all acreages are taken to be the same as actual except that crop production is estimated at only 27 per cent, and range land at 36 per cent. Details on potential agricultural land in California according to major types of usage is recorded for the base period actual and model solution in table 17.

The total model acreage required for the included crops is about 1,750,000 acres less than actual requirements in

TABLE 17  
LAND USE IN CALIFORNIA IN  
BASE PERIOD, 1961-65 AVERAGE  
ACTUAL AND ESTIMATED MODEL  
REQUIREMENTS

Land use category	Estimated acreage requirements	
	Actual	Model
	1,000 acres	
Nonagricultural land*	2,403.2	2,403.2
Semiagricultural land*	1,722.5	1,722.5
Agricultural requirements		
Commodities not in model†		
Irrigated	2,804.0	2,804.0
Nonirrigated	406.6	406.6
Subtotal	3,210.6	3,210.6
Included commodities		
Irrigated	4,763.3	5,098.0
Nonirrigated‡	2,126.0	38.0
Subtotal	6,889.3	5,136.0
All commodities		
Irrigated	7,567.3	7,902.0
Nonirrigated	2,532.6	444.6
Total agricultural requirements	10,099.9	8,346.6
Rangeland	5,399.7	7,153.0
Total land inventoried	19,625.3	19,625.3

\* Appendix table B-1.

† Orchard and excluded vegetable crops, irrigated pasture, and nonalfalfa hay—circa 1965-1966.

‡ The U.S. Bureau of the Census (1967) reports total and irrigated acreage of each crop harvested for 1964. If the percentage of crop acreage not irrigated in 1964 was the same as average 1961-65, irrigated harvested acreage of included commodities, mostly small grains, in the base period was 1,163,000 acres. Because a fallow year is required between small grain crops in many regions, the estimate of land required is considerably higher than harvested crop acreage.

the base period, whereas optimal irrigated acreage is 335,000 higher. One conclusion drawn from the model solution is that shifting all included crop production to optimal locations and increasing irrigated acreage by one-third million acres will substitute for more than 2 million acres of nonirrigated land.

The 1961-65 model location of production by crop and by region is given in table 18, with production regions shown graphically in figure 3. At the bottom of the table, a regional summary is given of net model acreage available, total land required for included crops, and the residual acreage. Pasture and nonalfalfa hay were not introduced as model activities, nor were they inventoried and projected exogenously as were the excluded, high-value crops. These low-value crops are included in the residual land use category in table 18.

In all regions, optimal land requirements for the model crops are less than net model acreage available. In fact, not more than two-thirds of available land is required for these crops in any region; in several regions, less than one-third of the land is required.

**Water use pattern.** This comparison of water resources consists of: (1) the acreage of land irrigated, and (2) the quantity of water applied under the actual and optimal land-use patterns of the base period.

**Irrigated acreage.** The 1964 acreage of land actually irrigated in each county is estimated by the U. S. Bureau of the Census (1967). Maps depicting the location of irrigated land within counties are published by the California Department of Water Resources (1966). County irrigated acreage was obtained from Census data, while its distribution among regions within a county was estimated from the Water Resources maps by planimetry. It is assumed that 1964 data provide reasonable estimates

**TABLE 18**  
**LAND USE BY REGION IN BASE PERIOD FOR INCLUDED CROPS, ESTIMATED MODEL REQUIREMENTS**

Crop activity	Region									State*
	Coastal			Central Valley			Desert	Mountain		
	1	2	3	4	5	6	7	8	9	
	1,000 acres									
Vegetable crops:										
Asparagus.....	0	42.8	0	0	0	0	0	0	0	42.8
Broccoli (single crop).....	0	0	0	0	0	2.4	0	0	0	2.4
Broccoli and fall or spring lettuce (double crop).....	0	40.5	0	0	0	0	0	0	0	40.5
Lettuce, fall or spring (single crop).....	0	0	0	0	0	0	0	0	0	0
Lettuce, fall and spring (double crop).....	0	0	0	0	0	0	0	0	0	0
Lettuce, fall or spring and summer (double crop).....	0	0	0	0	0	0	0	0	0	0
Lettuce, summer (single crop).....	0	34.1	0	0	0	0	0	0	0	34.1
Lettuce, winter (double crop).....	0	0	0	0	0	0	20.1	0	9	20.1
Cantaloupes, fall or spring.....	0	0	0	0	0	0	15.9	0	0	15.9
Cantaloupes, summer.....	0	0	0	0	0	47.0	0	0	0	47.0
Potatoes.....	0	54.8	0	0	10.0	15.6	0	0	14.7	95.1
Tomatoes, processing.....	0	71.5	0	19.0	78.3	0	0	0	0	168.8
Field crops:										
Corn.....	7.0	10.0	0	29.0	110.7	0	0	0	0	156.7
Barley (fallow).....	0	34.0	0	0	4.0	0	0	0	0	38.0
Barley (nonirrigated).....	0	0	0	0	0	0	0	0	0	0
Barley (irrigated, single crop).....	0	0	0	162.3	66.1	479.0	109.8	90.0	260.0	1,167.2
Barley and grain sorghum (irrigated, double crop).....	0	0	0	0	273.5	0	0	0	0	273.5
Grain sorghum (single crop).....	0	0	0	0	0	0	0	0	0	0
Alfalfa hay.....	28.0	16.0	0	341.0	357.5	363.2	0	57.0	97.2	1,259.9
Dry beans.....	0	79.4	0	38.0	20.0	56.8	0	0	0	194.2
Rice.....	0	0	0	208.7	0	0	0	0	0	298.7
Safflower.....	0	0	0	0	0	0	210.8	0	0	210.8
Sugar beets.....	0	72.0	72.0	0	0	96.4	0	18.0	0	258.4
Cotton.....	0	0	0	0	0	606.0	206.0	0	0	812.0
Total land utilized, Model 1961-65 optimal*.....	35.0	455.0	72.0	888.0	920.0	1,666.4	562.6	165.0	372.0	5,136.0
Residual land†.....	167	607	805	887	534	3,665	1,009	283	733	8,688
Net model acreage available, circa 1965†..	202	1,062	877	1,775	1,454	5,331	1,572	448	1,105	13,828

\* Computed from unrounded data.

† Includes acreage required for pasture and nonalfalfa hay.

† All figures except total are computed from unrounded data. Total is from Appendix table B-1, and includes all land suitable for crop production less acreage in urban, public or semi-agricultural uses or planted to orchards, vineyards, or excluded vegetable crops.

of the average acreage actually irrigated in the base period.

In this study, all but two crop activities require irrigation, and only 38,000 acres of nonirrigated barley enter the optimal solution. The remaining acreage requires irrigation. Optimal total irrigated acreage for all crops is 4 per cent higher than the Census estimate for 1964.

Region 8 shows the largest percentage increase in optimal regional irrigated acreage over the Agricultural Census estimate. The largest increase in real terms is in Region 5, followed closely by Region 4. The only regions in which a decline in irrigated acreage is suggested by the optimal solution are regions 3 and 6 (the South Coast and San Joaquin Valley). Table 19 summarizes the regional distribution of 1964 irrigated acreage, actual acreage used for excluded crops, and optimal requirements for the crops included in the model.

*Water requirements.* The California Department of Water Resources (1966, p. 53) estimates that a gross 28.5 million acre-feet of water were required for agricultural production in 1960. Lofting and McGauhey (1963, p. 57) estimate that 5.1 million acre-feet were lost in conveyance in that year which means that the net agricultural requirement of irrigated water equaled approximately 23.4 million acre-feet for 1960.

Similar estimates of the net agricultural water requirement have been obtained in this study under both the actual and the model cropping patterns (see table 20). Based on estimated irrigation water requirements per acre for each crop, the net State requirement for the actual cropping pattern would have been approximately 23.6 million acre-feet. For the model cropping pattern, the requirement is 23.4 million acre-feet of water, a level equal to the previous estimate for 1960.

Although more irrigated land is required for the model than for the actual cropping patterns, slightly less irrigation water may be needed. The water requirement per irrigated acre in the model solution is lower than actual because (1) the water requirement varies markedly with crop and climate and (2) two cropping patterns are significantly different. To illustrate, the requirement for one harvested acre of alfalfa ranges from a low of 2.25 acre-feet on alluvial soil in Climate 11 (North Coast) to 8.0 on similar soil in Climate 72 (Desert). In Climate 72, the requirement ranges from 2.5 acre-feet for barley to 10.0 acre-feet for rice on the same soil.

Some crops with high consumptive water requirements are shifted by the model from current locations to areas with lower irrigation requirements (e.g., considerable alfalfa acreage is shifted from the desert to northern parts of the Central Valley). In addition, the increase in total irrigated acreage is due to a shift from dryland to irrigated feed grain production in the model solution, and consumptive water requirements for feed grains are among the lowest for any of the included crops. Although there is also some incentive to double crop a slightly larger acreage, the forces of efficiency in the model combine to increase total acreage irrigated without increasing the quantity of water demanded.

The largest percentage increase in the optimal regional water requirement from the actual estimate is in Region 8. The largest increase in real terms is in Region 4; the increase in Region 5 is also very large. A decline in water requirements, as well as irrigated acreage, is suggested by the optimal solution in regions 3 and 6. Although irrigated acreage in Region 7 is higher for the model cropping pattern, a decline is suggested in water requirements.

TABLE 19  
IRRIGATED ACREAGE BY REGION IN BASE PERIOD, ACTUAL AND ESTIMATED MODEL REQUIREMENTS

Region	Region number	Included commodities		Commodities not in model		Base period total		Total model expressed as percentage of actual
		Actual, circa 1961-65*	Model 1961-65†	Irrigated pasture and nonalfalfa hay, circa 1965-1966‡	Orchard and excluded vegetable crops, 1965-1966¶	Actual	Model§	
		1,000 acres						
Coastal:								
North.....	1	4.5	35.0	28.4	21.3	54.2	84.7	156.3
Central.....	2	282.3	421.0	46.8	95.5	424.6	563.3	132.7
South.....	3	189.8	72.0	49.2	208.4	445.4	327.6	73.6
Subtotal.....		476.6	528.0	124.4	323.2	924.2	975.6	105.6
Central Valley:								
Sacramento.....	4	616.8	888.0	223.2	205.5	1,045.5	1,316.7	125.9
Delta.....	5	617.1	916.0	237.6	204.5	1,059.2	1,358.1	128.2
San Joaquin.....	6	2,377.3	1,666.4	409.9	701.7	3,488.9	2,778.0	79.6
Subtotal.....		3,611.2	3,470.4	870.7	1,111.7	5,593.6	5,452.8	97.5
Desert:								
Southern California.....	7	522.1	562.6	50.0	52.7	624.8	665.3	106.5
Mountain Valleys:								
Intermediate.....	8	22.9	165.0	20.2	18.6	61.7	203.8	330.3
High.....	9	130.5	372.0	230.2	2.3	363.0	604.5	166.5
Subtotal.....		153.4	537.0	250.4	20.9	424.7	808.3	190.3
State  .....		4,763.3	5,098.0	1,295.5	1,508.5	7,587.3	7,902.0	104.0

\* Computed as a residual: actual base period total acreage less acreage of commodities not in model.

† Includes acreage of all crop activities in the model except nonirrigated barley and barley-fallow.

‡ U. S. Bureau of the Census (1967) for irrigated pasture and proportion of nonalfalfa hay acreage which is irrigated; California Crop and Livestock Reporting Service (1967a) for 1965-66 acreage of nonalfalfa hay.

¶ All California vegetable crop acreage and 89 per cent of the orchard crop acreage was reportedly irrigated in 1964 (U. S. Bureau of the Census, 1967). The approximate

percentage of orchard and excluded vegetable acreage irrigated was estimated by region:

Region	Per cent	Region	Per cent	Region	Per cent
1	72	4	92	7	100
2	49	5	97	8	66
3	92	6	99	9	100

§ Computed as the sum of the model included crop acreage and the actual acreage of crops not in the model.

|| Computed from unrounded data.

TABLE 20  
AGRICULTURAL WATER REQUIREMENTS BY REGION IN BASE PERIOD, ESTIMATED ACTUAL AND MODEL REQUIREMENTS

Region	Region number	Included commodities		Commodities not in model		Base period total		Total model expressed as percentage of actual
		Estimated actual	Estimated model	Irrigated pasture and nonalfalfa hay, circa 1965-1966	Orchard and excluded vegetable crops 1965-1966	Actual	Model	
		1,000 acre feet						per cent
Coastal:								
North.....	1	9	82	71	45	125	198	158.4
Central.....	2	576	940	168	210	954	1,318	138.2
South.....	3	475	194	236	557	1,268	987	77.8
Subtotal.....		1,060	1,216	475	812	2,347	2,503	106.6
Central Valley:								
Sacramento.....	4	2,183	3,143	960	473	3,616	4,576	126.5
Delta.....	5	1,543	2,486	1,022	470	3,035	3,978	131.1
San Joaquin.....	6	6,593	4,359	1,886	1,965	10,444	8,210	78.6
Subtotal.....		10,319	9,988	3,868	2,908	17,095	16,764	98.1
Desert:								
Southern California.....	7	2,677	2,136	40	184	2,901	2,360	81.4
Mountain Valleys:								
Intermediate.....	8	69	341	73	43	185	457	247.0
High.....	9	248	552	806	5	1,059	1,363	128.7
Subtotal.....		317	893	879	48	1,244	1,820	146.3
State*.....		14,371	14,234	5,261	3,952	23,585	23,448	99.4

\* Computed from unrounded data.



## Harvested Crop Acreage

Because two crops are produced in one year on some land and a single crop is produced biennially on other land, the harvested acreage of all crops does not necessarily equal the acres of land required for production. In this subsection, the major differences in State and regional harvested crop acreage between the base period actual and model solution are highlighted.

**Base period actual.** The basic source of actual harvested crop acreage data used for comparison purposes in this study is the California Crop and Livestock Reporting Service (1966, 1967a). The annual State acreage of all model crops and the county acreage of several are estimated in these publications. The county acreage of other crops is reported by the County Agricultural Commissioner (1967). County estimates obtained from the latter source are adjusted proportionately so that the State total corresponds to the Crop and Livestock Reporting Service estimate.

The regional location of production within a county in the base period is assumed to be relatively the same as it was at the time of the California Department of Water Resources land use survey. This survey data, summarized by seven and one-half minute quadrangles, provide accurate estimates of crop acreage by region for one recent year.

**Comparison of results—actual and optimal for 1961-65.** In the period 1961-65 harvested acreage of the study crops averaged 6,019,000 acres. The optimal harvested acreage indicated by Model 1961-65 is 5,369,000 acres or 11 per cent less than actual acreage. (See table 21 for a comparison of base period actual and estimated model harvested

acreage by region and by crop.) The crop groups with the most pronounced declines in optimal acreage relative to the actual include asparagus, small grains, and safflower. The lower model acreage of asparagus is a result of a regional shift from the relatively low yielding Region 5 (San Joaquin Delta) to the very high-yielding Region 2 (Central Coast). In 1964 slightly more than half of the small grain acreage was irrigated as compared to 98 per cent according to Model 1961-65 results. A similar shift from nonirrigated to irrigated safflower production (62 per cent irrigated in 1964 and 100 per cent in Model 1961-65 would cause a substantial decline in the acreage required for this crop.)<sup>20</sup>

The model results indicate that the base period output of several other crop groups could have been produced on considerably less acres than were actually used. In addition to the three crops already cited, six groups are allocated by the model to less than 90 per cent of their actual 1961-65 total acreage. Regional shifts in production are important in explaining the difference between actual and optimal acreage of some crops, but interregional shifts between soils and climates are equally as important for other crops.

The crop groups with the least relative difference between base period actual and optimal acreage are alfalfa and lettuce. The optimal solution allocates both groups to just below 99 per cent of actual acreage.

The model acreage of one crop, cotton, is higher than actual acreage. In the 1961-65 period, a portion of the cotton production was planted in a skip-row pattern, with higher yields being obtained than from solid plant produc-

<sup>20</sup> Following a preliminary analysis of the comparative cost of producing safflower with or without irrigation, only the irrigated activity was specified in the LP models. Nonirrigated production on some rice land in the Sacramento Valley (Region 4), having a particularly high water table, may represent an optimal allocation of resources; but, in general, production could be increased sufficiently by applying supplementary water to make its application profitable in all areas.

TABLE 21

## HARVESTED CROP ACREAGE BY REGION AND BY CROP GROUP IN BASE PERIOD, ACTUAL AND ESTIMATED MODEL REQUIREMENTS

Item	Region number	Actual	Model	Model less actual	Model as percentage of actual
		1,000 acres			per cent
REGION					
Coastal:					
North.....	1	6	35.0	29.0	533.3
Central.....	2	333	478.5	145.5	143.7
South.....	3	218	72.0	-146.0	33.0
Subtotal.....		557	585.5	28.5	105.1
Central Valley:					
Sacramento.....	4	922	888.0	-34.0	96.3
Delta.....	5	805	1,109.4	304.4	137.8
San Joaquin.....	6	2,679	1,666.4	-1,012.6	62.2
Subtotal.....		4,406	3,663.8	-742.2	83.2
Desert:					
Southern California.....	7	649	582.7	-66.3	89.8
Mountain Valleys:					
Intermediate.....	8	249	165.0	-84.0	66.3
High.....	9	158	372.0	214.0	235.4
Subtotal.....		407	537.0	130.0	131.9
State.....		6,019	5,369.0	-650.0	89.2
CROP GROUP					
Asparagus.....		64	42.8	-21.2	66.9
Cole crops.....		48	42.0	-5.1	89.4
Lettuce.....		116	114.8	-1.2	99.0
Melons.....		73	62.9	-10.1	86.2
Potatoes.....		101	95.1	-5.9	94.2
Tomatoes.....		178	168.8	-9.2	94.8
Corn.....		180	156.7	-23.3	87.1
Small grains.....		1,871	1,418.6	-452.4	75.8
Sorghums.....		265	232.5	-32.5	87.7
Alfalfa.....		1,276	1,259.9	-16.1	98.7
Dry beans.....		217	194.2	-22.8	89.5
Rice.....		318	298.7	-19.3	93.9
Safflower.....		261	210.8	-50.2	80.8
Sugar beets.....		268	258.4	-27.6	90.3
Cotton.....		765	812.0	47.0	106.1
Total.....		6,019	5,369.0	-650.0	89.2

tion.<sup>27</sup> Marvin Hoover, University of California Extension Cotton Specialist, estimates that yields in this period were about 10 per cent higher because of skip-row planting than they would have

been from a 100 per cent solid planting. Because only solid planting is introduced in the linear programming models, 1961-65 acreage would have been exceeded by 10 per cent if there

<sup>27</sup> The higher yield for skip-row production is only a result of a technicality in the method of reporting yield. The strips of land left idle between rows of cotton are not included in the acreage base when yield is computed.

were no relative shifts among soils or climates.

The most pronounced absolute decline in acreage between the base period actual and model solution is in small grains, with optimal acreage being 452,000 acres lower than actual. This reflects a shift from nonirrigated to irrigated production.

The model acreage is higher than actual acreage in four of the regions and lower in the remaining five. The most significant absolute differences in regional acreage are in the Central Valley: the model acreage in Region 5 (San Joaquin Delta) is more than 300,000 acres higher than actual acreage, and the model acreage in Region 6 (San Joaquin Valley) is more than one million acres lower than actual. However, relative differences are most striking in two of the coastal regions: model acreage in Region 1 (North Coast) is more than 500 per cent higher than actual, and model acreage in Region 3 (South Coast) accounts for only 33 per cent of actual base period acreage.

**Regional shifts—individual crops.** Several striking redistributions of the harvested acreage of individual crops are manifest between 1961-65 actual and optimum regional locations (Appendix tables C-1 and C-2). Others are less pronounced. But, in general, regional shifts are the rule rather than across-the-board expansion or contraction of acreage in all major regions. The following observations emphasize this point:

- Safflower production shifts from regions 4, 5, and 6 (Central Valley) to Region 7 (Desert). The largest relative increase in the acreage, of any crop is safflower acreage in Region 7, with the base period optimal being 200 times greater than actual.
- Asparagus acreage shifts from regions 4, 5, 6, and 7, where the major concentration is in Region 5 (San Joaquin Delta), to Region 2 (Central Coast).

- Sugar beet acreage transfers from regions 4, 5, and 7 (Sacramento Valley, San Joaquin Delta, and Desert) to regions 2 and 3 (Central and South Coast), while the acreage in regions 6 and 8 (San Joaquin Valley and intermediate level valleys) expand somewhat.
- Grain sorghum production shifts from regions 4, 6, and 7 to Region 5.
- Corn shifts northward in the Central Valley from Region 6 to regions 4 and 5.
- Cotton acreage increases in Region 7 and decreases in Region 6.
- Substantial dry bean production in Region 3 moves northward to Region 2.
- Small grain acreage increases only in regions 5 and 9 (San Joaquin Delta and mountain valleys).
- Alfalfa acreage shifts northward completely out of Region 7 and partially out of Region 6 into regions 4 and 5.
- The dominant potato producing area moves from Region 6 to Region 2.
- Tomato production in regions 3 and 6 moves to Region 2 while the acreage in regions 4 and 5 remains quite similar to actual.
- The production of rice, melons, lettuce, and the cole crops becomes more concentrated in the major producing regions.

### **Production Cost, Resource Rent, and Product Price**

For every linear programming problem, there are two model solutions: the primal and the dual. In this cost minimization model, the primal provides the optimal location pattern of the included commodities. Simultaneously, the dual provides minimum nonland production cost, imputed price for each product, and imputed rent to each scarce resource. Up to this point, our discussion of the base period has focused on the optimal production patterns and resource requirements suggested by the

primal solution. The remainder of this discussion will concentrate on various observations from the dual solution.

**Production of base period output at least total cost.** Total imputed value of production may be ascertained in either of two ways:

$$TV = \sum_j P_j X_j, \quad (15)$$

or

$$TV = TC + \sum_i V_i R_i, \quad (16)$$

where

$TV$  is total imputed product value,

$TC$  is total nonland production cost,

$P_j$  is imputed price to commodity  $j$ ,

$X_j$  is output of commodity  $j$ ,

$V_i$  is imputed rent to one unit of resource  $i$ ,

$R_i$  is quantity of resource  $i$  required for production.

Value of production is illustrated here as the sum of total nonland costs and rents to fixed resources:

	Model solution (\$1,000,000)	Actual (\$1,000,000)
Total non- land costs	935.0	Not available
Total rents	87.4	Not available
Value of production	1,022.4	1,133.3 <sup>28</sup>

Primarily because of more efficient production patterns, the imputed value of production in the model solution is almost 10 per cent lower than actual product value in the base period.

**Imputed and actual product price.** In this model, the imputed product price is the marginal cost of producing

one more unit of each representative crop. If supply and demand were in long run, perfectly competitive equilibrium, the imputed price should equal the at-farm price.

Differences between imputed and actual product price may result as the aggregate effect of a number of causes. For example: (1) production is not optimally located; (2) supply and demand are not in long-run equilibrium; (3) perfect competition does not prevail; (4) cost estimates used in the model do not accurately reflect what farmers pay for resources, and/or (5) the price vector is not uniform in all areas because of the location of processing plants and commodity markets. All of these factors would have some effect on the relative differences between imputed and actual price, but only the net is measurable in this study.

Imputed 1961-65 prices are lower generally than actual average product price<sup>29</sup> for the same period (see table 22). Of the 18 representative crops in the study, only five have an imputed price higher than actual, with summer lettuce the highest, at 113 per cent of actual. Eleven have imputed prices which are between 70 and 99 per cent of actual. Two, safflower and grain sorghum, have the lowest imputed price—slightly more than 60 per cent of actual. The imputed prices average 88 per cent of actual prices with an average deviation of 15 per cent.

The imputed price for potatoes is 1 per cent higher than actual. However, the imputed price is for USDA No. 1's only, while the actual price is for the average of all potatoes marketed. If only USDA No. 1's were included in the determination of actual price, it should be significantly higher, and the imputed price relatively lower.

<sup>28</sup> California Crop and Livestock Reporting Service [1966, 1967a]. Nonrepresentative crops in each group are converted to units of the representative crop.

<sup>29</sup> Actual weighted 1961-65 price is estimated as average price at the farm or at the first delivery point, as reported by the California Crop and Livestock Reporting Service (1966, 1967a); it does not include government payments.

TABLE 22

## CROP PRICES, WEIGHTED BASE PERIOD ACTUAL, AND IMPUTED MODEL PRICES

Representative crop	1961-1965 price		Model as percentage of actual
	Actual*	Model imputed	
	<i>dollar/ton harvested</i>		<i>per cent</i>
Asparagus.....	273.18	249.10	91
Broccoli.....	160.60	137.12	85
Lettuce:			
Spring and fall.....	81.92	65.03	79
Summer.....	65.88	74.77	113
Winter.....	77.70	74.97	96
Cantaloupes:			
Spring and fall.....	111.44	82.48	74
Summer.....	84.86	76.78	90
Potatoes.....	51.42†	51.85‡	101
Tomatoes, processing.....	28.54	22.35	78
Corn for grain.....	51.10	50.29	98
Barley.....	46.32	47.34	102
Grain sorghum.....	43.82	27.37	62
Alfalfa hay.....	24.34	20.92	111
Dry beans.....	196.34	150.54¶	77
Rice.....	99.06	81.25	82
Safflower.....	84.77	51.64	61
Sugar beets.....	11.60	12.55	108
	<i>dollar/bale harvested</i>		
Cotton.....	164.00	127.75	78

\* Not including any government program payments.

† Average price of all potatoes marketed.

‡ Imputed price of USDA No. 1's only, which account for an estimated 75 per cent of all potatoes marketed; imputed price per ton of USDA No. 1 potatoes in Region 1 is \$54.42.

¶ Imputed price per ton of Central Valley dry beans is \$170.33.

As a direct result of differences between Model 1961-65 imputed and 1961-65 actual prices, Model 1980C was included in the analysis. This model forces the relative imputed prices of the feed grain groups—barley, corn, and grain sorghum—to equal their relative feeding values. In Model 1961-65, the imputed prices for barley and corn compared favorably with their actual prices, but the imputed price of grain sorghum was relatively much lower.

Assuming that the data used in the model are basically accurate and the model is adequate, the comparison of imputed and actual prices indicates those representative crops which show the largest deviation from a long-run equilibrium of supply and demand. It appears that excessive relative profits are enjoyed in the current production

of grain sorghum and safflower while net losses are experienced by many farmers in the production of summer lettuce, alfalfa hay, and sugar beets, in the absence of government payments. Such a conclusion must be carefully qualified at this point, but additional research may determine reasons for the discrepancies. If it can be shown that errors in the data used resulted in these differences, that is one matter. But if that is not the primary cause, then it becomes of economic (and possibly political) importance to determine which factors are responsible for the apparent cost-price disequilibrium. How important are barriers to entry, such as governmental allotments and contractual agreements, in the production of some commodities? What role does imperfect knowledge play? How extensive are

misallocations of resources? What effect do processing plant locations have on production location? Are producers slow to adjust to a changing market condition? Although definitive answers concerning the relative importance of each of these possibilities cannot be given by this study, the raising of relevant questions is an important by-product of analysis.

In the introduction to this section, attention was given to the primary reasons for including a 1961-65 model in the study. The empirical discussion which followed has been developed ex-

clusively to meet the first purpose—a comparison of differences between the real world and the linear programming solution for the base period.

In the following section, a number of important conclusions are drawn from a comparison of optimal solutions between two time periods. This was the second stated purpose for the base period model. Other conclusions are obtained through a comparison of the 1980 model solutions with each other and with the actual base-period parameters.

## 1980 REGIONAL RESOURCE USE

Major implications of three 1980 models are discussed in this section. The results of the preliminary 1980 models (i.e., models 1980A and 1980B) are outlined first. A detailed discussion of regional production shifts and imputed product prices indicated by these models is bypassed in favor of focusing attention on the results of Model 1980C. The results of Model 1980C appear to be more realistic as to the feed grain production pattern than those of preliminary models and, therefore, are presented in detail.

### Highlights of the Preliminary 1980 Models

Between 1965 and 1980 nearly one million additional acres will be required for nonagricultural and excluded crop uses. Although output levels for 1980 exceed those for the base period, the results from models 1980A and 1980B indicate continued excess productive capacity in California (see table 23).

#### Production of base period share of 1980 U. S. output (model 1980A).

*Acreage comparison.* California has the productive capacity to produce its base period share of projected national field crop and vegetable output in 1980 and still have considerable reserves of potential agricultural land used only

for range. Because mostly of the conversion of feed grain production from dryland to irrigated operations, 12 per cent less land and 11 per cent more irrigated acreage would be needed than were actually used in the base period for crops included in the model plus the excluded high-value crops. However, because of the higher output requirements, more inputs of all resources would be needed than were required in the base period model solution: land requirements are 7 per cent higher, and irrigated acreage requirements are 6 per cent higher. Potential agricultural land available for range is estimated to be 9 per cent higher than the base period actual and 18 per cent lower than base period optimal. Pasture and nonalfalfa hay acreage is equal to that for the 1961-65 average. Although model crop land requirements in the Model 1980A solution are 20 per cent lower than base period actual, harvested acreage of these crops is only 5 per cent lower because of a larger proportion of double-cropped acreage and less fallow acreage in the 1980 model solution. The proportion of double-cropped acreage is approximately the same in the model solutions of both time periods.

The regional distribution of included crop harvested acreage in the two model

TABLE 23

LAND USE, HARVESTED ACREAGE, AND PRODUCT VALUE OF INCLUDED CROPS IN CALIFORNIA, BASE PERIOD  
ACTUAL AND ALTERNATIVE MODEL ESTIMATES

Item	1981-85		1980		
	Actual	Model	Model A, constant share	Model B, trend share	Model C, modified Model B
	<i>1,000 acres</i>				
Land use					
Nonagricultural land*	2,403.2	2,403.2	3,221.3	3,221.3	3,221.3
Semiagricultural land*	1,722.5	1,722.5	1,640.5	1,640.5	1,640.5
Agricultural requirements					
Commodities not in study†					
Irrigated	2,804.0	2,804.0	2,963.7	2,963.7	2,963.7
Nonirrigated	406.6	406.6	426.5	426.5	426.5
Subtotal	3,210.6	3,210.6	3,390.2	3,390.2	3,390.2
Included commodities					
Irrigated	4,763.3	5,098.0	5,449.3	5,667.0	5,153.0
Nonirrigated	2,126.0	38.0	52.0	35.0	26.0
Subtotal	6,889.3	5,136.0	5,501.3	5,702.0	5,179.0
All commodities					
Irrigated	7,567.3	7,902.0	8,413.0	8,630.7	8,116.7
Nonirrigated	2,532.6	444.6	478.5	461.5	452.5
Total agricultural requirements	10,099.9	8,346.6	8,891.5	9,092.2	8,569.2
Range land	5,309.7	7,153.0	5,872.0	5,671.3	6,194.3
Total land inventoried	19,825.3	19,825.3	19,825.3	19,825.3	19,825.3
Harvested acreage, included commodities	6,019.0	5,369.0	5,740.8	5,924.0	5,893.0
	<i>million dollars</i>				
Product value, included crops					
Nonland costs	NA	935.0	1,275.4	1,381.8	1,361.0
Rents	NA	87.4	141.9	143.5	143.1
Value of production	1,133.3	1,022.4	1,417.3	1,525.3	1,504.1

\* Source: Appendix table B-1.

† Orchard and excluded vegetable crops, irrigated pasture, and nonalfalfa hay acreage.

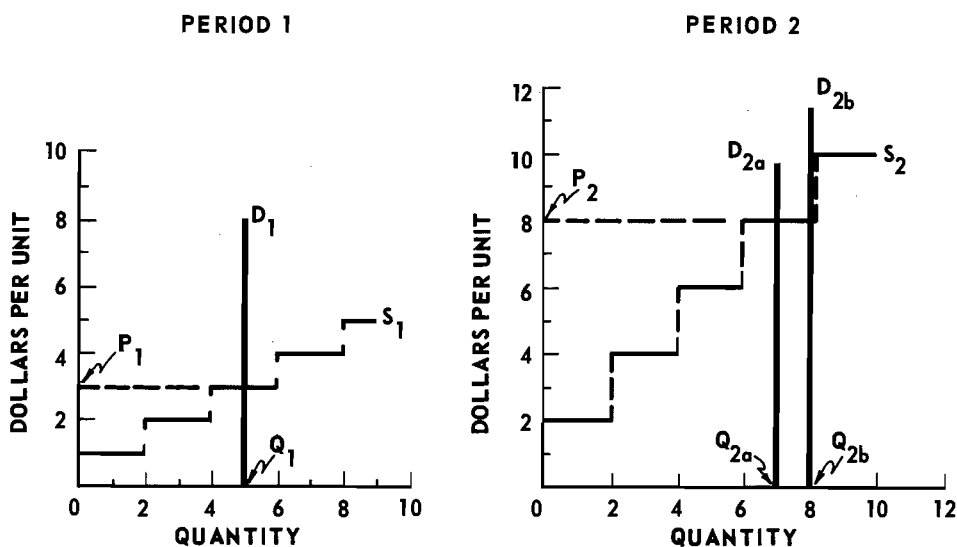


Fig. 4. Hypothetical single-commodity step supply curves and inelastic-demand curves in two time periods between which unit costs double and quantity demanded increases 40 per cent (Time Period 1) and 60 per cent (Time Period 2).

solutions shows that in eight of the nine regions (Region 4 being the only exception), optimal harvested crop acreage in the Model 1980A solution more closely approximates actual 1961-65 acreage than does that in the Model 1961-65 solution. While no explanation of this fact is proffered, it is of interest that the net effect of increasing costs and yields and changing demand between time periods is to partially offset the difference between the model solution and the actual pattern in the base period.

**Imputed value.** Imputed total product value of the model crops (in representative crop units) is 25 per cent higher than 1961-65 actual and 39 per cent higher than the imputed value from the 1961-65 model. Similarly, nonland production costs are 36 per cent higher than the base-period model suggests, and imputed rents to fixed resources are 62 per cent higher than the optimal solution in the base-period model.

It is possible to have either a larger or smaller relative increase in rents than the relative increase in product value when the supply and demand curves

shift. This is illustrated in figure 4 for the two time periods for a case of a stepped supply curve and an inelastic demand curve. With a 40 per cent increase in quantity demanded ( $Q_1$  to  $Q_{2a}$ ) and a doubling of unit costs, rents are increased relatively more than the increase in value of production. With 60 per cent increase in quantity demanded ( $Q_1$  to  $Q_{2b}$ ), rents increase relatively less than the increase in value of production. There is only one point between these extremes in demand at which product value, nonland costs, and rents to fixed resources all increase proportionately. With a set of supply curves for multiple crops that do not change proportionately between time periods, it is reasonable to expect that the individual components of the value of production will change nonproportionately also.

In this study, imputed rents increase relatively more than does value of production between the base period optimum and each of the 1980 models. In fact, the increase in relative rents is substantially greater than that of product



value in all cases. Therefore, optimum capitalized land value for agriculture is likely to increase proportionately more than value of farm production between the base period and 1980, as long as the interest rate on alternative investments does not increase between these time periods.

**Production of share of U. S. output projected by recent trends (Model 1980B).** The only differences between the structure of Model 1980A and Model 1980B are in the output restraints. The relative difference is the greatest for cotton and safflower, with the output of each in Model 1980B exceeding that in Model 1980A by more than 25 per cent. The output of sugar beets, tomatoes, and the cole crops is also higher while the output of alfalfa, dry beans, and each feed grain is lower.

*Acreage comparison.* In response to one of the questions raised at the outset of this study, California has more than enough agricultural capacity to produce its projected share of 1980 U. S. output. Although 14 per cent more land would require irrigation, 10 per cent fewer land resources would be needed than were actually used in the base period for the model and excluded, high-value crops. More outputs of all resources would be required than were needed in the base period model solution; both land and irrigated acreage requirements are 9 per cent higher. Potential agricultural land available for range is estimated to be 5 per cent greater than the base period actual and 21 per cent lower than the base period optimal.

Although Model 1980B output projections of field crops and vegetables

are considerably higher than the base period levels, it is possible to produce this increased output on fewer acres than actually used in the base period. To do so, however, yield levels must also increase, more land must be irrigated, two crops a year must be produced on a larger proportion of the acreage, and farmers must adjust their cropping practices to optimal production patterns.

*Imputed value.* Imputed total product value of the included crops is 35 per cent higher than base period actual and 49 per cent higher than the imputed value from the 1961-65 model. Similarly, nonland production costs are 48 per cent higher than the base period model suggests, and imputed rents to fixed resources are assessed at a 64 per cent higher level than the optimal solution in the base period.

### Best 1980 Projections Model

At the inception of this study, only two 1980 models, based on alternative demand assumptions, were planned. However, an unrealistic relationship was obtained between the relative feeding values and the imputed prices of the individual feed grains in these models.<sup>30</sup> Because of this inadequate relationship, Model 1980C was developed. Yields of barley and grain sorghum activities are converted to equivalent feeding units of corn, and Model 1980B output restraints for individual feed grains are replaced with a single restraint for all feed grains. All other output restraints and parameters remain at Model 1980B levels.

The assumptions underlying Model 1980C seem to be the most realistic, in

<sup>30</sup> Actual base period prices did not correlate closely with scientifically estimated feeding values either. For example, the ratio of annual grain sorghum to corn prices has been lower in each of the last 10 years than their relative feeding values. This observation is true when feeding value is computed on the basis of net energy only and also when digestible protein is assessed in the measure. The cause for this low relationship has been attributed by specialists to old wives' tales, lower quality of sorghum shipments, and feeder inflexibilities. However, it is assumed in this model that full adjustment to least cost feeding rations will be made by 1980 such that prices paid by feeders will reflect the true feeding value in net energy equivalents of the alternatives.

the absence of governmental programs, of the 1980 models. It seems reasonable that by 1980 the share of U. S. output supplied by California would be different from the base period and that feeders should adjust their rations to a least-cost mix. Therefore, the Model 1980C solution will be presented in detail in this section.

To facilitate the orderly presentation of these results, this section is divided into five parts. In the first two, the projected land and water use patterns are compared to previous patterns. In the third, the projected harvested acreage of each crop and its regional distribution are contrasted. Fourth, the major implications of the dual solution are highlighted. And finally, the sensitivity of the optimal solution to errors in parameter estimation is discussed.

**Land use pattern.** Land required to produce Model 1980C output of included crops amounts to 5,179,000 acres, as shown in table 24. This is only 43,000 acres more than optimal acreage in Model 1961-65 and is the lowest of the 1980 models, being more than  $\frac{1}{2}$  million acres less than Model 1980B requirements.

As compared with the base-period feed grain mix consisting of 71 per cent small grains,<sup>31</sup> 16 per cent sorghum, and 13 per cent corn, the minimum-cost feed grain mix is comprised of 44 per cent small grains, 56 per cent sorghum, and no corn. The latter mix is produced almost exclusively in barley-grain sorghum double-crop activities in this model. An additional 697,600 acres of the double-crop activity displaces 1,133,300 acres of single-cropped irrigated barley, 9,000 acres of fallowed barley, and 141,300 acres of corn in the Model 1980B solution.

Because of additional nonagricultural and excluded crop requirements for land between the base period and 1980, idle land is projected by Model 1980C to be more than 900,000 acres less

than in the base period *optimal* pattern. However, because of the shift to more irrigated, double-crop production of feed grains, projected idle land in Model 1980C is nearly 800,000 acres *higher* than *actual* idle land in the base period.

**Regional model crop acreage requirements.** Some production of included crops is projected by this model in all regions (see table 24). The acreage in Region 6 is projected to be higher than it is in the base-period optimal solution. In all other regions, a net decline in acreage is estimated. The adjustment in the feed grain mix, with the consequent move to more double cropping in the Central Valley, is responsible for part of this regional realignment. However, the adjustments due to the decreasing resource base and increasing demand between the base period and 1980 were also significant. Regional adjustments in the included crop acreage are the net result of the entire complex of urban expansion, increased excluded crop acreage requirements, and a changing demand structure for the model crops.

**Soil categories required for model crop activities.** Table 25 shows that model crop production is concentrated almost entirely on alluvial and basin soils. All of the valley floor acreage (soils 01-15) in the Central Valley from Merced County north and virtually all of the irrigable acreage in these soil groups in the Central Coast enters the solution (see Appendix table C-10). Nearly all of soil 11 (organic soil) acreage in the entire State enters the solution.

A considerable acreage of saline-alkaline soil (including all of soils 13 and 15 in the Central Valley from Merced County north) is projected for reclamation, but little production is projected for terrace soils. In fact, the only crop activity on a terrace soil is 23,000 acres of sugar beets on soil 21 in the Central Coast. Apparently the esti-

<sup>31</sup> Oats and barley in units of barley, the representative crop.

**TABLE 24**  
**LAND USE BY REGION FOR INCLUDED CROPS, ESTIMATED MODEL 1980C REQUIREMENTS**

Crop activity	Region									State*
	Coastal			Central Valley			Desert	Mountain		
	1	2	3	4	5	6	7	8	9	
	1,000 acres									
Vegetable crops:										
Asparagus.....	0	40.8	0	0	0	0	0	0	0	40.8
Broccoli (single crop).....	0	0	0	0	0	11.6	0	0	0	11.6
Broccoli and fall or spring lettuce (double crop).....	0	41.7	0	0	0	0	0	0	0	41.7
Lettuce, fall or spring (single crop).....	0	0	0	0	0	0	0	0	0	0
Lettuce, fall and spring (double crop).....	0	0	0	0	0	0	0	0	0	0
Lettuce, fall or spring and summer (double crop).....	0	0	0	0	0	0	0	0	0	0
Lettuce, summer (single crop).....	0	38.4	0	0	0	0	0	0	0	38.4
Lettuce, winter (double crop).....	0	0	0	0	0	0	21.9	0	0	21.9
Cantaloupes, fall or spring.....	0	0	0	0	0	0	14.0	0	0	14.0
Cantaloupes, summer.....	0	0	0	0	0	40.9	0	0	0	40.9
Potatoes.....	0	28.0	0	0	20.0	30.5	0	0	14.3	92.8
Tomatoes, processing.....	0	0	0	57.2	110.0	0	0	0	0	167.2
Field crops:										
Corn.....	0	0	0	0	0	0	0	0	0	0
Barley (fallow).....	0	26.0	0	0	0	0	0	0	0	26.0
Barley (nonirrigated).....	0	0	0	0	0	0	0	0	0	0
Barley (irrigated, single crop).....	0	0	0	0	0	0	0	0	0	0
Barley and grain sorghum (irrigated, double crop).....	0	4.0	0	249.6	330.0	365.2	0	0	0	948.8
Grain sorghum (single crop).....	0	0	0	0	0	0	0	0	0	0
Alfalfa hay.....	24.0	16.0	0	267.8	340.0	267.0	0	81.3	298.0	1,294.1
Dry beans.....	0	60.7	21.0	0	49.0	62.2	0	0	0	192.9
Rice.....	0	0	0	268.4	0	0	0	0	0	268.4
Safflower.....	0	0	0	0	0	271.6	240.0	0	0	511.6
Sugar beets.....	0	111.0	32.0	0	6.0	124.4	0	38.0	0	311.4
Cotton.....	0	0	0	0	0	954.3	202.0	0	0	1,156.3
Total land utilized Model 1980C optimal*	24.0	366.7	53.0	843.0	855.0	2,127.8	477.9	119.4	312.3	5,179.0
Residual land, projected 1980†.....	172	546	415	870	502	3,048.0	1,062	323	762.0	7,726.0
Net model acreage available, projected 1980†.....	196	913	468	1,713	1,357	5,176	1,540	442	1,104	12,905

\* Computed from unrounded data.

† Includes acreage used for pasture and nonalfalfa hay.

‡ All figures except total are computed from unrounded data. Total is from Appendix table B-1 and includes all land suitable for agriculture less projected acreage requirements for urban, public, and semiagricultural uses and for orchard, vineyard, and included vegetable crop production.

TABLE 25  
TOTAL LAND USE FOR INCLUDED CROPS BY SOIL TYPE, ESTIMATED  
MODEL 1980C REQUIREMENTS

Soil type	Soil number	Net model acreage available, projected 1980*	Total land utilized by included crops, Model 1980C optimal†	Residual land, projected 1980‡
1,000 acres				
Alluvial:				
Loam.....	01	1,377	981	396
Loam.....	02	956	850	106
Loam.....	03	2,384	761	1,623
Sandy.....	05	380	266	114
Subtotal.....		5,097	2,858	2,239
Basin:				
Organic.....	11	319	317	2
Clay.....	12	1,913	1,488	425
Clay with salts.....	13	479	247	232
Basin rim.....	14	301	119	182
Basin rim with salts.....	15	788	127	661
Subtotal.....		3,800	2,298	1,502
Terrace:				
Loam.....	21	1,108	23	1,085
Clay.....	22	447	0	447
Claypan.....	23	884	0	884
Hardpan.....	24	1,575	0	1,575
Subtotal.....		4,014	23	3,991
State total.....		12,905	5,179	7,726

\* Equal to total inventoried acreage less urban, extra-urban, semiagricultural, and orchard and excluded vegetable crops. All figures except total are computed from unrounded data.

† See Appendix table C-11 for detail.

‡ Includes the acreage to be used for pasture and nonalfalfa hay.

mated annual cost per unit of output is less to reclaim certain saline and alkaline soils for production than to irrigate with sprinklers on the sloping terraces. There are enough cheaper alternatives in the relevant section of the supply function to prevent any greater expansion on terrace soils in any of the models.

**HPA land requirements.** Of the 95 HPAs delineated in the early stages of this study, crop activities are optimally located in 57. Because supplementary restraints are imposed on the maximum acreage of individual crops or total irrigated acreage in a given HPA, there are considerably more than 57 HPA crop activities in the solution. Actually there are 120 elements in the optimal

basis, which includes acreage in 17 of the 24 different crop activities. The acreage of a crop activity is limited in two instances by irrigated acreage restraints, in 69 by rotation restraints, in 31 by net model acreage restraints, and the limiting restraint for 18 others is minimum crop output. The Model 1980C acreage by crop in each HPA is recorded in Appendix table C-12 together with an identification of the variable which restricts production in each case.

**Water use pattern.** As in the base-period section, this comparison of water resources consists of (1) the acreage of land irrigated, and (2) the quantity of water applied.

**Irrigated acreage required.** The only

TABLE 26  
IRRIGATED ACREAGE BY REGION, ESTIMATED MODEL 1980C  
REQUIREMENTS

Region	Projected 1980:					
	Region number	Included crops, Model 1980C	Orchard and excluded vegetable crops*	Total†	Total as percentage of base period actual	Total as percentage of base period optimal
		1,000 acres			per cent	
Coastal:						
North.....	1	24.0	23.3	75.7	140	89
Central.....	2	340.7	106.1	493.6	116	88
South.....	3	53.0	228.6	330.8	74	101
Subtotal.....		417.7	358.0	900.1	97	92
Central Valley:						
Sacramento.....	4	843.0	228.7	1,204.9	124	98
Delta.....	5	855.0	226.0	1,318.6	124	97
San Joaquin.....	6	2,127.8	773.6	3,311.3	95	119
Subtotal.....		3,825.8	1,228.3	5,924.8	106	109
Desert.....	7	477.9	58.4	586.3	94	88
Mountain Valleys:						
Intermediate.....	8	119.3	20.9	160.4	260	79
High.....	9	312.3	2.6	545.1	150	90
Subtotal.....		431.6	23.5	705.5	166	87
State†.....		5,153.0	1,668.2	8,116.7	107	103

\* See footnote ¶ in table 19 for the percentage of these crops irrigated in each region.

† The 1980 total includes Model 1980C irrigated acreage of model crops, projected 1980 irrigated acreage of orchard and excluded vegetable crops, and circa 1965-66 acreage of irrigated pasture and nonalfalfa hay.

‡ Computed from unrounded data.

nonirrigated activity which enters the optimal solution is nonirrigated barley—with 26,000 acres. All other activities require the application of supplementary water. Irrigated acreage requirements for all crops are 7 per cent higher than estimated base period acreage actually irrigated (table 26). They are only 3 per cent higher than the base-period optimal irrigated acreage and 6 per cent lower than the optimum estimated by Model 1980B.

The only regional change from the base period actual which is in a different direction than that of the base-period model solution is in Region 7. Total irrigated acreage in this region is projected to be 6 per cent lower than base-period actual. Region 8 shows the

largest relative increase over the base-period actual in this model (as it did also in Model 1961-65). The largest absolute increases are in regions 4 and 5, with almost equal changes in both.

The projected regional changes in total irrigated acreage are different when Model 1980C and the base-period optimum are compared. The largest relative increase between the two optima is in Region 6. A slight increase is projected also in Region 3. In all other regions, however, the change in optimal irrigated acreage is downward.

For a final comparison, the California Department of Water Resources (1966) published projections of irrigated acreage in California by hydrographic region. They anticipate a 17.5

per cent increase in California's irrigated acreage between 1960 and 1990, with major expansion in the Central Valley and with contraction in the South Coast. Their 1990 projection for the State is considerably higher than our 1980 projection. Their 1990 projections in most regions are also higher than ours. They are lower only in the Delta (Region 5), and in the mountain valleys (regions 8 and 9).

With the abundant supply of water it seems likely that in the Delta, irrigation facilities could be expanded in this region beyond the Department's projected level. The high rate of expansion projected by this study in the mountain regions, however, does not seem as plausible. Whereas the Department projects that irrigated acreage will increase only marginally in these regions (less than 20,000 acres), we have projected an increase of about 65 per cent (nearly 300,000 acres). This high projection is presented even though we previously emphasized that little expansion is likely in Region 9, and irrigation restraints were imposed at actually observed past levels. The reason for this apparent discrepancy is explained by the role of irrigated pasture and nonalfalfa hay in that region's economy. These crops are assumed, in this analysis, to be residual takers of available resources. Therefore, the acreage of these crops irrigated in Region 9 was not subtracted from the total in deriving the irrigation restraints. But in discussing future irrigation requirements, we have made no independent projection of total or regional adjustments in irrigated pasture acreage. Instead, in table 26 the acreage is assumed to remain constant in all regions. If all irrigated pasture were transferred out of both mountain regions, the model projections could be produced with little aggregate increase of irrigated acreage.

The primary model crop projected for expansion in these regions is alfalfa

hay. Therefore, what will actually happen there depends primarily on the relative competition between alfalfa and pasture for scarce irrigated land. Because irrigated pasture activities were not included endogenously in the allocation model, no insights can be offered by this study on the competitive nature of these two crops. However, production tests recently performed by farm advisors in Modoc County have indicated favorable yields of alfalfa in some areas. Being deficit suppliers of their own hay needs, these regions face a good market for the expansion of alfalfa hay production. Therefore, with limited irrigation facilities, some alfalfa hay will likely substitute for irrigated pasture production. But more alfalfa and/or irrigated pasture will undoubtedly have to be produced in other regions (probably the Central Valley) to meet projected demand requirements.

*Water requirements.* Because of the projected increase in double-cropped acreage, the quantity of water required for production is expected to increase at a more rapid rate than the acreage of land which must be irrigated. Water requirements for agriculture in 1980 are projected to be 11 and 12 per cent higher than base-period actual and optimal requirements respectively (table 27). This increase is projected on the basis that the quantity of water applied per acre of each crop harvested will not change from the base period. If the applied water requirements were to increase in order to obtain higher yields, this projection would be an underestimate. For example, if per-acre water requirements increase 5 per cent (which was the aggregate increase in input per acre expected in projecting 1980 costs), the agricultural demand for water would be 16 per cent higher than realized in the base-period actual. In either case, our projection suggests a slightly more rapid annual rate of increase in the demand for water deliveries than

TABLE 27  
 AGRICULTURAL WATER REQUIREMENTS BY REGION, ESTIMATED MODEL  
 1980C REQUIREMENTS\*

Region	Region number	Projected 1980 requirements:				
		Included crops, Model 1980C	Orchard and excluded vegetable crops	Total††	Total as percentage of base period actual	Total as percentage of base period optimal
		1,000 acre feet			per cent	
Coastal:						
North.....	1	60	40	180	144.0	90.9
Central.....	2	750	233	1,152	120.8	87.4
South.....	3	134	617	987	77.8	100.0
Subtotal.....		944	899	2,319	98.8	92.6
Central Valley:						
Sacramento.....	4	3,081	526	4,567	126.3	99.8
Delta.....	5	6,469	2,166	10,521	100.7	128.1
Subtotal.....		12,003	3,212	19,083	111.6	113.8
Desert.....	7	1,976	204	2,580	88.9	109.3
Mountain valleys:						
Intermediate.....	8	387	48	508	274.6	111.2
High.....	9	907	6	1,718	162.2	126.0
Subtotal.....		1,294	54	2,226	178.9	122.3
State†.....		16,217	4,370	26,208	111.1	111.8

\* Water requirements per harvested acre are assumed to be the same as in the base period.

† The 1980 total includes water requirements for: (1) Model 1980C irrigated acreage of model crops, (2) projected 1980 irrigated acreage of orchard and excluded vegetable crops, and (3) circa 1965-66 acreage of irrigated pasture and nonalfalfa hay.

†† Computed from unrounded data.

the Department of Water Resources projection (14 per cent increase between 1960 and 1990).

With a higher State demand for water, the demand is projected to be higher also in most regions by 1980 than was actually used in the base period. The only regions projected to have a decreased demand are the South Coast (because of a projected decline in harvested crop acreage) and the Desert Region (because of a shift in cropping patterns to lower water-using crops). The relative increase in water requirements in all other regions is slightly higher than the relative increase in irrigated acreage. Although the 1980 cropping pattern is quite different from the base period actual, the

largest projected increases in water demand are still in the regions with the largest increase in irrigated acreage. The largest percentage increases are in the mountain valleys (regions 8 and 9), and the largest absolute increases are in the Delta (Region 5) and the Sacramento Valley (Region 4).

The most important projected increase over the base period optimal requirement is in the San Joaquin Valley (Region 6). With a projected 28 per cent increase, the demand for water is more than 2 million acre-feet higher than the base period optimal requirement. However, the 1980 water demand projection is still only slightly above the base period actual requirement, and this is the region whose water supply is

TABLE 28  
HARVESTED CROP ACREAGE BY CROP GROUP FOR INCLUDED  
COMMODITIES, BASE PERIOD ACTUAL AND ESTIMATED MODEL  
REQUIREMENTS\*

Crop group	Base period		1980				
	Actual	Model	Model C	Model C less base period actual	Model C as percentage of base period actual	Model C less base period model	Model C as percentage of base period model
	1,000 acres				per cent	1,000 acres	per cent
Asparagus.....	64	42.8	40.8	-23.2	63.8	-2.0	95.4
Cole crops.....	48	42.9	53.3	5.3	111.1	10.4	124.4
Lettuce.....	116	114.8	123.9	7.9	106.9	9.1	107.9
Melons.....	73	62.9	54.9	-18.1	75.3	-8.0	87.3
Potatoes.....	101	95.1	92.8	-8.2	91.9	-2.3	97.6
Tomatoes.....	178	168.8	167.2	-10.8	93.9	-1.6	99.1
Corn.....	180	156.7	0	-180.0	0	-156.7	0
Small grains.....	1,871	1,418.6	819.1	-1,051.9	43.8	-599.5	57.7
Sorghums.....	265	232.5	806.1	541.1	304.2	573.6	346.8
Alfalfa.....	1,276	1,259.9	1,294.1	18.1	101.4	34.2	102.7
Dry beans.....	317	194.2	192.9	-24.1	58.9	-1.3	99.4
Rice.....	318	298.7	268.4	-49.6	84.4	-30.3	89.9
Safflower.....	261	210.8	511.6	250.6	196.0	300.8	242.7
Sugar beets.....	286	258.4	311.4	25.4	108.9	53.0	120.5
Cotton.....	765	812.0	1,156.3	391.3	151.2	344.3	142.4

\* SOURCE: Appendix C.

expected to benefit more from the construction of the California Water Project.

**Harvested crop acreage.** The earlier parts of this discussion of the Model 1980C solution have focused on the land and water resources required for the production of model and high-value, excluded crops. Because significant acreages of land were fallowed or double-cropped in the base period or are expected to be double cropped in 1980, this previous discussion does not adequately depict the adjustments expected in the acreage of crops actually harvested. Therefore, we will now focus on a comparison of the harvested acreage of the crops included in the model.

**State acreage.** Optimal 1980C acreage of model crops harvested is 5,893,000 acres. This figure is 126,000 acres, or 2 per cent, less than actual 1961-65 harvested crop acreage. Although the total land required for these crops is projected to be similar to the estimated base period optimal requirement, har-

vested crop acreage is more than ½ million acres higher than in that solution. This is an 11 per cent increase. In comparison to the Model B trend share model, the land required for Model 1980C solution is ½ million acres less, but the reduction in harvested crop acreage is only 31,000 acres. The shift to much more double cropping of feed grains in Model 1980C is responsible for the increased disparity between total land required and harvested crop acreage.

**Major changes in crop acreage.** As indicated in table 28, the largest relative increase in the harvested acreage of any crop group between 1961-65 actual and Model 1980C is for sorghum, with an increase of more than 200 per cent. The acreage of safflower (or other oilseeds) increases 96 per cent and of cotton, 51 per cent. For each of these crops, the 1980 output is significantly higher than the base-period output. Four other crop acreage increases occur, each being less than 12 per cent.



TABLE 29  
HARVESTED CROP ACREAGE BY REGION FOR INCLUDED COMMODITIES, BASE PERIOD ACTUAL AND ESTIMATED  
MODEL REQUIREMENTS\*

Region	Region number	Base period		1980				
		Actual	Model	Model C	Model C less base period actual	Model C as percentage of base period actual	Model C less base period model	Model C as percentage of base period model
		<i>1,000 acres</i>				<i>per cent</i>	<i>1,000 acres</i>	<i>per cent</i>
Coastal:								
North.....	1	0	35.0	24.0	18.0	400.0	-11.0	58.6
Central.....	2	333	478.5	398.2	65.2	119.6	-80.4	83.2
South.....	3	218	72.0	53.0	-165.0	24.3	-19.0	73.7
Subtotal.....		557	585.5	475.2	-81.8	85.3	-110.4	81.2
Central Valley:								
Sacramento.....	4	922	888.0	992.8	70.8	107.7	104.8	111.8
Delta.....	5	805	1,109.4	1,086.0	231.0	134.9	-23.4	97.9
San Joaquin.....	6	2,679	1,666.4	2,407.6	271.4	89.9	741.2	144.5
Subtotal.....		4,406	3,663.8	4,486.4	80.4	101.8	822.6	122.5
Desert.....	7	649	582.7	499.9	-149.1	77.0	-82.8	85.8
Mountain Valleys:								
Intermediate.....	8	249	165.0	119.3	-129.7	47.9	-45.7	73.3
High.....	9	158	372.0	312.3	154.3	197.7	-59.7	84.0
Subtotal.....		407	537.0	431.6	24.6	106.0	-105.4	80.4
State.....		6,019	5,369.0	5,893.1	-125.9	97.8	524.0	109.8

\* SOURCE: Appendix C.

Decreases include corn, 100 per cent (no corn is projected for production by this model); small grains, 56 per cent (because of a lower projected output and extensive conversion from dry land to irrigated production); asparagus, 32 per cent (resulting from higher yields in the new production locations); and melons, 25 per cent (output in both periods is similar, yields are higher in 1980, and there is a shift to the highest yielding HPA in the 1980 solution). Four other crop acreage decreases are within 16 per cent of original acreage.

Harvested acreage of small grains shows the largest absolute decrease of more than 1 million acres. A significant reduction in acreage is also noted for corn of 180,000 and for rice of almost 50,000 (rice yield estimates in 1980 are 35 per cent higher than in the base period, and projected output in 1980 is only 22 per cent higher). Increases in absolute, as well as relative, terms are the greatest for sorghum, cotton, and safflower—all of which increase more than 250,000 acres.

In comparison with Model 1961–65 crop acreage, the largest relative and absolute increases in Model 1980C crop acreage are also for sorghum, cotton, and safflower. Decreases in both relative and absolute terms are most significant for small grains and corn.

The relative difference between Model 1980C crop acreage and base period actual is greater than the difference between Model 1980C and 1961–65 optimal for six crops, the same for one, and less for eight.

The acreage change by moving from 1961–65 actual to optimal locations is greater than the change between Models 1961–65 and 1980C for only five crops. For the remaining ten crop groups, the effect of structural changes in yield, cost, and demand between the two time periods is more important than shifting production to optimal locations in the base period.

*Regional shifts—total harvested acre-*

*age.* Major regional acreage changes from 1961–65 actual include relative increases of 300 per cent in Region 1 and 98 per cent in Region 9, and decreases of 76 per cent in Region 3 and 52 per cent in Region 8 (table 29). In absolute terms the largest increases are 281,000 acres in Region 5 and 154,300 in Region 9. The largest decrease is 271,400 acres in Region 6. Others with sizable decreases include regions 3, 7, and 8.

When compared with the 1961–65 optimal, the largest relative change is a 45 per cent increase in Region 6 acreage. The only other region with a projected increase is Region 4. Declines are greatest in regions 1, 3, and 8 with 31, 26, and 28 per cent decreases, respectively. The impact on total regional acreage of moving from actual to optimal base-period locations is greater than the impact of structural changes between the two dates in seven of the nine regions.

*Regional shifts—individual crop harvested acreage.* Several major shifts in the regional distribution of individual crops are noted between the 1961–65 optimal and the Model 1980C solution (see Appendix table C-5):

1. Grain sorghum production expands mainly in regions 4 and 6, from which production originally shifted to Region 5 in the base-period model solution.

2. Some of the bean production shifts back to Region 3 so the 1980C optimal pattern is similar to the base-period actual. The only exception is that there is no 1980C production in Region 4.

3. Safflower acreage increases mainly in Region 6. Approximately 53 per cent of the base-period actual acreage was in Region 6. Region 6 has this same share of optimal 1980C acreage, but had none in the base-period optimal. The acreage that shifted from regions 4 and 5 in the base-period actual to Region 7 in the base-period optimal remains there in the 1980C optimal.

4. Some sugar beet production shifts from Region 3, a small acreage returns to Region 5, and expansion of 1961-65 optimal acreage occurs in regions 2, 6, and 8.

5. Approximately 15 per cent of the State's optimal-base period alfalfa acreage shifts from the Central Valley to the mountain valleys (particularly to Region 9).

6. Small grain acreage declines in regions 6 to 9. The only region with a projected increase in optimal acreage is Region 4.

7. Cotton acreage expands only in Region 6, but the 1980C regional distribution is still more heavily weighted to Region 7 than is actual-base period acreage.

8. While more than 40 per cent of tomato acreage in the 1961-65 optimal solution was in Region 2, it is concentrated entirely in regions 4 and 5 in 1980.

9. Approximately half of Region 2's optimal-base period potato acreage shifts to regions 5 and 6, giving Region 6 the largest share of the total in 1980 (which was actually the case in the base period also).

10. Little or no regional realignment of optimal acreage is projected for rice, asparagus, lettuce, or melon production.

**Production of projected output at least total cost.** The imputed value of Model 1980C output is more than \$1.5 billion. This figure is 33 per cent higher than the actual value of base period output and 47 per cent higher than the imputed value of Model 1961-65 production. The increase in imputed product value over the base period is caused by (1) generally higher unit costs, (2) higher output requirements, and (3) less land available in 1980 in HPAs to which crop production was allocated by the base-period model. Nonland produc-

tion costs are 46 per cent higher than suggested by Model 1961-65, and imputed rents are 64 per cent higher (table 23).

*Least cost feed grain mix.* Output requirements and all other parameters in Model 1980C are the same as in Model 1980B. The only difference between the two models is the addition of a feed grain restraint which requires that the model select the least-cost mix of individual feed grains to satisfy the aggregate 1980B feed-grain net energy requirement.

The Model 1980C imputed value of production of all model crops is approximately \$21 million lower than the Model 1980B imputed value. Shifting from a 1980 fixed proportion feed grain mix, in which the percentage of individual feed grains in the mix is the same as during the base period, to a least-cost mix results in a saving of 1.4 per cent in imputed value of model crop production. In a perfectly competitive system, this net saving would be passed on to consumers.

In Model 1980B, the imputed product value of all feed grains amounts to \$173.5 million. The imputed value in Model 1980C is \$24.3 million less. This saving in the imputed feed grain product value over Model 1980B rations amounts to 14 per cent. If production occurs under perfect competition, this is the saving that would be passed on to the feeding industry.<sup>22</sup> A considerable improvement in production efficiency could thereby be obtained by moving to the optimum product mix in this crop group alone.

The fact that the imputed saving in the production of feed grains is greater than total imputed saving of all crops implies that the market value of some other crops will be higher under conditions of optimum location if the least-

<sup>22</sup> California is a deficit region in the supply of feed grains. A deficit is projected to continue through 1980, so that feed grains will still be shipped into California. Hence, under equilibrium conditions, if the imputed value of feed grains produced in the State is lower than the cost of feed grains shipped in, the production of these crops would be increased within California, and inshipments would be decreased.

cost feed grain mix is produced. The only crops for which imputed prices in Model 1980C are higher than in Model 1980B are alfalfa hay and rice.

*Imputed value of restricting variables.* The imputed value of a variable is interpreted as the decrease (or, if negative, the increase) in cost that would occur if the restraint level were increased by one unit. The imputed value of variables not at restricting levels is zero. The dual value for resources is imputed rent and for minimum output restraints it is the marginal cost of producing one more unit of that product. The restricting variable to the production of a crop activity in the basis is recorded along with its imputed value in Appendix table C-12.

The highest imputed rent to an additional acre of land is \$61 in the Central Coast HPA 0122. Other land rents are all less than \$50 per acre. Enough water to irrigate one additional acre of land would be worth \$41 in the Central Coast HPA 0222 and \$29 in HPA 0224.

Rotation restraints, which limit the acreage that can be planted to a particular crop activity in any HPA, are specified in all models. However, it is possible to reduce the extent to which rotations are required in the production of most crops through good management, weed and pest control, proper fertilization, etc. Hence, the imputed rent to a rotation restraint may be interpreted as the dollar amount which could be spent on nonland resources in order for one more acre of that crop activity to be planted in the HPA. An additional \$88 could be spent on nonland resources to relax by one acre the rotation restraint for cotton in the Desert HPA 0372. Similarly, \$74 in HPA 0572, \$61 in the San Joaquin Valley HPA 1263, \$60 in HPA 1262, or \$30 to \$40 in several other areas could be spent on alternative resources to relax the cotton rotation restraint by one acre. The only other crops for which an additional acre in the rotation restraint is worth

more than \$20 are sugar beets, dry beans, and alfalfa hay in very few HPAs.

*Imputed product prices.* Model 1980C representative crop imputed prices (or the marginal costs of production expressed as positive values) average 4 per cent lower than actual 1961-65 prices and 10 per cent higher than imputed 1961-65 prices (table 30). The average deviation of 1980C imputed prices expressed as a percentage of base period actual prices is 19 per cent. This is a wider relative deviation than that of the base period imputed prices with respect to actual. In addition, the average deviation of 1980C prices as a percentage of base period imputed is the lowest of the three ratios at 11 per cent. There are at least two implications of the relative magnitude of these deviations:

1. The impact on the *relative* product price vector is caused less by changing cost, yield, and output parameters between the two time periods than by the net effect of: (a) higher actual price-cost ratios in the base period for some crops than for others, (b) the possibility for decreasing costs by moving to optimal locations, and (c) having some budgets which are less representative of actual costs than others.

2. The changing parameters between time periods do not offset any of the *relative* price deviation obtained by moving from actual to optimal production locations in the base period.

The 1980C imputed prices which are the largest relative to 1961-65 actual prices are for summer lettuce (+ 31 per cent), alfalfa hay (+ 24 per cent), and sugar beets (+ 24 per cent). The lowest relative to the base period actual are for safflower (- 34 per cent), tomatoes (- 26 per cent), corn (- 26 per cent), and barley (- 24 per cent). The highest 1980C prices relative to 1961-65 imputed prices are for grain sorghum (+ 32 per cent), asparagus (+ 21 per cent), dry

TABLE 30  
IMPUTED CROP PRICES, MODEL 1980C

Representative crop	Model 1980C imputed price	1961-65 actual price*	Model 1961-65 price
	<i>dollar/ton harvested</i>	<i>per cent</i>	
Asparagus.....	302.22	111	121
Broccoli.....	146.47	91	107
Lettuce:			
Spring and fall.....	76.90	94	118
Summer.....	86.26	131	115
Winter.....	85.38	110	114
Cantaloupes:			
Spring and fall.....	97.06	87	118
Summer.....	90.84	107	118
Potatoes.....	58.45†	114‡	113
Tomatoes, processing.....	21.26	74	95
Corn for grain.....	37.70¶	74	75
Barley.....	35.06§	76	74
Grain sorghum.....	36.19	83	132
Alfalfa hay.....	30.17	124	112
Dry beans.....	181.97	93	121
Rice.....	78.07	79	96
Safflower.....	55.81	66	108
Sugar beets.....	14.48	124	115
	<i>dollar/bale harvested</i>		
Cotton.....	152.92	93	120

\* Not including any government payments.

† Imputed price of USDA No. 1's; imputed price per ton of Region 1 potatoes is \$60.52.

‡ Average for all potatoes marketed.

¶ No corn activities entered the optimal basis.

§ Estimated from imputed price of feed grains: imputed price of barley is 93 per cent of feed grain price, and grain sorghum is 96 per cent.

|| Imputed price per ton of Central Valley dry beans is \$195.12.

beans (+21 per cent), and cotton (+20 per cent). The lowest are for barley (-26 per cent) and corn (-25 per cent). Each of these crops whose 1980 to 1961-65 imputed price ratio is at one of the extremes either has a very low 1980 yield relative to the base period, or it is a feed grain crop and is affected by the minimum-cost feed grain restraint in Model 1980C.

**Sensitivity of solution to errors in parameter estimation.** To indicate the sensitivity of the optimal solution to possible data errors, three observations are offered.

First, there are 120 activities in the basis. The basis will change if the real cost per unit in any one of a subset of 30 activities is underestimated relative to all others by only 1 per cent. In a second mutually exclusive subset of 18, underestimation of between 1 and 2 per

cent would cause an incorrect solution; in another of 29, 2-5 per cent, in a fourth of 27, 5-10 per cent, and in still another subset of 16, underestimation of more than 10 per cent would cause incorrect solutions. Some of the changes so prompted in the basis would amount to only a few acres of crop shifting location and others to more than 10,000 acres. No summarization has been made of the effect of data errors in the non-basic activities, but they appear generally to be somewhat less sensitive to overestimation of unit cost than the basic activities are to underestimation. Some changes would also occur if unit costs of the basic activities are overestimated, but these are less important than underestimation in that group.

The second point deals with the parametric programming of certain water costs in the following section. The solu-

tion changes when the water cost is reduced as little as \$2 per acre-foot in HPAs 0362 and 0363. But all of the idle land in these areas does not optimally come into production until water prices are lowered \$12 per acre-foot (or more than 60 per cent from original prices).

Finally, solutions were obtained for two additional models to obtain a rough idea of the supply function for feed grains in California. The only difference in the structure of these models from Model 1980C is in the feed grain output level. In one model the restraint is lowered 25 per cent and in the other it is raised 25 per cent. The imputed price of feed grains in corn ton equivalents is \$37.65 in the first and \$38.26 in the latter as compared to \$37.70 in Model 1980C. When output is decreased 25 per cent, imputed price decreases only .14 per cent; when increased 25 per cent, imputed price increases 1.55 per cent. The only other crops for which the imputed price varies between models are alfalfa (- .07 per cent in the former and + .07 per cent in the latter) and rice (+.81 per cent).

It is concluded from the alternative feed grain output models that the supply function for feed grains is extremely elastic with respect to price with very minor cross effects on the supply of other crops. It may also be concluded that the Model 1980C location pattern of feed grain production within the State may be altered considerably with little impact on total production costs.

In this entire past section, attention has been focused on the findings of Model 1980C. The projections of this model have been referred to as the "best" of the 1980 models in the absence of governmental programs.

### Summary of Projection Models

Three projection models have been discussed. In each model, land, irrigated acreage, and rotation restraints are set at projected 1980 levels. Yield and non-land cost per harvested acre are pro-

jected to be representative of 1980 also. The demand restraints are the only elements which differ between the primary models (Models 1980A and 1980B). In Model 1980C the least-cost feed grain mix is determined simultaneously with the optimal location of production. This last model has been discussed in this section as the most reasonable of the 1980 projection models.

The combined effect of shifting production from nonoptimal base period to optimal Model 1980C locations, increasing the relative use of irrigation in production, and harvesting two crops from a larger proportion of acres more than offsets the greater requirements for land resources because of increased demand. Land requirements for the included crops in Model 1980C are considerably lower than actual requirements in the base period. While Model 1980C land and irrigated acreage requirements are the lowest of the 1980 models, land requirements in all of the 1980 models are lower than actual requirements in the base period. However, irrigation water requirements for the 1980C cropping pattern are significantly higher than for the base-period actual or optimal cropping patterns.

Harvested included crop acreage in Model 1980C, although higher than the base period optimal, is lower than actual acreage in the base-period and optimal acreage in Model 1980B. The Model 1980C regional distribution of crop acreage is quite different from the actual base period distribution. Actually, significant contrast also can be observed between the 1980C solution and any of the other model solutions.

The total value of model crops produced in California will increase markedly from the base period, but primarily because of a higher output. In a perfectly competitive market, crop prices in the 1980C solution are projected to average slightly lower than actual prices in the base period. Significant changes will likely occur in the relative

price vector, with some crop prices much higher and others much lower than in the base period. Scarce resources in the base period will become even more scarce by 1980 and will earn a higher rent for their usage in production. Finally, it is projected that the least-cost feed grain mix in 1980 will be comprised of a larger proportion of grain sorghum and a smaller proportion of barley and corn than the base-period mix.

By means of extending Model 1980C, two other important issues concerning California agriculture are discussed in the next section: (1) the demand for water on the West Side, San Joaquin Valley (with consequent implications to the California Water Project pricing policy); and (2) the impact on production of a more rapid rate of urban expansion in the State.

## APPLICATION OF ALLOCATION MODELS TO PARTICULAR RESOURCE USE PROBLEMS

California agriculture is continually adjusting to changes in governmental policies and projects affecting resource production decisions, rapid mechanization of production and processing methods, and increased urban pressure for land. The allocation models developed for this study lend themselves to analyzing some of the more pressing resource-use problems in California. Specifically, in this section, we consider (1) the demand for water on the West Side San Joaquin—an emerging agricultural area faced with high water costs, and (2) implication on the land-food base from higher rates of urban expansion.

### West Side San Joaquin Valley Water Pricing

**Relevance of the parametric pricing problem.** Because of high water costs on the West Side, only a portion of the acreage in HPAs 0362 and 0363 (West Side area) is used for production in any of the models. Cotton and melons are produced in HPA 0362 in all four models and cotton in HPA 0363 in

Models 1980B and 1980C. In the past, only parts of the West Side area have been irrigated by deep wells drawing on diminishing and sometimes brackish ground water sources.

However, beginning in 1968 the California Aqueduct, a part of the comprehensive California Water Project, began delivering water to acreage in HPAs 0362 and 0363. Moreover, it is anticipated by the U. S. Bureau of Reclamation and the California Department of Water Resources that more than  $\frac{1}{2}$  million acres of West Side land will be irrigated in 1980. But with currently estimated cost of water and the crop alternatives considered in this study, less than 300,000 acres enter any of the optimal solutions.<sup>33</sup>

If the parameter levels in this study are reasonably accurate and the model structure is adequate, then one would conclude that it will be uneconomic in 1980 for farmers to use the total volume of water projected for delivery on the West Side. Since the California Aqueduct is a joint State and Federal proj-

<sup>33</sup> Undoubtedly, some additional production of crop alternatives not included in this study will optimally occur in this area. However, the acreage in these alternatives will not require all the irrigated land to be available. In Model 1980C more than 725,000 acres in this area are projected to be idle or available for pasture of nonalfalfa hay. The cost of water is too high to support a pasture-hay economy. Therefore, the major alternatives left are export cotton, orchards, and vegetable crops. If a major portion of the projected net acreage expansion of these crops between 1961-1965 and 1980 were to occur on HPA 0362 and 0363 land, it would require less than 100,000 additional acres to meet projected market requirements. Even then, at least 150,000 fewer acres would be irrigated in 1980 than is estimated by the Department of Water Resources and Bureau of Reclamation sources.

ect, these governments have control over the base price charged for water. If it is uneconomic for many farmers to use the water at the higher price levels, it may be possible to increase the total annual return to the public's capital investment by lowering the price and extending the repayment period.

The parametric objective function (variable cost) programming method is applied to the Model 1980C solution to determine the demand function for water on the West Side. This programming method is a modification of the standard simplex linear programming model (see Heady and Candler, 1963, chapter 8). The effects of a wide range of costs or prices on the optimal solution to the simplex problem can be studied. For an input such as water, parametric programming may be used to indicate the optimum quantity of water to be purchased at each possible unit cost; i.e., to indicate the optimum acreage of land and type of crops to be irrigated in relation to water cost.

Solutions are obtained at 1965 water cost decrements of \$2.00 per acre-foot in HPAs 0362 and 0363. Because of the method of budgeting and projecting costs used in this study, a \$1.00 change in the 1965 unit cost of water (or of any of the budgeted resource activities) results in a \$1.10 total change per unit in the 1965 production cost and \$1.35 in the 1980 cost. Therefore, in the discussion to follow, when a \$2.00 decrease in the 1965 water cost per acre-foot is mentioned, it really refers to a \$2.70 decrease in 1980 nonland production cost.<sup>34</sup>

**Demand for irrigated land on the West Side.** It is not until the 1965 water price declines by \$12 per acre-foot that all of the net model acreage in both HPAs enters the basis. However, all of the HPA 0362 acreage, 504,000 acres, is brought into production with a \$6

per acre-foot decrease in water price. In HPA 0363, 163,000 acres are brought into production with a \$6 decrease. With only a \$4 price decrease, a combined total of 413,300 acres is brought into production. Hence, the marginal cost of water to the farmer would have to be reduced between \$4 and \$6 to bring the 1/2 million acres of land into production for which water is planned to be available in 1980. The specific crop activity acreages in these two HPAs at each incremental price level are recorded in table 31.

**West Side irrigation water demand by study crops.** A continuous 1980 demand function for irrigation water used by the study crops in these HPAs is estimated in loglinear form from the eight parametric program observations. The demand function is for all irrigation water in the area, not only for that which is delivered by the California Aqueduct. With the total quantity of water demanded in both HPAs, estimated as a function of 1965 price in each HPA, these least-squares equations are obtained:

$$\log_{10} Q = 3.64 - .052 P_{0362}, \quad (17)$$

$$\log_{10} Q = 3.89 - .052 P_{0363}, \quad (18)$$

where

$P_{0362}$  is the unit cost of water to the farmer in HPA 0362;

$P_{0363}$  is the unit cost of water to the farmer in HPA 0363; and

$Q$  is the total quantity of water demanded, in 1,000 acre-feet units, in HPAs 0362 and 0363.

The regression coefficient is the same in both equations. The difference in the intercept value is due to the difference

<sup>34</sup> The irrigation requirements for each crop are given by Shumway and Stults (1970). The 1965 costs per acre-foot is \$14.70 in HPA 0362 and \$19.36 in HPA 0363. The total generated nonland production cost in 1980 per acre-foot of water applied (assuming no change over time in water requirements per harvested acre) is \$19.89 in HPA 0362 and \$26.19 in HPA 0363.



TABLE 31  
MODEL 1980C CROP ACTIVITY ACREAGE IN HPAs 0362 AND 0363 AT  
ALTERNATIVE 1965 PRICES OF WATER

HPA 0362								
1965 water price	Alfalfa hay	Barley- sorghum	Cotton	Dry beans	Safflower	Canta- loupes	Potatoes	Total
dollars/acre-foot.	acres							
14.70 .....			166,000			40,936		206,936
12.70 .....			166,000			40,936		206,936
10.70 .....			166,000	43,383		40,936		250,319
8.70 .....			166,000	64,872	201,644	40,936	30,546	503,998
6.70 .....			166,000	64,872	201,644	40,936	30,546	503,998
4.70 .....	27,412	59,852	166,000		220,188		30,546	503,998
2.70 .....	307,998	30,001	166,000					503,998
.70 .....	338,000		166,000					504,000

HPA 0363						
1965 water price	Dry beans	Cotton	Safflower	Sugar beets	Cantaloupes	Total
dollars/acre-foot	acres					
14.70 .....		65,329				65,329
12.70 .....		94,741				94,741
10.70 .....		163,000				163,000
8.70 .....		163,000				163,000
6.70 .....		163,000				163,000
4.70 .....	64,872	163,000			41,318	269,190
2.70 .....	64,872	163,000	189,935	35,873	41,318	494,908
.70 .....	35,755	163,000	196,627	58,297	41,318	494,997

in cost of water of \$4.66 per acre-foot.

Demand equations are plotted on a semilog scale in figure 5. The 1965 price of water is identified on the horizontal axis and the combined quantity demanded in both HPAs on the vertical axis.

**Elasticity of demand.** The point elasticity of demand with respect to the 1965 price of water is estimated at selected prices and recorded also in figure 5. For HPA 0362, the elasticity is determined at prices of \$14.70, \$9.70, and \$4.70; for HPA 0363, the estimates are at prices of \$19.36, \$14.36, and \$9.36.

Demand is elastic at all prices except one. It is inelastic at the low water price in HPA 0362, but is elastic at the low price in HPA 0363. Hence, if the \$4.66 water price differential is maintained between production areas, total revenue to the water project would be maxi-

mized by decreasing the price in both areas by at least \$5.00, and possibly as much as \$10.00, per acre-foot.

If there are any variable costs incurred in supplying incremental units of water to farmers, the quantity at which profits, or net returns on investment, are maximized would be lower than that at which total returns are maximized.

In contrast to this, generally elastic demand function for water on the West Side of the San Joaquin Valley is the inelastic demand for water on Tulare County farms estimated by Moore and Hedges (1963, p. 133). At a 1965 water price per acre-foot of \$9.70 in HPA 0362 or \$9.36 in HPA 0363, the West Side demand for water is elastic; that is, a 1 per cent decrease in price would result in more than a 1 per cent increase in quantity demanded, so total revenue

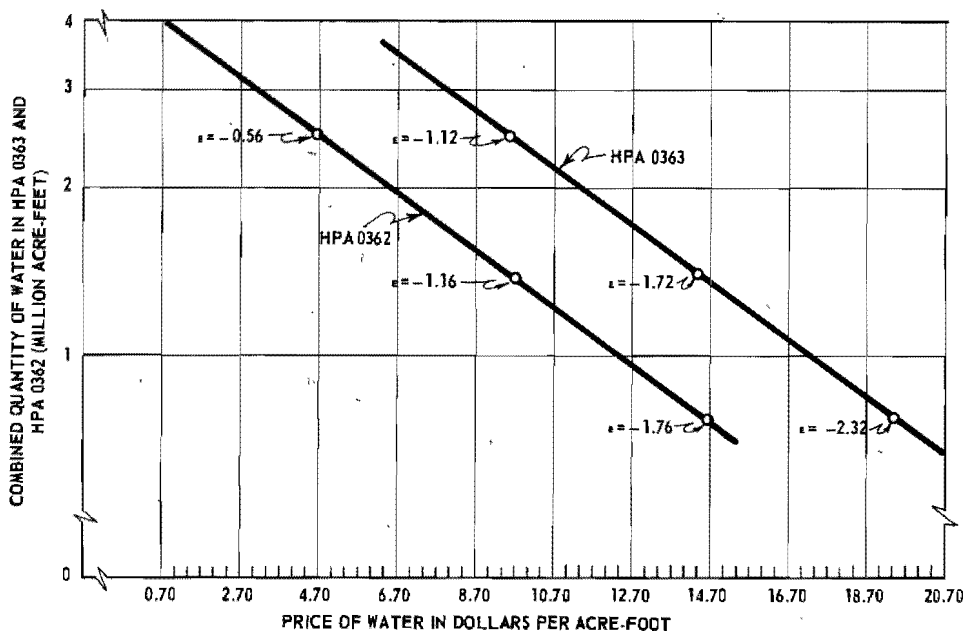


Fig. 5. Composite demand for water, HPAs 0362 and 0363.

to water suppliers could be increased by lowering the price in these areas. However, at a price of \$9.44 in Tulare County, Moore and Hedges estimated demand to be very inelastic ( $e = -0.188$ ). A 1 per cent decrease in price would result in only a .188 per cent increase in quantity demanded; therefore, total revenue to water suppliers would increase by raising the price of water in Tulare County. Even at a price of \$23.30 per acre-foot, demand was still estimated to be inelastic by Moore and Hedges.

Both the Moore-Hedges study and the present one of demand curves for water were derived with parametric programming. However, certain differences exist in the underlying assumptions and technique, as well as the area of analysis. Moore and Hedges derived their aggregate demand function from summing individual demands by different sized farms. A different aggregation procedure is used in this study wherein each HPA is represented by a typical farm. The demand curve derived by Moore

and Hedges included the water demanded for orchard and vineyard crops, whereas these crops are excluded in our analysis. Because water costs comprise a smaller portion of nonland production costs for orchard and vineyard crops than for the purported West Side field crops and vegetables, one would expect the water demand for the Moore-Hedges study to be less elastic than for this analysis. However, a more complete analysis of the West Side which explicitly includes orchard and vineyard crops as production alternative could alter these conclusions.

At least two conclusions may be drawn from this extension of Model 1980C:

1. Unless water costs in these two HPAs are substantially overestimated or important deficiencies exist in other parameter levels or structural aspects of the model, it will not be economic at these unit costs to irrigate all of the land on the West Side for which water is expected to be available in 1980.

2. Annual revenues to suppliers of water on the West Side may be increased by lowering the unit price of water sufficiently to irrigate all of the available land by 1980. There are important implications and possible income affects, however, for other producing regions in the State if such a policy were adopted.

### High Rate of Urban Expansion

The conversion of agricultural land to nonagricultural uses has caused alarm to those who foresee food shortages resulting from a declining land base. Several researchers have focused their attention on the extent of historical transfers of land out of agriculture and have projected future transfers. Unfortunately, there is little agreement on either the amount of land currently in nonagricultural uses, particularly urban, or on future requirements in California. Some estimates differ by as much as 100 per cent. Part of the discrepancy is due to definition and part to method of measurement. For example, for the urban estimates some persons have relied on published acreage of land within city limits. Others have estimated urban acreage from aerial photographs. Estimates from the latter method of measurement may still vary considerably depending upon what is defined as urban land. Difference in the interpretation of the "pockets" of idle land within the general urban boundaries may account for a significant portion of the aggregate deviations.

The basic source of urban land estimates used in this study was chosen because of the apparently sound scientific procedures underlying the actual urban estimates and the detail in which historical and projected future land conversions from nonurban to urban uses were reported. These estimates are limited to land converted from agricultural or idle land to built-up or established urban uses (intensive and extensive) and are the most conservative of the

various estimates available. Also included in our nonagricultural land-use tabulation are estimates of the acreage in public ownership (roads, parks, military reservations, etc.).

In the earlier analyses of optimal production patterns, it has been assumed that all suitable land not in public ownership nor required (current or projected) for built-up urban uses is available for agricultural purposes. However, if (1) a sizable acreage of land on the urban fringe is taken out of agriculture and left idle temporarily prior to urban development or (2) the quantity of land required for urban and other nonagricultural uses is underestimated, then the adjustments prompted in agriculture by expansion in the nonagricultural sectors will be underestimated, also. Because of this possible bias, the impact of a more rapid conversion of agricultural land to nonagricultural uses is analyzed in the framework of the major projection model (Model 1980C).

**California conservation needs inventory.** Preliminary estimates of current and future urban land acreage have recently been made by the California Conservation Needs Committee (1961) under the chairmanship of the USDA Soil Conservation Service. They estimate total State urban acreage in 1967 to be 3,354,000 acres and the conversion of land from agricultural to nonagricultural uses between 1968 and 1980 to be 2,016,000 acres. The 1980 projection of 5,370,000 acres in urban and related uses compares to our 1980 projection of 2,971,000 acres in urban usage in the State and 804,000 acres in public ownership in the HPAs.

The two sets of estimates are not exactly comparable for reasons already mentioned. While our estimates and projections of urban and other nonagricultural land requirements are on the low end of the scale of estimates, the Conservation Needs Committees' estimates are on the high end. Thus, the two

estimates may bracket the relevant range. The agricultural orientation of these committees may have influenced them to include in the urban and related categories estimates of agricultural acreage left idle prior to nonagricultural development. If urban expansion continues to leave significant pockets of idle land in the wake of its sprawl, as it has in the post-World-War II era, and if the population grows more rapidly than we have assumed, these higher estimates of acreage losses for agriculture may be more realistic. Therefore, in this exercise, the Conservation Needs Committees' preliminary projections of urban and related acreage are used in place of our nonagricultural-acreage requirements.

Subcounty detail is not available for the Committee projections. Therefore, the county estimates are distributed among HPAs according to specific assumption. Specifically, it is assumed that: (1) each Committee projection of urban and related acreage in a county is distributed between agricultural and nonagricultural areas in the same proportion as our urban projection, and (2) that portion in agricultural areas is distributed among individual HPAs in proportion to our urban and public land projections. Based on these assumptions and aggregated for the State, 81.5 per cent of the Committee's 1980 projections are allocated to agricultural areas. However, the regional distribution within the agricultural areas is somewhat different from our 1980 projections of urban and public land (table 32). Their projections are higher in all regions, with the largest difference being in the San Joaquin Valley. Important differences also exist in the Desert Region and in the rest of the Central Valley. While the absolute difference is important also in the Central and South Coast, the relative difference in those regions is not as great as in

others. Much of this additional acreage for urban uses is projected to be withdrawn from prime agricultural land.

Because semiagricultural land requirements have been calculated at 10 per cent of gross agricultural acreage, an increase in urban acreage decreases the semiagricultural requirement. Therefore, the reduction in the model acreage restraints is 90 per cent of the increase in urban acreage.

### **Impact on California agriculture.**

With more than 1 million fewer acres available for crop production, *more than 300,000 acres* of included crops shift from HPAs with increased urban pressure to HPAs with idle land.<sup>85</sup> Total land required for the model crops is 24,000 acres higher than in Model 1980C. The productivity of the land to which these crops are shifted is about 8 per cent lower than the original land used in Model 1980C.

Nonland production costs are \$10.6 million (0.8 per cent) higher; total value of production, or cost to consumers under perfect competition, is \$19.8 million (1.3 per cent) higher; and aggregate rents to the fixed resources used in production are \$9.2 million (6.4 per cent) higher.

Harvested crop acreage is up 28,000 acres (see Appendix table C-12), with considerable redistribution among regions. The largest increase in harvested acreage is in Region 6 (+153,200 acres). Regions 8 and 9 experience an increase of almost 50,000 acres each. The most significant decrease is in Region 5 (-102,000), and it is sizable also in Region 4 (-55,600). Somewhat surprisingly, the decrease in regions 2 and 3 is far less significant. Although the difference between the Committee's and our nonagricultural acreage projection in these regions is similar to the difference in regions 4 and 5, the decrease in harvested acreage in both regions together is only 59,100 acres.

<sup>85</sup> Combined adjustments in the model crops and the high-value excluded crops are much higher (about 600,000 acres).

TABLE 32  
NONAGRICULTURAL ACREAGE IN CALIFORNIA, 1980 ALTERNATIVE  
PROJECTIONS

Area	Region number	Source of projection		
		Shumway et al.*	Conservation Needs Committees†	Committee less Shumway
1,000 acres				
In homogeneous production areas:				
Coastal				
North.....	1	31.3	60.7	29.4
Central.....	2	551.3	660.8	109.5
South.....	3	1,350.6	1,524.4	173.8
Subtotal.....		1,933.2	2,245.9	312.7
Central Valley				
Sacramento.....	4	183.6	315.3	131.7
Delta.....	5	290.5	477.3	186.8
San Joaquin.....	6	437.5	696.7	259.2
Subtotal.....		911.6	1,489.3	577.7
Desert.....	7	179.2	361.9	182.7
Mountain valleys				
Intermediate.....	8	34.9	47.5	12.6
High.....	9	162.3	231.5	69.2
Subtotal.....		197.2	279.0	81.8
TOTAL.....		3,221.4†	4,375.9	1,154.5
Not in homogeneous production areas:				
		553.0‡	994.0	441.0
State total.....		3,775.0	5,370.0	1,595.0

\* In urban uses and public ownership.

† In urban and related uses.

‡ Urban and public land use.

¶ Urban acreage only.

Some production area shifting is observed for all crops except melons, winter lettuce, rice, corn, and nonirrigated barley. There is only minor change in the production patterns of the other vegetables and safflower.

The most important production pattern changes are in the field crops:

1. The largest increase in the harvest acreage of any crop is for alfalfa (+41,200 acres). Major shifting occurs out of the Delta (Region 5) and the southern part of the San Joaquin Valley (Region 6) to the northern end of the San Joaquin Valley (Region 6) and to the in-

termediate- and high-level mountain valleys (regions 8 and 9). The higher acreage requirement is due to this transfer of acreage from the high-yielding Central Valley to the less productive mountain valleys.

2. A major shift, with important implications concerning the conclusions drawn from an earlier extension of Model 1980C, affects cotton. Production from 80,000 acres of land on the eastern part of the San Joaquin Valley shifts to the West Side. Productivity is enough higher in the new areas to

- reduce the total acreage required by 13,500 acres.
3. More than 50,000 acres of double cropped barley and grain sorghum shift southward in the Central Valley from regions 4 and 5 to Region 6.
  4. Dry bean acreage shifts generally northward—both along the Coast and in the Central Valley.
  5. Sugar beet acreage shifts somewhat from the Coast to the San Joaquin Valley and the intermediate level mountain valleys. The acreage on terrace soil almost doubles.

## SUMMARY AND CONCLUSIONS

Agriculture in California is continually adjusting to changes in resource availability, production relationships, and demand for its products. While increased urban competition for land and water resources is reducing the supply available for agriculture in some areas of the State, water development projects are bringing arid land into production in other areas. Technological developments, such as improved plant varieties, will increase yields for most crops in the next decade and alter the demand for inputs and basic resources used in production. Demand for output of California agriculture will change with consumer preferences, population and income growth, and changes in foreign-market developments. Focusing on the year 1980, a major goal of this study is to provide a framework for analyzing the impact of these factors on the location of production in California and on the aggregate demand for land and water resources.

A linear programming spatial allocation model is used to determine the "optimum" location of production in the base period of 1961–65 and for 1980 under alternative projections of demand, urban expansion, feed grain production, and water pricing on the West Side of the San Joaquin Valley. Various estimation procedures are used to develop the considerable data requirements of this approach, including (1) demand for output of all major agricultural commodities produced in the State is specified for the base period

and is projected to 1980; (2) areas with moderate to high agricultural production potential, accounting for some 19.6 million acres of the State's 100 million, are delineated into 95 homogeneous production regions with similar soil and climatic conditions; (3) crop yields and nonland costs are determined for each of these areas for the base period and are projected to 1980; (4) urban land use, public land use, and semiagricultural land use are determined for each homogeneous production area in the base period and are projected to 1980; and (5) the availability of irrigable land in the various regions is specified. The commodity coverage in the model includes 15 field crop and vegetable groups that accounted for 72 per cent of the harvested acreage in California in the 1961–65 period. The acreage, water requirements, and location patterns for excluded commodities—all orchard and certain vegetable crops—are considered predetermined. Results are discussed for the base-period model and for the 1980 Models.

### Base-Period Model

Although the major focus is on 1980, it was considered important to obtain a linear programming solution for base period conditions of demand, supply, and resource availability as a point of reference for 1980 changes in these conditions. Also, the 1961–65 study is of interest of itself to indicate the difference between actual and model locations of production, land use, water use, and harvested acreage.

**Land use.** Total land available in the 95 homogeneous production areas is 19.6 million acres. Urban use of land in the State is estimated at 2.0 million acres, of which 1.6 million is in the homogeneous production areas. To obtain the available supply for agricultural production, urban land (1.6), public land (0.8), and semiagricultural land uses (1.7) are deducted from the study area total to give a base of 15.5 million acres. Of this base acreage, the excluded commodities of orchard and certain vegetable crops plus irrigated pasture and nonalfalfa hay require 3.2 million acres. In the *actual* base-period land use, included commodities use 6.9 million acres, leaving 5.4 million for range land. For the *base-period model*, 5.1 million are allocated to included commodities, leaving 7.2 million acres for other uses such as range land. This lower land requirement for included crops is due primarily to the shift from dryland grain production to irrigated double-cropping production, as well as shifts in the location of production.

**Water use.** The *actual irrigated acreage* in the base period is based on Census data plus the use of maps of the Department of Water Resources to allocate land to the homogeneous production areas. The total irrigated acreage of 7.6 million acres in the study area includes 2.8 million acres for the excluded commodities (irrigated pasture and nonalfalfa hay, 1.3; and orchard crops, 1.5) plus 4.8 million acres for the included crops. In comparison, the model 1961-65 acreage includes 5.1 million irrigated acres for the included crops plus the same requirement for the excluded crops, giving a total of 7.9 million acres. This increase shown in the allocation model is due, also, to a shift from dryland to irrigated production, with the major shift being to irrigated alfalfa hay and barley in the higher elevation valley areas.

*Water requirements* are similar for the base-period actual and model esti-

mates, in spite of the increase in irrigated acreage noted above. Total water requirements equal 23.6 million acre-feet for the actual versus 23.4 million acre-feet for the allocation model. This latter estimate is comparable to the *gross* requirement for 1960 of 28.5 million acre-feet estimated by the California Department of Water Resources less a loss in conveyance of 5.1 million acre-feet for that year estimated by Lofting and McGauhey (1963), giving a *net* requirement of 23.4 million acre-feet. For the *base period actual* requirements, included commodities require 14.4 million acre-feet and excluded commodities 9.2 (irrigated pasture and nonalfalfa hay, 5.3; and orchard crops and excluded vegetables, 3.9), giving the total of 23.6 million acre-feet. The model results indicate slightly less water requirements but higher irrigated acreage because of the shift in location of production and the difference in water requirements by area. For example, one harvested acre of alfalfa requires 2.25 acre-feet on the alluvial soil in the North Coast as compared with 8.0 acre-feet on a similar soil in the Desert Region. Location shifts and water requirements by region are shown in detail in the report.

**Harvested crop acreage.** The *actual* harvested acreage of crops is based on Crop and Livestock Reporting Service estimates plus the California Department of Water Resources unpublished land-use survey, summarized by seven and one-half minute quadrangles. Harvested acreage for included commodities equals 6.0 million acres based on actual data, as compared with 5.4 million acres for the allocation base-period model. Of the reduction of 650,000 acres, 70 per cent is due to the reduction of small-grain acreage. As noted previously, dryland barley production is replaced by double-cropped feed grain production. The remaining reduction is due to shifts in location to

take advantage of lower-cost regions of production.

**General conclusions.** A close inspection of actual versus model results indicates considerable difference in location patterns. This is not entirely unexpected because of the nature of linear programming solutions of this type where important simplifications are introduced. For example, the location of sugar beet refineries is not specified as a restraint to the location of sugar beets and the associated shipment costs. Neither are government programs (such as acreage allotments on cotton, wheat, and feed grain) introduced as constraints to adjustments of these crops. Long-run adjustments are assumed. Further, price and yield uncertainty for farmers in a given homogeneous production region is not directly taken into account, which might result in more diversified cropping patterns rather than the specialization that might be implied by the linear programming solution. The authors are aware of the pitfalls of the analysis, yet find the model a useful device for appraising the impact of changes in such factors as urbanization, yield, and demand shifts to 1980. It is helpful to have this model bench mark, as well as actual 1961-65 conditions, to compare the impact of these changes. One further bit of information is worthy of note; namely, the value of production for included commodities, as reported by the Crop and Livestock Reporting Services, is \$1.13 billion as compared with the imputed value obtained from the base period model of \$1.02 billion. One interpretation might be that there was a misallocation of production location of 10 per cent, in value terms. Recognizing the sensitivity of the model to slight changes in yields, costs, and transportation costs (which are not specified in the model), one might reasonably conclude that this magnitude of difference is not serious since the model does not consider farmer-produc-

tion adjustment to uncertainty that is reflected in diversification of crop production. On the other hand, a cross-section view of a dynamically changing industry is apt to point out nonoptimum location patterns of production. We conclude that the model appears to offer sufficient validity to explore the implications of change for 1980.

## 1980 Models

Several 1980 models are designed to answer specific questions concerning the future of California's agricultural industry under given projected conditions. The cost and yield estimates, as projected to 1980, are the same in each of these models, as are the total land, irrigated acreage, and land use in homogeneous production areas for public use, semiagricultural use, and excluded commodities. Difference among models are specified to determine the impact of: (a) alternative demand levels for California crops (Models A and B); (b) a minimum cost feed grain production mix (Model C); (c) a conservative estimate of 1980 urban land use (Models A, B, and C) as compared with a high estimate (a modification of Model C); and (d) the effect of water prices on production on the West Side of the San Joaquin Valley (a further modification of Model C).

### Effect of alternative demand levels.

In Model A, the proportion of projected 1980 U. S. output demanded from California producers is assumed to be the same as the 1961-65 share, whereas Model B output is based on a *projected share* of U. S. output for most crops, with the exception of feed grains, hay and silage, which are based on independent livestock projections. The *projected-share* output levels are equal to or greater than the constant-share levels for all included commodities with the exceptions of dry beans, grain sorghum, barley, and oats. A significant increase in cotton output is specified in the projected share model of 58 per cent above



the 1961-65 level, associated with the assumption of discontinuation of government programs which currently limit interregional shifts in production. The authors feel that further work is required in analyzing the cotton program and demand prospects due to competition with synthetics and changes in world trade. The 1980 Model A *constant-share* assumption indicates an 11 per cent increase in cotton production in California. A significant increase also is projected for oilseed production.

Crop yields are projected from inspection of past trends plus informed estimates of crop production specialists. For the 15 included crops or crop groups, projected yield increases over 1961-65 base period were greater than *projected-share* production projections for nine of these groups.

Harvested acreage for included commodities is estimated at 5.7 million acres for the constant-share model and 5.9 million acres for the projected-share model. These levels are above that for the 1961-65 model (5.4 million acres) but below that for actual 1961-65 (6.0 million acres). On the other hand, irrigated acreage requirements are greater than either the actual or model 1961-65 usage. The regional distribution of harvested acreage in the constant share 1980 model more nearly approximates that of actual 1961-65 than was indicated in Model 1961-65 locations.

The difference in the value of production due to the generally higher demand specification in Model B is \$108,000 higher than for Model A. Similarly, the value of production for these included commodities is considerably higher than for the 1961-65 period. For example, the projected-share model value is 49 per cent above the 1961-65 model value. Some of this increase is due to higher imputed land rents as production is relocated because of urban expansion, which according to the conservative projection of urban use

will require an additional 818,200 acres of the land with moderate to high agricultural potential by 1980.

**Land and cost saving by production of a least-cost feed grain mix.** Results obtained in the imputed prices to the individual feed grains in Model B led to a reformulation that would assure a more realistic relationship between prices and relative feeding values of these grains. The basic assumption is that feeders would adjust their rations to a least-cost mix, and thus relative prices would be equal to relative feeding values. This is accomplished by converting yields of barley and sorghum grains to corn-equivalent feeding values, and allowing the model to select the least-cost production mix of these grains. This specification results in a reduction of harvested acreage of 30,000 acres. However, the introduction of irrigated double-cropping production of barley and sorghum grains as the major grain production source results in reductions in both the irrigated acreage and total land required for production of the included crops of over 500,000 acres. The total water requirements for Model 1980C equal 26.21 million acre-feet as compared with the base period actual of 23.6 million acre-feet.

**West Side San Joaquin Valley water pricing.** Mostly because of high water costs on the West Side, only a portion of the acreage is estimated in the 1980 models for production of cotton and melons. Prior to 1968 the area was irrigated almost exclusively by deep wells, but since 1968 the California Aqueduct has been supplying some water to the West Side. With currently estimated costs of water, demand levels, and crop alternatives considered in this study, less than 300,000 acres of production are included in the model solutions. This analysis explores the effect of reduced water costs on the cropping pattern on the West Side, using Model C as the basis of comparison.

There are approximately 1 million acres of land in homogeneous production areas 0362 and 0363 on the West Side. The analysis specifies decreases in water costs for each area at \$2 increments (equivalent to \$2.706 decreases in the 1980 nonland production costs). The initial water price is \$14.70 per acre-foot for area 0362 and \$19.36 per acre-foot for area 0363. It is not until the 1965 water price declines by \$12 per acre-foot that all of the net acreage of these regions enters the model solution. However, all of region 0362 acreage, 504,000 acres, is brought into production with a \$6 decrease. In addition, 163,000 acres of region 0363 is brought into the solution with this decrease. With only a \$4 price decline, a combined total of 413,000 acres is brought into production. Hence, the marginal cost of water to the farmer would have to be reduced between \$4 and \$6 to bring the  $\frac{1}{2}$  million acres of land into production for which water is planned to be available in 1980.

**Alternative levels of urban expansion.** There are several estimates of the use of land for nonagricultural purposes, both for the base period and for 1980, that unfortunately differ significantly as to definition and magnitude. For the State *urban land use*, our base period estimate is 2.0 million acres, and our conservative 1980 estimate is 3.0 million acres. Adding our estimate of *public land use in the 95 homogeneous production areas* of 0.8 million acres

gives a base period total of 2.8 million, and a 1980 total of 3.8 million acres.

A much higher 1980 urban estimate of 5.4 million acres recently has been given by the County Conservation Needs Committees and is the basis for our high urban expansion estimate for the production areas. Actually, their estimate for urban acreage in 1967 is 3.4 million acres which is considerably higher than our estimate or that of the California Department of Water Resources. For this analysis, the Conservation Needs Committees' estimates are adjusted for urban expansion in nonagricultural areas, and are allocated to our production regions.

With more than 1 million fewer acres available for crop production, more than 300,000 acres of crops shift from production areas in which the higher urban land projections further restricts production to land which was not cropped under the Model 1980C conditions. Total land required for included crops is 24,000 acres higher; the productivity of this land is about 8 per cent lower; nonland costs are \$10.6 million (0.8 per cent) higher; total value of production, or the cost to consumers under perfect competition, is \$19.8 million (1.3 per cent) higher; and aggregate rents to the fixed resources used in production are \$9.2 million (6.4 per cent higher). Even if these estimates of urban use are high for 1980, they may well be applicable for the not too distant future.

## APPENDIX A

### MAPS OF HOMOGENEOUS PRODUCTION AREAS

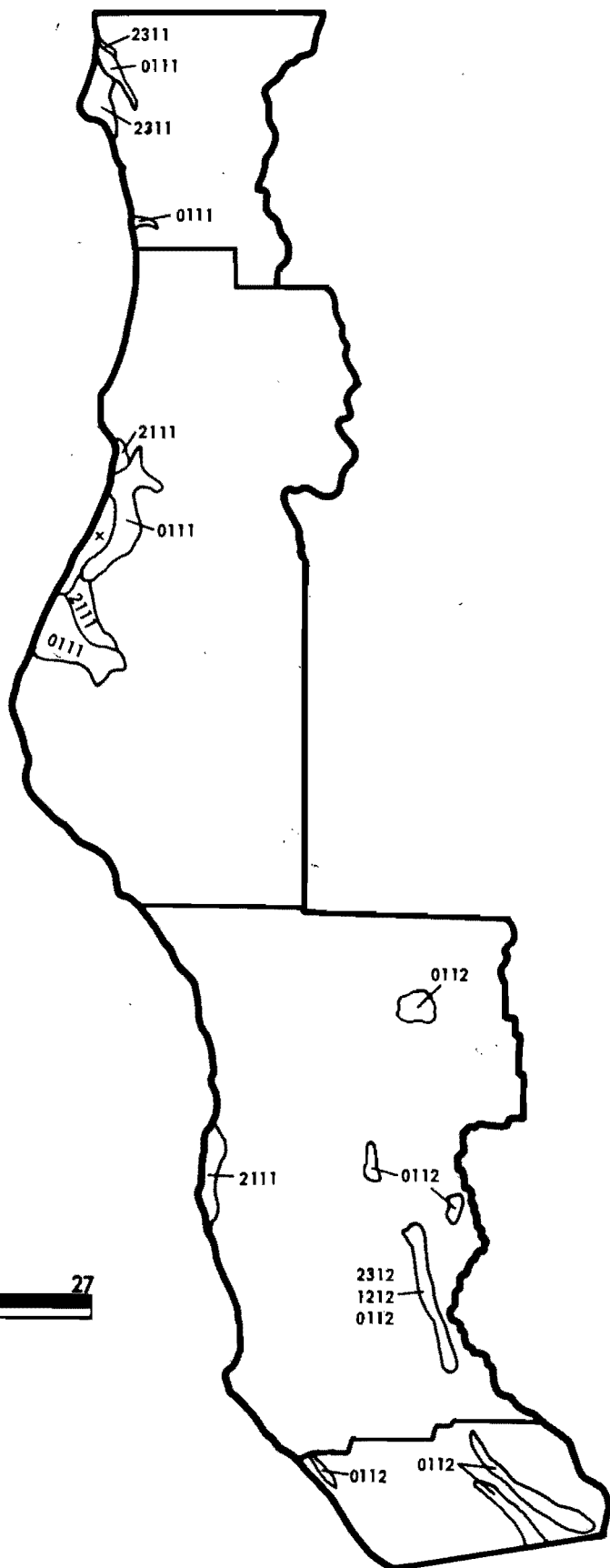
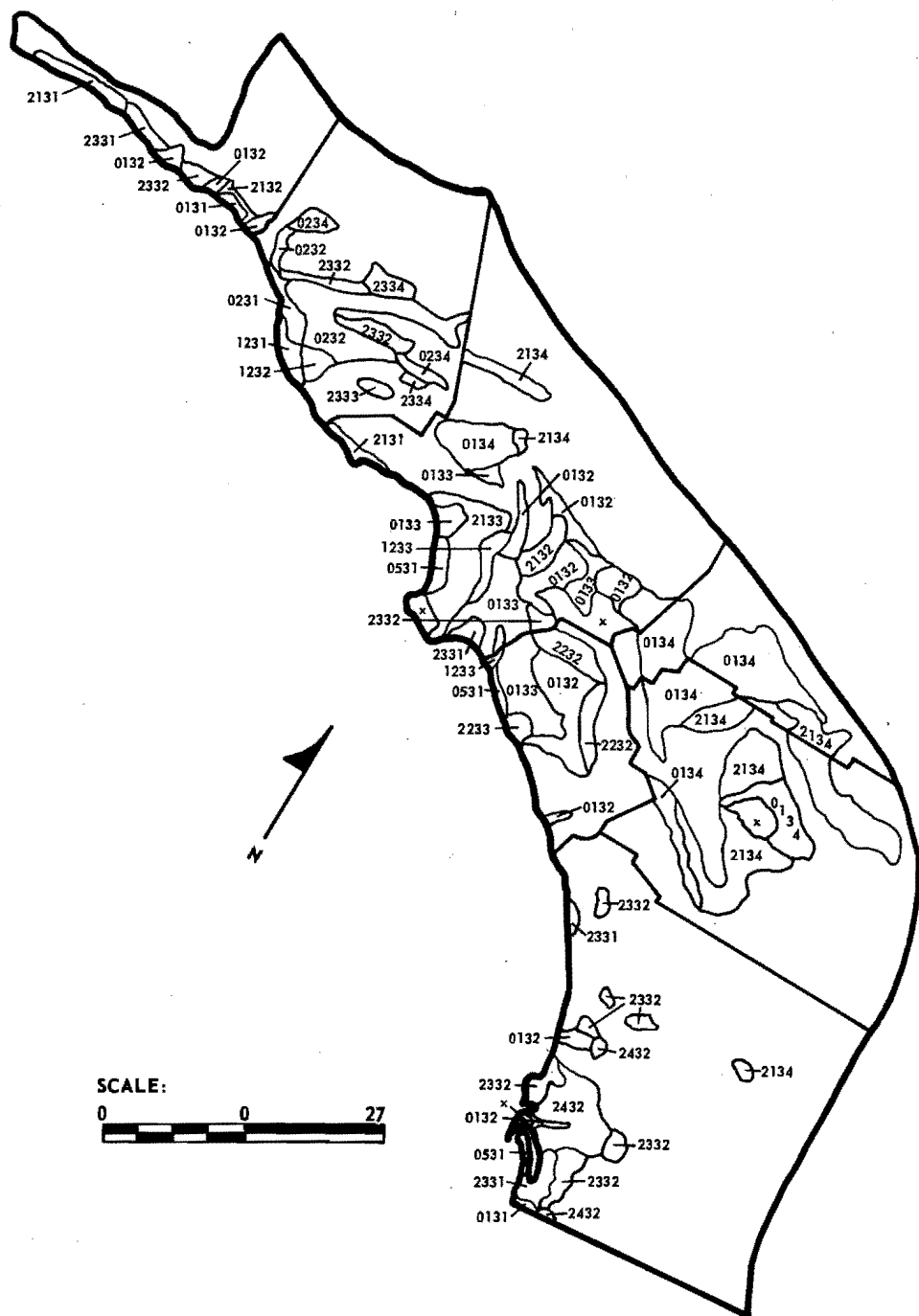


Fig. A-1. Region 1—North Coast. The four-digit numbers designate the HPAs. The first two digits refer to the soil, the last two digits to the climate.







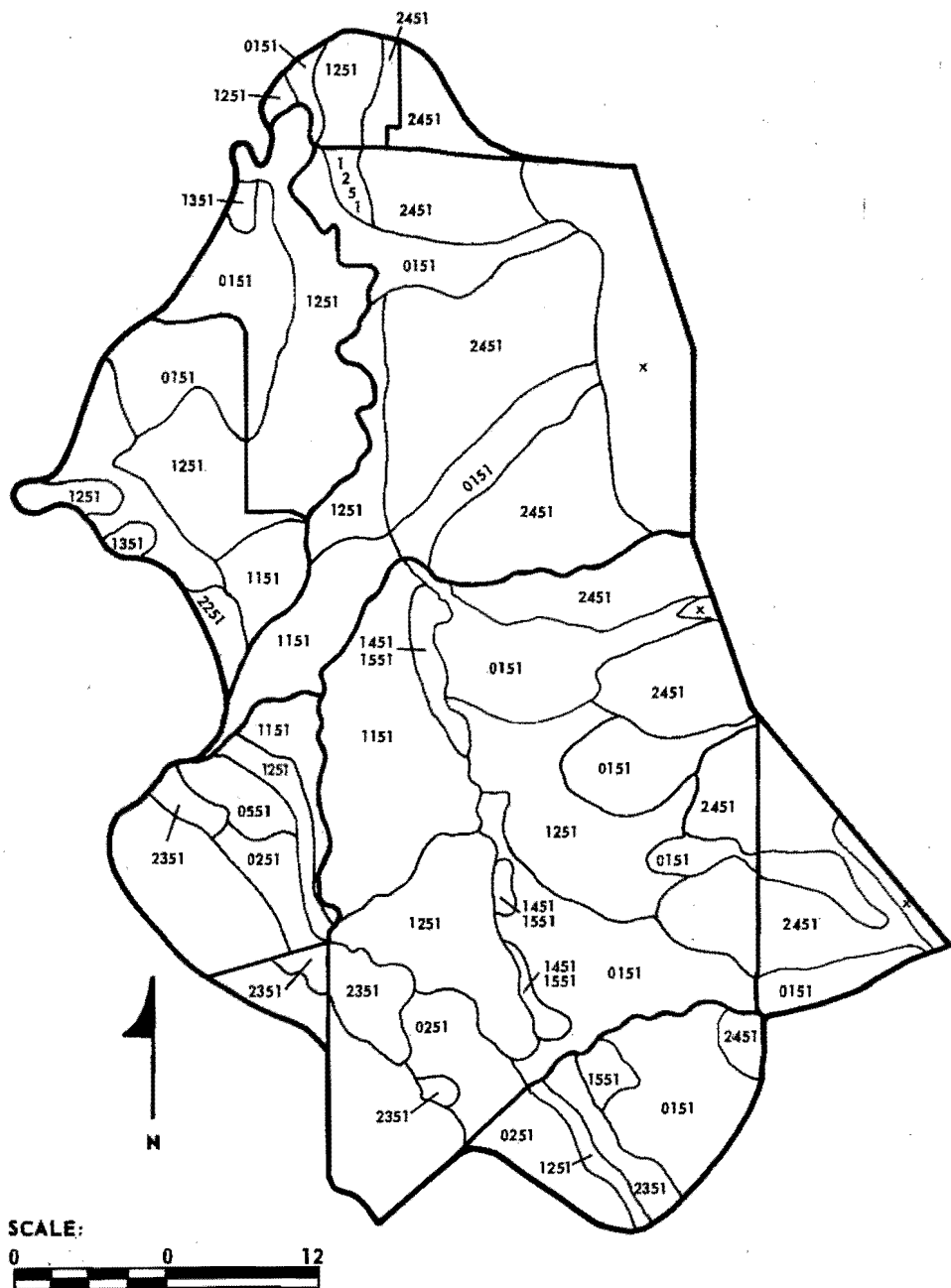


Fig. A-5. Region 5—San Joaquin Delta. See legend to figure A-1.



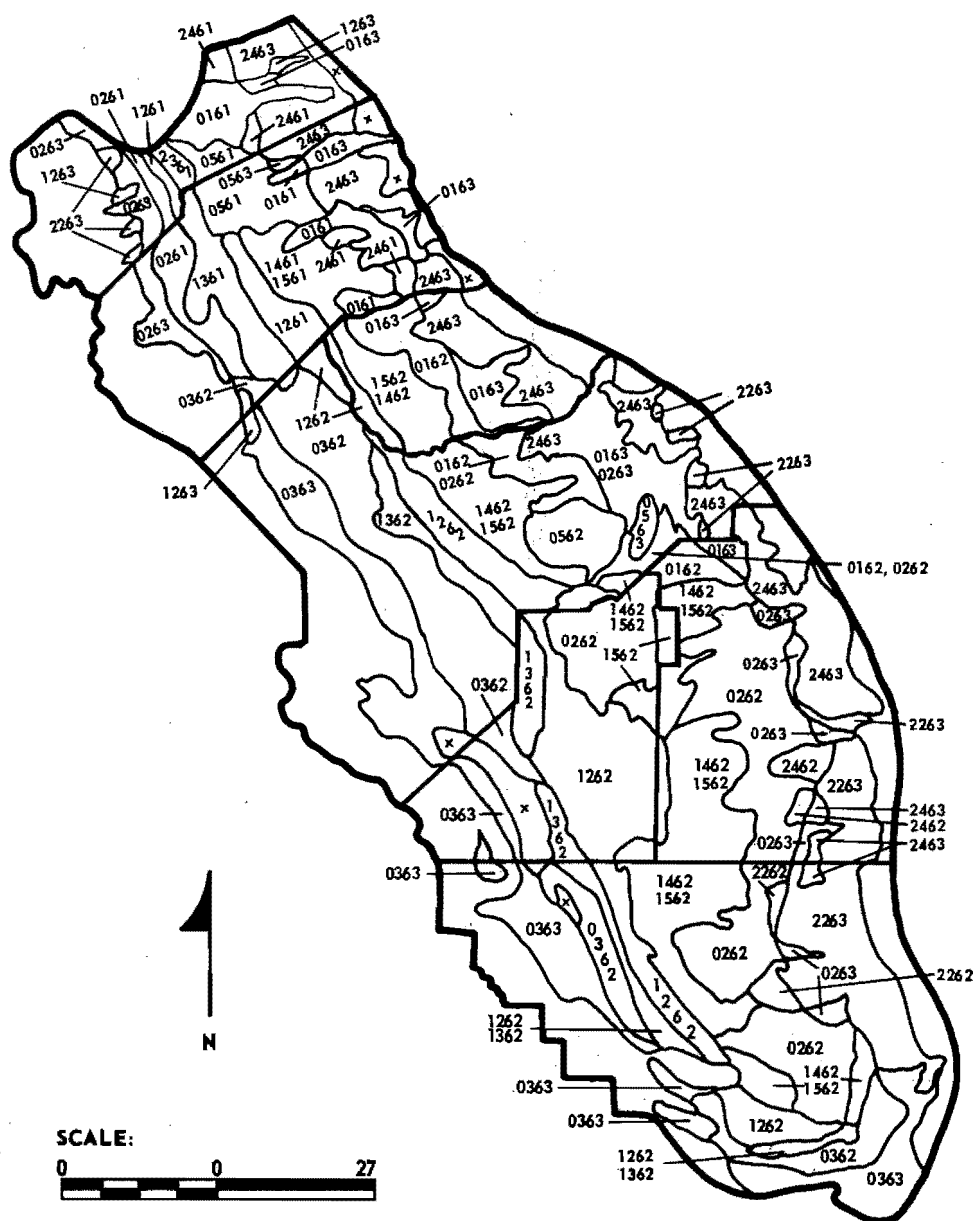


Fig. A-6. Region 6—San Joaquin Valley. See legend to figure A-1.

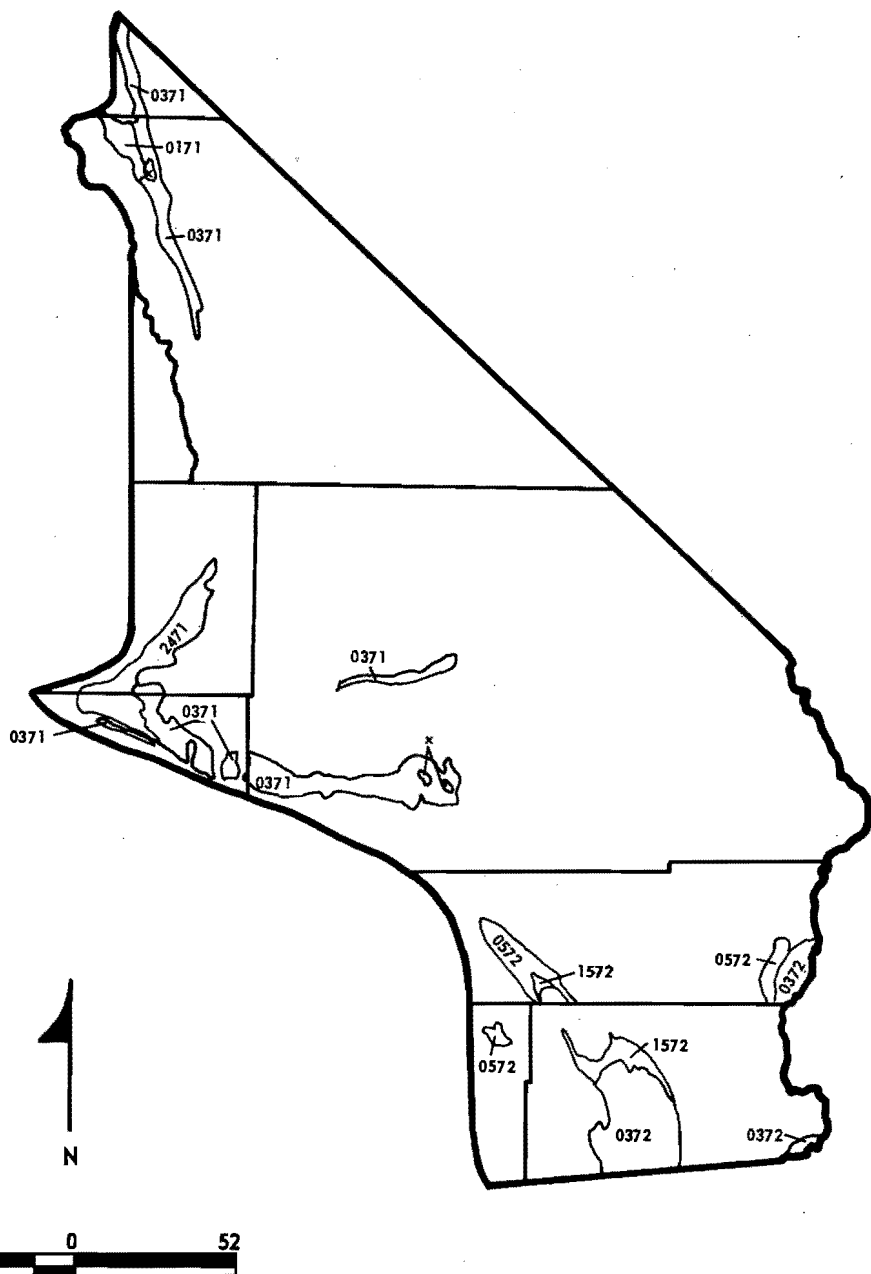


Fig. A-7. Region 7—Southern California Desert. See legend to figure A-1.

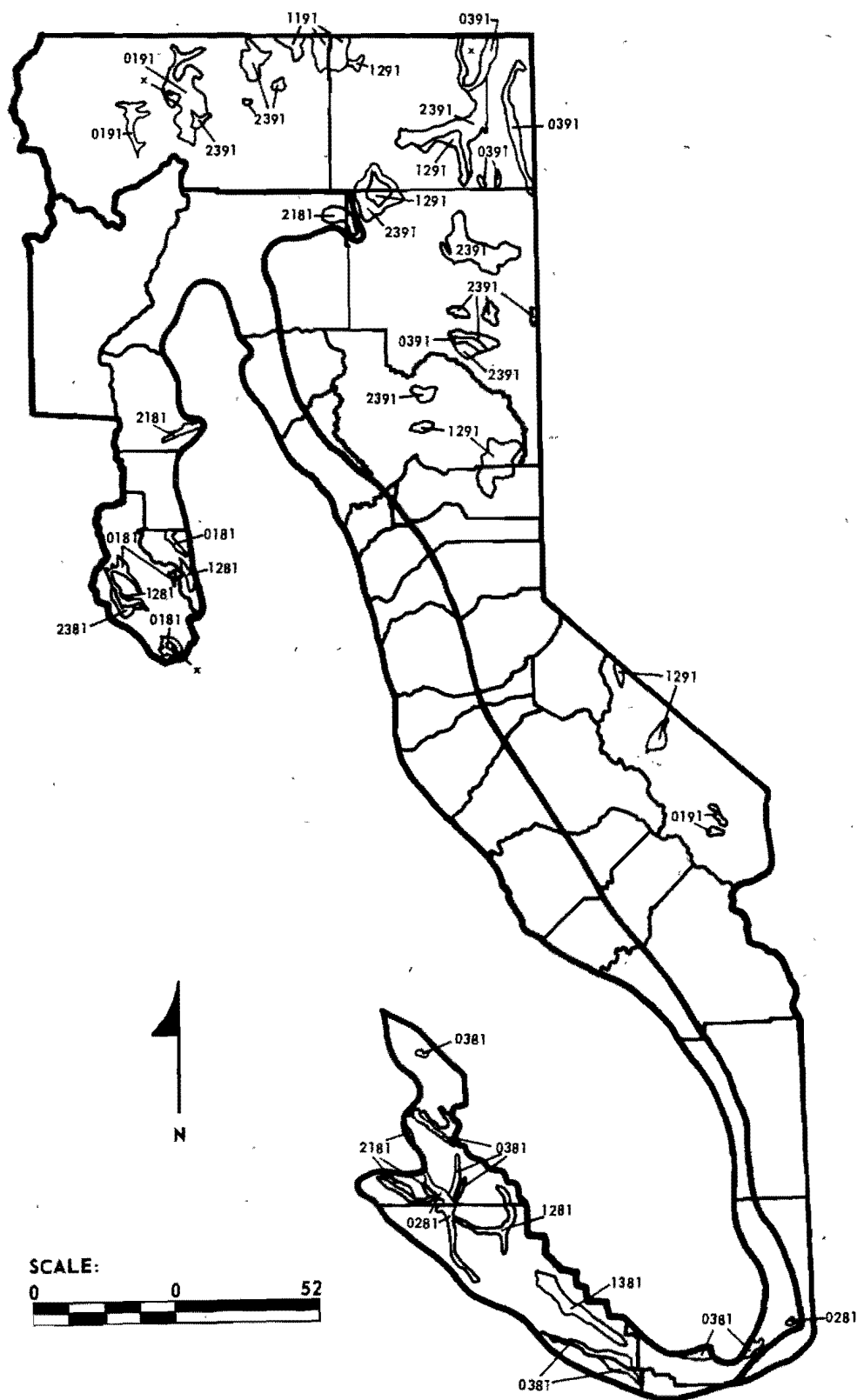


Fig. A-8. Region 8—Intermediate level valleys, and Region 9—Mountain valleys.  
See legend to figure A-1.

**APPENDIX B**  
**LAND, IRRIGATED ACREAGE, ROTATION,**  
**AND DEMAND RESTRAINTS**

TABLE B-1  
ACREAGE IN MAJOR LAND USES IN CALIFORNIA BY HOMOGENEOUS PRODUCTION AREA (HPA), 1964 AND  
PROJECTED 1980\*

HPA	Total acreage	Base period						1980				
		Urban land, 1964	Public land, 1964	Gross acreage for agri- culture, 1964	Semi- agricultural land use	Orchard and excluded vegetable crops	Net acreage for included crops	Additional land for urban use	Gross acreage for agriculture	Semi- agricultural land use	Orchard and excluded vegetable crops	Net acreage for included crops
		1,000 acres										
0111.....	122.0	6.3	4.8	110.9	11.3	0	98.6	0.7	110.2	11.0	0	99.2
0112.....	77.0	3.3	4.3	69.4	7.0	27.6	34.8	2.1	67.4	6.7	30.5	30.2
0121.....	90.3	50.9	0.1	39.4	3.0	6.6	28.9	15.0	24.3	2.4	7.3	14.6
0122.....	173.4	66.9	11.4	95.1	9.5	35.2	50.4	33.4	61.7	6.1	39.0	16.6
0123.....	201.3	32.1	2.5	166.7	16.7	63.4	86.0	24.8	141.9	14.1	70.2	57.6
0124.....	41.2	5.7	0.1	35.5	3.6	21.6	10.3	5.8	29.7	3.0	23.9	2.8
0131.....	12.1	1.9	0	10.2	1.0	2.0	7.2	1.1	9.1	.9	2.3	5.9
0132.....	274.6	186.9	2.6	105.1	10.5	30.4	58.2	56.3	48.8	4.9	42.0	1.9
0133.....	222.8	150.3	0	66.5	0.6	4.8	55.1	48.1	18.4	1.8	5.3	11.8
0134.....	475.3	192.5	0	282.8	28.3	72.3	182.2	70.9	211.9	21.1	81.8	109.0
0141.....	907.8	26.5	10.8	570.5	56.9	178.9	334.7	15.1	555.4	55.3	198.1	302.0
0142.....	137.1	7.2	2.0	127.8	13.0	23.0	91.8	3.6	124.2	12.4	25.5	86.3
0151.....	489.5	61.3	12.3	415.9	41.2	167.1	207.6	25.3	390.6	38.9	185.0	166.7
0161.....	213.6	5.8	4.9	202.9	20.5	94.0	88.4	1.6	201.3	20.0	104.1	77.2
0162.....	211.9	12.3	8.7	190.9	19.1	93.2	78.6	6.1	184.8	18.4	103.2	63.2
0163.....	221.9	11.8	2.5	207.0	20.7	109.8	77.1	6.5	201.1	20.0	121.0	59.5
0171.....	70.0	0.5	8.9	60.6	6.0	0	54.0	0.2	60.4	6.0	0	54.4
0181.....	81.6	1.5	4.4	75.7	7.8	18.5	49.6	0.6	75.1	7.5	20.5	47.1
0191.....	211.0	1.1	4.4	205.0	20.6	0	185.0	0.1	205.5	20.5	0	185.0
0221.....	41.5	3.0	7.8	30.8	3.1	3.8	23.9	2.6	28.1	2.8	4.2	21.1
0222.....	160.1	16.7	2.7	140.6	14.1	23.3	103.2	9.5	131.2	13.1	25.8	92.3
0223.....	99.6	2.3	4.8	92.4	9.3	27.9	55.2	1.4	91.1	9.1	30.9	51.1
0224.....	54.5	0	3.5	50.9	5.1	2.3	43.5	0	50.9	5.1	2.6	43.2
0231.....	25.9	8.8	0	17.1	1.7	7.0	7.8	9.7	7.4	.7	6.7	0
0232.....	140.2	9.4	0	130.8	13.1	50.5	61.2	11.5	119.3	11.9	62.0	44.8
0234.....	25.9	5.0	13.7	7.2	.7	1.5	5.0	7.2	0	0	0	0
0251.....	90.0	6.6	0.9	82.5	8.3	22.1	52.1	1.7	80.8	8.0	24.5	48.3
0261.....	105.0	3.0	3.8	98.7	9.9	7.5	81.3	1.0	97.7	9.7	8.3	79.7
0262.....	828.4	54.4	24.2	749.8	75.0	165.3	509.5	23.9	725.9	72.2	183.1	470.6
0263.....	269.8	21.3	4.4	244.1	24.4	148.5	71.2	6.8	237.4	23.6	104.4	49.4
0281.....	88.7	7.5	13.5	67.8	7.1	7.7	53.0	3.3	64.5	6.4	8.6	40.5
0362.....	596.1	3.4	16.6	576.2	57.6	12.2	506.4	0.8	575.3	57.3	13.5	504.5
0363.....	583.9	4.9	4.7	574.4	57.5	17.9	499.0	2.0	572.4	57.0	19.8	405.6
0371.....	884.3	10.5	54.3	819.4	81.9	2.6	734.0	16.7	802.6	79.8	2.9	719.9
0372.....	587.0	9.7	29.6	547.7	54.8	7.5	485.4	4.0	543.7	54.1	8.3	481.3
0381.....	117.7	0	1.6	116.1	11.6	.7	103.8	0	116.1	11.6	.8	103.7
0391.....	130.0	0	41.2	88.8	8.9	0	79.9	0	88.8	8.8	0	80.0
0521.....	95.3	11.6	42.7	41.0	4.1	1.0	35.9	8.1	32.9	3.3	1.1	28.5
0522.....	36.7	5.6	14.6	16.6	1.7	0	14.9	4.2	12.4	1.2	0	11.2
0531.....	39.8	30.0	0	9.8	1.0	.5	8.3	4.2	5.6	.6	.5	4.5
0551.....	24.0	2.0	0	22.0	2.2	12.5	7.3	1.7	20.3	2.0	13.8	4.5
0561.....	166.8	8.3	9.6	148.9	15.2	14.8	118.9	2.7	146.2	14.6	16.4	115.2
0562.....	102.5	1.9	0	100.6	10.1	19.9	70.0	0.6	100.0	10.0	22.0	68.0
0563.....	27.7	1.4	0	26.2	2.6	0	23.0	0.4	25.8	2.6	0	23.2
0572.....	318.1	4.1	11.4	202.7	20.3	41.0	140.8	6.3	196.4	19.6	46.1	130.7
1123.....	15.9	0	0	15.9	1.6	0	14.3	0	15.9	1.6	0	14.3
1151.....	256.1	1.9	0	253.2	25.3	2.5	225.4	0.7	252.5	25.1	2.8	234.6
1191.....	127.0	0	36.8	90.2	9.0	1.5	70.7	0	90.2	9.0	1.6	70.6
1221.....	45.5	24.9	0.1	20.5	2.1	.3	18.1	8.5	12.1	1.2	.4	10.5
1222.....	9.0	4.1	0.1	4.7	.5	.6	3.6	1.7	3.1	.3	.0	2.2
1223.....	74.6	10.8	4.8	59.0	5.9	2.0	51.1	6.8	52.3	5.2	2.2	44.9
1231.....	23.9	3.8	5.7	15.0	1.5	.1	13.4	5.5	9.5	.9	0	8.6
1232.....	17.1	0	0	17.1	1.7	0	15.4	0	17.1	1.7	0	15.4
1233.....	30.0	22.2	0	7.8	.5	0	7.0	7.5	0.3	0	0	.3
1241.....	470.3	1.5	16.1	452.6	45.2	0	407.4	0.3	452.2	45.0	0	407.2
1251.....	462.2	39.8	2.6	419.8	42.0	5.3	372.5	23.3	396.5	39.5	5.9	351.1
1261.....	99.0	0.5	4.0	94.4	9.4	0	85.0	0.2	94.2	9.4	0	84.8
1262.....	741.6	1.6	18.0	722.1	72.2	.3	649.6	0.4	721.7	71.9	.3	649.5
1263.....	24.0	0	1.2	22.8	2.3	0	20.5	0	22.8	2.3	0	20.5
1281.....	69.3	0	1.7	67.5	6.8	1.6	59.1	0	67.5	6.7	1.7	59.1
1291.....	309.5	3.1	15.1	291.2	29.1	.1	262.0	0.5	260.8	29.0	0	261.8
1341.....	69.0	0	8.8	60.2	6.0	.6	53.8	0	60.2	6.0	.7	53.5
1351.....	21.4	0	0	21.4	2.1	0	19.3	0	21.4	2.1	0	19.3
1361.....	121.0	0	4.2	116.8	11.7	0	105.1	0	116.8	11.6	0	105.2
1382.....	261.0	0.0	24.2	236.3	23.6	0	212.7	0.3	236.0	23.5	0	212.5
1381.....	99.0	0	0.9	98.1	9.8	0	88.3	0	98.1	9.8	0	88.3
1451.....	23.0	1.6	0	21.4	2.3	0	19.1	0.5	20.9	2.1	0	18.8
1461.....	10.0	0	0.7	9.3	.9	0	8.4	0	9.3	.9	0	8.4

TABLE B-1 *continued*

HPA	Total acreage	Base period						1980				
		Urban land, 1964	Public land, 1964	Gross acreage for agri- culture, 1964	Semi- agricultural land use	Orchard and excluded vegetable crops	Net acreage for included crops	Additional land for urban use	Gross acreage for agriculture	Semi- agricultural land use	Orchard and excluded vegetable crops	Net acreage for included crops
		1,000 acres										
1462.....	314.0	4.3	5.2	304.5	30.5	.2	273.8	2.4	302.1	30.1	.3	271.7
1551.....	14.0	0.2	0.4	13.4	1.4	0	12.0	0	13.4	1.3	0	12.1
1561.....	137.0	0	8.9	128.1	12.8	0	115.3	0	128.1	12.8	0	115.3
1562.....	678.0	9.6	11.9	656.5	65.8	.1	590.6	5.1	651.3	64.9	.1	586.3
1572.....	104.0	0	22.0	82.0	8.2	.9	72.9	0	82.0	8.2	1.0	72.8
2111.....	35.0	2.8	2.8	29.3	2.9	1.7	24.7	0.3	29.1	2.9	1.9	24.3
2121.....	92.7	10.1	5.8	76.8	7.7	2.5	66.6	4.1	72.7	7.2	2.7	62.8
2122.....	196.2	10.5	25.7	160.0	16.0	2.7	141.3	4.5	155.5	15.5	2.9	137.1
2123.....	21.6	0	0	21.0	2.2	.8	18.6	0	21.6	2.2	.9	18.5
2124.....	157.8	0	3.1	154.7	15.5	1.2	138.0	0	154.7	15.4	1.3	138.0
2131.....	38.3	0	0	38.3	3.8	.5	34.0	0	38.3	3.8	.5	34.0
2132.....	34.2	22.0	0	12.1	1.2	1.6	9.3	7.8	4.4	.4	1.7	2.3
2133.....	100.3	81.6	0	18.7	1.9	.1	16.7	18.7	0	0	0	0
2134.....	332.5	40.2	0.1	283.2	28.3	26.2	228.7	33.4	249.9	24.9	29.1	195.9
2141.....	134.8	0.7	2.9	131.2	13.2	2.7	115.3	0.2	131.0	13.0	3.0	115.0
2142.....	345.2	2.6	6.5	336.2	33.7	16.6	285.9	0.6	335.6	33.4	18.4	288.8
2151.....	15.0	0	0	15.0	1.5	0	13.5	0	15.0	1.5	0	13.5
2181.....	89.5	0	2.9	86.7	8.7	0	78.0	0	86.7	8.6	0	78.1
2223.....	51.0	0	0	51.0	5.1	.1	45.8	0	51.0	5.1	.1	45.8
2232.....	62.7	21.3	0	41.4	4.1	6.2	31.1	8.2	33.2	3.3	7.1	22.8
2233.....	15.3	9.8	0	5.5	.6	0	4.9	4.1	1.4	0.1	0	1.3
2251.....	9.0	0.5	0	8.5	.9	.2	7.4	0.4	8.2	.8	.2	7.2
2262.....	12.6	0	0.3	12.3	1.2	0	11.1	0	12.3	1.2	0	11.1
2263.....	429.4	6.1	7.6	415.7	41.6	9.5	364.6	6.9	408.8	40.7	10.5	357.0
2311.....	31.0	3.5	1.5	26.0	2.6	0	23.4	0.1	25.9	2.6	0	23.3
2312.....	20.0	0	1.0	19.0	1.9	0	17.1	0	19.0	1.9	0	17.1
2321.....	24.0	0.7	1.3	22.0	2.2	.3	19.5	0.3	21.7	2.2	.3	19.2
2322.....	5.0	1.5	0	3.5	.3	0	3.2	0.9	2.6	.3	0	2.3
2323.....	127.2	18.2	3.4	105.6	10.6	0	95.0	8.9	96.7	9.6	0	87.1
2331.....	45.1	14.0	6.3	24.8	2.5	0	22.3	12.1	12.7	1.3	0	11.4
2332.....	99.0	39.8	7.3	51.9	5.2	8.0	38.7	33.4	18.5	1.8	8.8	7.9
2333.....	3.2	1.4	0	1.8	.2	.2	1.4	1.7	0.1	0	0	0
2334.....	10.8	0.2	5.0	5.6	.6	0	5.0	0	5.6	.6	0	5.0
2341.....	21.0	0.7	0	20.3	2.0	0	18.3	0.9	19.5	1.9	0	17.6
2342.....	120.0	1.2	3.3	115.5	11.6	1.0	102.9	0.9	114.6	11.4	1.1	102.1
2351.....	97.8	8.1	0.8	88.9	8.9	.3	79.7	3.9	85.0	8.5	.3	76.2
2361.....	21.5	0	1.0	20.5	2.0	0	18.5	0	20.5	2.0	0	18.5
2381.....	15.0	0	0.1	14.9	1.5	0	13.4	0	14.9	1.5	0	13.4
2391.....	614.6	1.4	58.3	554.9	55.5	.8	498.6	0.2	554.7	55.1	.8	498.8
2432.....	115.0	32.6	14.0	71.4	7.1	0	64.3	20.0	51.3	5.1	0	46.2
2441.....	187.2	3.4	6.1	177.7	17.8	0	159.9	1.4	176.2	17.6	0	158.6
2442.....	271.1	19.6	24.2	227.2	22.8	1.5	202.9	8.8	218.5	21.8	1.7	195.0
2451.....	548.7	54.9	11.4	482.4	48.2	.5	433.7	22.1	460.3	45.8	.5	414.0
2461.....	43.9	4.8	0.8	38.4	3.8	0	34.6	2.0	36.4	3.6	0	32.8
2462.....	49.1	3.2	1.8	44.1	4.5	0	39.6	1.0	43.1	4.3	0	38.8
2463.....	787.3	16.1	15.8	755.3	75.6	12.6	667.1	10.2	745.1	74.2	14.0	656.9
2471.....	92.2	0	0	92.2	9.2	0	83.0	0	92.2	9.2	0	83.0
Subtotal†.....	19,624.9	1,615.2	803.8	17,205.8	1,722.5	1,673.5	13,809.8	732.1	16,473.7	1,640.5	1,853.0	12,980.2
NPA†.....		449.3						185.6				
TOTAL.....		2,064.5						917.7				

\* For purposes of analysis, the number of homogeneous production areas was reduced from 115 to 95 because 20 HPAs had only small acreages. The following groupings were made:

## Primary HPA

0224  
0182  
0134  
0251  
1151  
1223

## HPA included with primary HPA

0124  
0131, 0133, 0231, 0531  
0234  
0551  
1123  
1222

## Primary HPA

1232  
2263  
2122  
2134  
2232  
2223

## HPA included with primary HPA

1233  
2262  
2322  
2334  
2132, 2133, 2233, 2332, 2333, 2432  
2251

† Computed from unrounded data.

‡ Includes all areas in the State outside the HPAs.

TABLE B-2  
IRRIGATED ACREAGE RESTRAINTS

HPA	Maximum acreage irrigable by available water supplies
	1,000 acres
0171.....	19
0191.....	77
0222.....	65
0224.....	20
0371.....	142
0391.....	67
1291.....	148
1381.....	0
2121.....	7
2122.....	71
2124.....	25
2391.....	0
2471.....	0

TABLE B-3  
ROTATION RESTRAINTS

Crop activity	Rotation restraint as proportion of net model acreage
Vegetable crops:	
Asparagus.....	1.00
Broccoli (single crop).....	1.00
Broccoli-fall or spring lettuce (double crop).....	1.00
Lettuce, fall or spring (single crop).....	1.00
Lettuce, fall or spring (double crop).....	1.00
Lettuce, fall or spring and summer (double crop).....	1.00
Lettuce, summer (single crop).....	1.00
Lettuce, winter (double crop).....	1.00
Cantaloupes, fall or spring.....	1.00
Cantaloupes, summer.....	1.00
Potatoes.....	.50
Tomatoes, processing.....	.67
Field crops:	
Corn.....	.80
Barley (fallow).....	1.00
Barley (nonirrigated).....	.70
Barley (irrigated, single crop).....	.70
Barley-grain sorghum (irrigated, double crop).....	.50
Grain sorghum (single crop).....	.80
Alfalfa hay.....	.80
Dry beans.....	.33
Rice.....	1.00
Safflower.....	.50
Sugar beets.....	.33
Cotton.....	.33

TABLE B-4  
LINEAR PROGRAMMING MINIMUM DEMAND RESTRAINTS

Crop	Representative commodity	Model 1961-65*	Model 1980A	Model 1980B	Model 1980C
1,000 tons					
Vegetable crops:					
Asparagus	Same	95	100	100	100
Cole crops:	Broccoli	151	179	221	221
Broccoli					
Brussels sprouts					
Cauliflower					
Lettuce:					
Spring and fall	Same	388	544	544	544
Summer	Same	368	518	518	518
Winter	Same	388	547	547	547
Melons, spring and fall:	Cantaloupes, spring and fall	99	100	100	100
Cantaloupes, spring and fall					
Honeydew melons, spring					
Watermelons, spring					
Melons, summer:	Cantaloupes, summer	397	398	398	398
Cantaloupes, summer					
Honeydew melons, summer					
Watermelons, summer					
Potatoes:	Same	1,139	1,336	1,336	1,336
Russet burbank	Same	149	175	175	175
Tomatoes, fresh and processing	Tomatoes, processing	3,333	4,917	5,127	5,127
Field crops:					
Feed grains:	Corn for grain	NA	NA	NA	3,958
Corn	Corn for grain	405	620	576	0
Small grains:	Barley	2,258	3,418	2,931	420†
Barley					
Oats					
Wheat					
Sorghums	Sorghums for grain	522	769	683	0
Alfalfa hay and seed	Alfalfa hay	6,837	8,002	7,699	7,699
Dry beans	Same	157	203	176	176
Baby lima, kidney, blackeye, and pink	Same	85	110	95	95
Rice	Same	764	934	934	934
Safflower seed	Same	257	678	880	880
Sugar beets	Same	5,866	7,591	7,892	7,892
1,000 bales					
Cotton.....	Same	1,753	1,948	2,771	2,771

\* SOURCE: California Crop and Livestock Reporting Service (1967a and 1968).

† Projected output of wheat in barley units.



# APPENDIX C

## STUDY CROP ACREAGE, ACTUAL AND ESTIMATED MODEL REQUIREMENTS

TABLE C-1  
HARVESTED STUDY CROP ACREAGE IN BASE PERIOD, 1961-65, ACTUAL  
REQUIREMENTS

Crop group	Region									State
	Coastal			Central Valley			Desert	Mountain		
	1	2	3	4	5	6	7	8	9	
	1,000 acres									
Vegetable crops:										
Asparagus.....	0	3	0	1	53	1	6	0	0	64
Cole crops.....	0	41	4	0	0	2	1	0	0	48
Lettuce*.....	0	59	6	0	4	4	43	0	0	116
Melons*.....	0	0	2	3	5	47	16	0	0	73
Potatoes*.....	0	13	11	0	5	57	0	0	15	101
Tomatoes.....	0	25	12	26	80	33	2	0	0	178
Field crops:										
Corn.....	1	4	4	13	58	95	2	3	0	180
Small grains*.....	3	104	110	301	199	744	116	203	91	1,871
Sorghums*.....	0	1	7	50	55	74	77	1	0	265
Alfalfa.....	2	19	31	114	151	624	259	24	52	1,276
Dry beans*.....	0	50	26	33	46	62	0	0	0	217
Rice.....	0	0	0	258	34	25	0	1	0	318
Safflower.....	0	0	0	83	39	137	1	1	0	261
Sugar beets.....	0	14	5	40	76	75	60	16	0	286
Cotton.....	0	0	0	0	0	699	66	0	0	765
Total.....	6	333	218	922	805	2,679	649	249	158	6,019

\* Alternative crop varieties, seasons, and activities are not differentiated.

TABLE C-2  
HARVESTED STUDY CROP ACREAGE IN BASE PERIOD, 1961-65, ESTIMATED  
MODEL REQUIREMENTS

Crop group	Region									State*
	Coastal			Central Valley			Desert	Mountain		
	1	2	3	4	5	6	7	8	9	
	1,000 acres									
Vegetable crops:										
Asparagus.....	0	42.8	0	0	0	0	0	0	0	42.8
Cole crops.....	0	40.5	0	0	0	2.4	0	0	0	42.9
Lettuce†.....	0	74.6	0	0	0	0	40.2	0	0	114.8
Melons†.....	0	0	0	0	0	47.1	15.8	0	0	62.9
Potatoes†.....	0	54.8	0	0	10.0	15.6	0	0	14.7	95.1
Tomatoes.....	0	71.5	0	19.0	78.3	0	0	0	0	168.8
Field crops:										
Corn.....	7.0	10.0	0	29.0	110.7	0	0	0	0	156.7
Small grains†.....	0	17.0	0	162.3	300.5	479.0	109.8	90.0	260.0	1,418.6
Sorghums†.....	0	0	0	0	232.5	0	0	0	0	232.5
Alfalfa.....	28.0	16.0	0	341.0	357.5	363.2	0	57.0	97.2	1,259.9
Dry beans†.....	0	79.4	0	38.0	20.0	56.8	0	0	0	194.2
Rice.....	0	0	0	298.7	0	0	0	0	0	298.7
Safflower.....	0	0	0	0	0	0	210.8	0	0	210.8
Sugar beets.....	0	72.0	72.0	0	0	95.4	0	18.0	0	258.4
Cotton.....	0	0	0	0	0	606.0	206.0	0	0	812.0
Total*.....	35.0	478.5	72.0	888.0	1,109.4	1,665.4	582.7	165.0	372.0	5,369.0

\* Computed from unrounded data.

† Alternative crop varieties, seasons, and activities are not differentiated. Activity acreage is converted to crop acreage harvested.

TABLE C-3

HARVESTED STUDY CROP ACREAGE IN BASE PERIOD, 1961-65, ESTIMATED  
MODEL LESS ACTUAL REQUIREMENTS

Crop group	Region									State*
	Coastal			Central Valley			Desert	Mountain		
	1	2	3	4	5	6	7	8	9	
	1,000 acres									
Vegetable crops:										
Asparagus.....	0	39.8	0	-1.0	-53.0	-1.0	-6.0	0	0	-21.2
Cole crops.....	0	-0.5	-4.0	0	0	0.4	-1.0	0	0	-5.1
Lettuce.....	0	15.6	-6.0	0	-4.0	-4.0	-2.8	0	0	-1.2
Melons.....	0	0	-2.0	-3.0	-5.0	0.1	-0.2	0	0	-10.1
Potatoes.....	0	41.8	-11.0	0	5.0	-41.4	0	0	-0.3	-5.9
Tomatoes.....	0	46.5	-12.0	-7.0	-1.7	-33.0	-2.0	0	0	-9.2
Field crops:										
Corn.....	6.0	6.0	-4.0	16.0	52.7	-95.0	-2.0	-3.0	0	-23.3
Small grains.....	-2.0	-87.0	-110.0	-138.7	101.5	-265.0	-6.2	-113.0	169.0	-452.4
Sorghums.....	0	-1.0	-7.0	-50.0	177.5	-74.0	-77.0	-1.0	0	-32.5
Alfalfa.....	26.0	-3.0	-31.0	227.0	206.5	-260.8	-259.0	33.0	45.2	-16.1
Dry beans.....	0	29.4	-26.0	5.0	-26.0	-5.2	0	0	0	-22.8
Rice.....	0	0	0	40.7	-34.0	-25.0	0	-1.0	0	-19.3
Safflower.....	0	0	0	-83.0	-39.0	-137.0	209.8	-1.0	0	-50.2
Sugar beets.....	0	58.0	67.0	-40.0	-76.0	21.4	-60.0	2.0	0	-27.6
Cotton.....	0	0	0	0	0	-93.0	140.0	0	0	47.0
Total*.....	29.0	145.5	-146.0	-34.0	304.4	-1,012.6	-66.3	-94.0	214.0	-650.0

\* Computed from unrounded data.

TABLE C-4

HARVESTED STUDY CROP ACREAGE IN BASE PERIOD, 1961-65, ESTIMATED  
MODEL EXPRESSED AS A PERCENTAGE OF ACTUAL REQUIREMENTS

Crop group	Region									State
	Coastal			Central Valley			Desert	Mountain		
	1	2	3	4	5	6	7	8	9	
	per cent									
Vegetable crops:										
Asparagus.....	100.00	1,426.28	100.00	0	0	0	0	100.00	100.00	66.86
Cole crops.....	100.00	98.84	0	100.00	100.00	118.11	0	100.00	100.00	89.35
Lettuce.....	100.00	126.47	0	100.00	0	0	93.52	100.00	100.00	98.99
Melons.....	100.00	100.00	0	0	0	100.11	99.06	100.00	100.00	86.16
Potatoes.....	100.00	421.16	0	100.00	200.00	27.43	100.00	100.00	98.33	94.20
Tomatoes.....	100.00	285.87	0	73.08	97.88	0	0	100.00	100.00	94.62
Field crops:										
Corn.....	700.00	250.00	0	223.10	190.85	0	0	0	100.00	87.05
Small grains.....	0	16.35	0	53.93	151.02	64.38	94.03	44.33	235.71	75.82
Sorghums.....	100.00	0	0	0	423.65	0	0	0	100.00	87.72
Alfalfa.....	1,400.00	84.21	0	299.12	236.72	58.21	0	237.50	187.02	98.74
Dry beans.....	100.00	158.75	0	115.14	43.48	91.61	100.00	100.00	100.00	89.48
Rice.....	100.00	100.00	100.00	115.76	0	0	100.00	0	100.00	93.92
Safflower.....	100.00	100.00	100.00	0	0	0	21,081.97	0	100.00	80.77
Sugar beets.....	100.00	514.29	1,440.00	0	0	128.50	0	112.50	100.00	90.34
Cotton.....	100.00	100.00	100.00	100.00	100.00	86.70	312.12	100.00	100.00	106.14
Total.....	583.33	143.70	33.03	96.31	137.82	62.20	89.78	66.27	235.44	89.20

TABLE C-5  
HARVESTED STUDY CROP ACREAGE, ESTIMATED MODEL 1980C  
REQUIREMENTS

Crop group	Region									State*
	Coastal			Central Valley			Desert	Mountain		
	1	2	3	4	5	6	7	8	9	
	1,000 acres									
Vegetable crops:										
Asparagus.....	0	40.8	0	0	0	0	0	0	0	40.8
Cole crops.....	0	41.7	0	0	0	11.6	0	0	0	53.3
Lettuce†.....	0	80.1	0	0	0	0	43.8	0	0	123.9
Melons†.....	0	0	0	0	0	40.9	14.0	0	0	54.9
Potatoes†.....	0	28.0	0	0	36.0	14.5	0	0	14.3	92.8
Tomatoes.....	0	0	0	57.2	110.0	0	0	0	0	167.2
Field crops:										
Corn.....	0	0	0	0	0	0	0	0	0	0
Small grains†.....	0	16.4	0	199.7	266.9	296.1	0	0	14.7	793.8
Sorghums†.....	0	3.4	0	199.7	266.9	296.1	0	0	0	766.1
Alfalfa.....	24.0	16.0	0	267.8	340.0	267.0	0	81.3	298.0	1,294.1
Dry beans†.....	0	60.7	21.0	0	49.0	62.2	0	0	0	192.9
Rice.....	0	0	0	268.4	0	0	0	0	0	268.4
Safflower.....	0	0	0	0	0	271.6	240.0	0	0	511.6
Sugar beets.....	0	111.0	32.0	0	6.0	124.4	0	38.0	0	311.4
Cotton.....	0	0	0	0	0	954.3	202.0	0	0	1,156.3
Total*.....	24.0	398.2	53.0	992.8	1,074.8	2,338.8	499.9	119.3	327.0	5,827.8

\* Computed from unrounded data.

† Alternative crop varieties, seasons, and activities are not differentiated. Activity acreage is converted to crop acreage harvested.

TABLE C-6

# HARVESTED STUDY CROP ACREAGE, ESTIMATED MODEL 1980C LESS BASE PERIOD ACTUAL REQUIREMENTS

Crop group	Region									State*
	Coastal			Central Valley			Desert	Mountain		
	1	2	3	4	5	6	7	8	9	
	1,000 acres									
Vegetable crops:										
Asparagus.....	0	37.8	0	-1.0	-53.0	-1.0	-6.0	0	0	-23.2
Cole crops.....	0	0.7	-4.0	0	0	9.6	-1.0	0	0	5.3
Lettuce.....	0	21.1	-8.0	0	-4.0	-4.0	0.8	0	0	7.9
Melons.....	0	0	-2.0	-3.0	-5.0	-6.1	-2.0	0	0	-18.1
Potatoes.....	0	15.0	-11.0	0	31.0	-42.5	0	0	-0.7	-8.2
Tomatoes.....	0	-25.0	-12.0	31.2	30.0	-33.0	-2.0	0	0	-10.8
Field crops:										
Corn.....	-1.0	-4.0	-4.0	-13.0	-58.0	-95.0	-2.0	-3.0	0	-180.0
Small grains.....	-3.0	-87.6	-110.0	-101.3	67.9	-447.9	-116.0	-203.0	-76.3	-1,077.2
Sorghums.....	0	2.4	-7.0	149.7	211.9	222.1	-77.0	-1.0	0	501.1
Alfalfa.....	22.0	-3.0	-31.0	153.8	189.0	-357.0	-259.0	57.3	246.0	18.1
Dry beans.....	0	10.8	-5.0	-33.1	3.0	0.2	0	0	0	-24.1
Rice.....	0	0	0	10.4	-34.0	-25.0	0	-1.0	0	-49.6
Safflower.....	0	0	0	-83.0	-39.0	134.6	239.0	-1.0	0	250.6
Sugar beets.....	0	97.0	27.0	-40.0	-70.0	49.4	-60.0	22.0	0	25.4
Cotton.....	0	0	0	0	0	255.3	136.0	0	0	391.3
Total*.....	18.0	65.2	-165.0	70.8	269.8	-340.2	-149.1	-129.7	169.0	-191.2

\* Computed from unrounded data.

TABLE C-7

# HARVESTED STUDY CROP ACREAGE, ESTIMATED MODEL 1980C EXPRESSED AS A PERCENTAGE OF BASE PERIOD ACTUAL REQUIREMENTS

Crop group	Region									State
	Coastal			Central Valley			Desert	Mountain		
	1	2	3	4	5	6	7	8	9	
	per cent									
Vegetable crops:										
Asparagus.....	100.00	1,360.54	100.00	0	0	0	0	100.00	100.00	63.78
Cole crops.....	100.00	101.72	0	100.00	100.00	581.11	0	100.00	100.00	111.10
Lettuce.....	100.00	135.75	0	100.00	0	0	101.98	100.00	100.00	106.85
Melons.....	100.00	100.00	0	0	0	87.10	87.50	100.00	100.00	75.26
Potatoes.....	100.00	215.38	0	100.00	720.00	25.52	100.00	100.00	95.33	91.93
Tomatoes.....	100.00	0	0	219.98	137.50	0	0	100.00	100.00	93.93
Field crops:										
Corn.....	0	0	0	0	0	0	0	0	100.00	0
Small grains.....	0	15.77	0	66.34	134.12	39.80	0	0	16.15	42.43
Sorghums.....	100.00	340.00	0	399.37	485.27	400.14	0	0	100.00	289.09
Alfalfa.....	1,200.00	84.21	0	234.92	225.17	42.79	0	338.91	573.08	101.42
Dry beans.....	100.00	121.51	80.77	0	106.52	100.26	100.00	100.00	100.00	88.90
Rice.....	100.00	100.00	100.00	104.03	0	0	100.00	0	100.00	84.40
Safflower.....	100.00	100.00	100.00	0	0	198.27	24,000.00	0	100.00	196.03
Sugar beets.....	100.00	792.86	640.55	0	7.89	165.84	0	237.50	100.00	108.88
Cotton.....	100.00	100.00	100.00	100.00	100.00	136.53	306.06	100.00	100.00	151.15
Total.....	400.00	119.57	24.32	107.68	133.52	87.30	77.02	47.93	206.96	96.82

TABLE C-8  
HARVESTED STUDY CROP ACREAGE, ESTIMATED MODEL 1980C LESS MODEL  
1961-65 REQUIREMENTS

Crop group	Region									State
	Coastal			Central Valley			Desert	Mountain		
	1	2	3	4	5	6	7	8	9	
	1,000 acres									
Vegetable crops:										
Asparagus.....	0	-2.0	0	0	0	0	0	0	0	-2.0
Cole crops.....	0	1.2	0	0	0	9.3	0	0	0	10.4
Lettuce.....	0	5.5	0	0	0	0	3.6	0	0	9.1
Melons.....	0	0	0	0	0	-6.1	-1.9	0	0	-8.0
Potatoes.....	0	-26.8	0	0	26.0	-1.1	0	0	-0.5	-2.3
Tomatoes.....	0	-71.5	0	38.2	31.7	0	0	0	0	-1.6
Field crops:										
Corn.....	-7.0	-10.0	0	-29.0	-110.7	0	0	0	0	-156.7
Small grains.....	0	-0.6	0	37.4	-33.6	-182.9	-109.8	-90.0	-245.3	-624.8
Sorghums.....	0	3.4	0	199.7	34.4	296.1	0	0	0	533.6
Alfalfa.....	-4.0	0	0	-73.2	-17.5	-96.2	0	24.3	200.8	34.2
Dry beans.....	0	-18.6	21.0	-38.0	29.0	5.4	0	0	0	-1.3
Rice.....	0	0	0	-30.3	0	0	0	0	0	-30.3
Safflower.....	0	0	0	0	0	271.6	29.2	0	0	300.8
Sugar beets.....	0	39.0	-40.0	0	6.0	28.0	0	20.0	0	53.0
Cotton.....	0	0	0	0	0	348.3	-4.0	0	0	344.3
Total.....	-11.0	-80.4	-19.0	104.8	-34.6	672.4	-82.8	-45.7	-45.0	458.7

TABLE C-9  
HARVESTED STUDY CROP ACREAGE, ESTIMATED MODEL 1980C EXPRESSED  
AS A PERCENTAGE OF MODEL 1961-65 REQUIREMENTS

Crop group	Region									State
	Coastal			Central Valley			Desert	Mountain		
	1	2	3	4	5	6	7	8	9	
	per cent									
Vegetable crops:										
Asparagus.....	100.00	95.39	100.00	100.00	100.00	100.00	100.00	100.00	100.00	95.39
Cole crops.....	100.00	102.91	100.00	100.00	100.00	492.05	100.00	100.00	100.00	124.35
Lettuce.....	100.00	107.34	100.00	100.00	100.00	100.00	109.05	100.00	100.00	107.94
Melons.....	100.00	100.00	100.00	100.00	100.00	87.01	88.33	100.00	100.00	87.34
Potatoes.....	100.00	51.14	100.00	100.00	360.00	93.02	100.00	100.00	96.95	97.59
Tomatoes.....	100.00	0	100.00	301.03	140.48	100.00	100.00	100.00	100.00	99.06
Field crops:										
Corn.....	0	0	100.00	0	0	100.00	100.00	100.00	100.00	0
Small grains.....	100.00	96.47	100.00	123.01	88.81	61.82	0	0	5.65	55.95
Sorghums.....	100.00	∞	100.00	∞	114.82	∞	100.00	100.00	100.00	329.56
Alfalfa.....	85.71	100.00	100.00	78.53	95.12	73.51	100.00	142.70	306.43	102.72
Dry beans.....	100.00	76.54	∞	0	245.00	109.44	100.00	100.00	100.00	99.36
Rice.....	100.00	100.00	100.00	89.86	100.00	100.00	100.00	100.00	100.00	89.86
Safflower.....	100.00	100.00	100.00	100.00	100.00	∞	113.84	100.00	100.00	242.68
Sugar beets.....	100.00	154.17	44.48	100.00	∞	129.06	100.00	211.11	100.00	120.53
Cotton.....	100.00	100.00	100.00	100.00	100.00	157.48	98.06	100.00	100.00	142.41
Total.....	68.57	83.21	73.65	111.80	96.88	140.35	85.79	72.33	87.90	108.54

TABLE C-10  
STUDY CROP LAND USE BY SOIL CATEGORY, ESTIMATED MODEL 1980C  
REQUIREMENTS

Crop activity	Soil										State*†
	Alluvial				Basin					Terrace	
	01	02	03	05	11	12	13	14	15	21	
	1,000 acres										
Vegetable crops:											
Asparagus.....	5.8	35.0	0	0	0	0	0	0	0	0	40.8
Broccoli (single crop)....	11.6	0	0	0	0	0	0	0	0	0	11.6
Broccoli and fall or spring lettuce (double crop).....	41.7	0	0	0	0	0	0	0	0	0	41.7
Lettuce, fall or spring (single crop).....	0	0	0	0	0	0	0	0	0	0	0
Lettuce, fall and spring (double crop).....	0	0	0	0	0	0	0	0	0	0	0
Lettuce, fall or spring and summer (double crop).....	0	0	0	0	0	0	0	0	0	0	0
Lettuce, summer (single crop).....	4.7	0	0	2.7	0	31.0	0	0	0	0	38.4
Lettuce, winter (double crop).....	0	0	21.9	0	0	0	0	0	0	0	21.9
Cantaloupes, fall or spring.....	0	0	14.0	0	0	0	0	0	0	0	14.0
Cantaloupes, summer....	0	0	40.9	0	0	0	0	0	0	0	40.9
Potatoes.....	0	68.5	0	0	24.3	0	0	0	0	0	92.8
Tomatoes, processing....	57.2	0	0	0	110.0	0	0	0	0	0	167.2
Field crops:											
Corn.....	0	0	0	0	0	0	0	0	0	0	0
Barley (fallow).....	0	26.0	0	0	0	0	0	0	0	0	26.0
Barley (nonirrigated)....	0	0	0	0	0	0	0	0	0	0	0
Barley (irrigated, single crop).....	0	0	13.0	0	1.7	0	0	0	0	0	14.7
Barley and grain sorghum (irrigated, double crop).....	59.0	14.0	0	83.0	119.0	583.4	45.0	0	0	0	903.4
Grain sorghum (single crop).....	0	0	0	0	0	0	0	0	0	0	0
Alfalfa hay.....	614.8	111.0	54.0	20.0	64.0	295.3	9.0	24.0	102.0	0	1,294.1
Dry beans.....	74.7	71.2	0	44.0	0	3.0	0	0	0	0	192.9
Rice.....	0	0	0	0	0	215.4	53.0	0	0	0	268.4
Safflower.....	29.0	242.6	240.0	0	0	0	0	0	0	0	511.6
Sugar beets.....	42.4	96.0	0	4.0	0	81.0	35.0	5.0	25.0	23.0	311.4
Cotton.....	40.0	170.0	390.3	112.0	0	249.0	105.0	90.0	0	0	1,156.3
Total land utilized, Model 1980C optimal†..	981.0	834.3	774.2	265.7	319.0	1,458.2	247.0	119.0	127.0	23.0	5,148.4
Residual land, projected 1980†.....	396	122	1,610	114	0	455	232	182	661	1,085	7,757†
Net model acreage avail- able, projected 1980†.....	1,377	956	2,384	380	319	1,913	479	301	788	1,108	12,905†

\* In the optimal solution, no production is projected on soils 22-24.

† Computed from unrounded data.

‡ Includes acreage to be used for pasture and nonalfalfa hay.

§ Includes acreage of soils 22-24. Figure is from Appendix table B-1.

TABLE C-11

STUDY CROP ACREAGE AND IMPUTED VALUE OF RESTRICTING VARIABLE  
BY HPA, MODEL 1980C ESTIMATES

HPA*	Crop activity	Acreage	Restricting variable†	Imputed rent to restricting variable
		1,000 acres		dollars per unit
<b>Vegetable crops:</b>				
0123	Asparagus.....	5.8	D	-302.22
0223	" ".....	35.0	L	41.43
0161	Broccoli (single crop).....	11.6	D	-146.47
0121	Broccoli and lettuce.....	10.0	L	34.80
0122	" " " ".....	14.0	L	61.25
0123	" " " ".....	17.7	D	-70.90
0123	Lettuce (spring, single crop).....	4.7	L	44.43
0522	" " " ".....	2.7	D	-86.26
1223	" " " ".....	31.0	L	30.75
0372	" (winter, double crop).....	21.9	D	-85.38
0362	Cantaloupes (spring).....	40.9	D	-90.64
0372	" (fall).....	14.0	D	-97.06
0221	Potatoes.....	7.0	L	20.53
0222	" ".....	21.0	I	40.83
0251	" ".....	26.0	R	.08
0262	" ".....	14.5	D	-58.45
1151	" ".....	10.0	R	12.57
1191	" ".....	14.3	D	-2.32†
0142	Tomatoes.....	57.2	D	-21.26
1151	" ".....	110.0	L	45.08
<b>Field crops:</b>				
0112	Alfalfa hay.....	24.0	R	11.67
0141	" ".....	237.0	R	8.44
0142	" ".....	30.8	L	33.58
0151	" ".....	128.0	R	5.07
0161	" ".....	63.0	R	1.15
0162	" ".....	21.0	L	32.59
0163	" ".....	11.0	L	27.74
0181	" ".....	35.0	R	.93
0191	" ".....	62.0	R	6.03
0224	" ".....	16.0	R	2.65
0261	" ".....	53.0	L	49.24
0281	" ".....	42.0	R	1.93
0391	" ".....	54.0	R	10.40
0561	" ".....	20.0	L	3.66
1191	" ".....	64.0	R	1.06
1251	" ".....	176.0	L	21.47
1281	" ".....	1.3	D	-30.17
1291	" ".....	118.0	R	3.80
1351	" ".....	9.0	L	5.47
1451	" ".....	17.0	R	20.89
1461	" ".....	7.0	R	2.29
1551	" ".....	10.0	R	21.89
1561	" ".....	92.0	R	2.29
0224	Barley (fallow).....	26.0	L	3.28
0391	" (irrigated, single crop).....	13.0	I	1.54
1191	" " " ".....	1.7	L	3.14
0141	" and grain sorghum.....	69.0	L	36.28
0224	" " " ".....	4.0	I	26.64
0251	" " " ".....	10.0	L	23.92
0561	" " " ".....	50.0	R	.11
0562	" " " ".....	24.0	L	.21
1151	" " " ".....	119.0	R	14.20
1241	" " " ".....	190.6	L	26.69
1251	" " " ".....	175.0	R	9.18
1261	" " " ".....	29.0	L	27.48
1262	" " " ".....	188.8	D	-35.99†
1351	" " " ".....	10.0	R	7.18
1361	" " " ".....	35.0	L	10.48
0121	Dry beans.....	5.0	R	10.84
0123	" ".....	9.8	D	-181.97
0132	" ".....	7.0	R	6.24
0151	" ".....	32.0	L	34.71
0162	" ".....	21.0	R	2.12
0221	" ".....	7.0	R	6.07
0222	" ".....	23.0	R	9.98
0232	" ".....	14.0	R	5.78
0251	" ".....	17.0	R	11.54



TABLE C-11 continued

HPA*	Crop activity	Acreage	Restricting variable†	Imputed rent to restricting variable
		1,000 acres		dollars per unit
	Field crops—continued			
	Dry beans—continued			
0262	" " .....	3.2	D	-13.15‡
0263	" " .....	8.0	L	13.00
0521	" " .....	10.0	R	28.24
0522	" " .....	4.0	R	34.70
0562	" " .....	22.0	R	14.99
0563	" " .....	8.0	R	16.20
1221	" " .....	3.0	R	14.94
1241	Rice.....	215.4	D	-78.07
1341	" .....	53.0	L	34.69
0163	Safflower.....	29.0	R	2.26
0262	" .....	217.6	D	-55.81
0263	" .....	25.0	R	3.00
0372	" .....	240.0	R	17.00
0123	Sugar beets.....	19.0	R	.08
0132	" " .....	7.0	R	20.12
0134	" " .....	3.0	D	-14.48
0161	" " .....	4.4	L	38.67
0181	" " .....	9.0	L	25.74
0221	" " .....	7.0	R	19.62
0222	" " .....	22.0	R	22.18
0223	" " .....	17.0	R	9.13
0232	" " .....	14.0	R	32.68
0261	" " .....	26.0	R	3.62
0281	" " .....	10.0	L	5.74
0522	" " .....	4.0	R	3.68
1221	" " .....	3.0	R	36.89
1223	" " .....	16.0	R	16.15
1231	" " .....	3.0	R	13.41
1232	" " .....	5.0	R	35.23
1261	" " .....	28.0	R	9.23
1263	" " .....	7.0	R	4.54
1281	" " .....	10.0	R	12.13
1361	" " .....	35.0	R	9.23
1451	" " .....	4.0	L	2.93
1461	" " .....	1.0	L	23.45
1551	" " .....	2.0	L	2.93
1561	" " .....	23.0	L	12.45
2122	" " .....	23.0	R	1.48
0162	Cotton.....	21.0	R	19.89
0163	" .....	19.0	R	24.73
0262	" .....	154.0	R	22.48
0263	" .....	16.0	R	24.48
0362	" .....	166.0	R	19.00
0363	" .....	65.3	D	-152.92
0372	" .....	159.0	R	87.69
0561	" .....	39.0	R	.12
0562	" .....	22.0	R	19.10
0563	" .....	8.0	R	19.30
0572	" .....	43.0	R	73.69
1261	" .....	28.0	R	38.99
1262	" .....	214.0	R	60.00
1263	" .....	7.0	R	81.00
1361	" .....	35.0	R	38.99
1362	" .....	70.0	R	26.00
1462	" .....	90.0	R	13.30

\* The first two digits identify the soil; the latter two, the climate.

† D = demand restraint in tons, except cotton in bales,

I = irrigated acreage restraint in acres,

L = land restraint in acres,

R = rotation restraint in acres.

‡ Marginal cost of transferring production of one additional ton of potatoes to Region 1.

§ Marginal cost per ton corn equivalent of feed grains.

¶ Marginal cost of transferring production of one additional ton of dry beans to the Central Valley.

TABLE C-12  
HARVESTED STUDY CROP ACREAGE, ESTIMATED 1980 REQUIREMENTS  
WITH HIGHER RATE OF URBAN EXPANSION

Crop group	Region									State*
	Coastal			Central Valley			Desert	Mountain		
	1	2	3	4	5	6	7	8	9	
1,000 acres										
Vegetable crops:										
Asparagus.....	0	40.8	0	0	0	0	0	0	0	40.8
Cole crops.....	0	39.0	0	0	0	15.1	0	0	0	54.1
Lettuce†.....	0	79.1	0	0	0	0	43.8	0	0	122.9
Melons†.....	0	0	0	0	0	0	14.0	0	0	54.9
Potatoes†.....	0	0	0	0	0	49.2	0	0	14.3	93.5
Tomatoes.....	0	0	0	85.8	99.7	0	0	0	0	165.6
Field crops:										
Corn.....	0	0	0	0	0	0	0	0	0	0
Small grains†.....	0	13.0	0	167.0	256.2	380.0	0	0	0	816.2
Sorghum†.....	0	0	0	167.0	256.2	380.0	0	0	0	803.2
Alfalfa.....	19.0	20.0	0	254.0	291.6	282.9	0	120.9	347.0	1,335.3
Dry beans†.....	.9	68.2	12.0	15.1	35.0	62.8	0	0	0	194.0
Rice.....	0	0	0	268.4	0	0	0	0	0	268.4
Safflower.....	0	0	0	0	9.3	263.0	240.0	0	0	512.3
Sugar beets.....	0	102.0	18.0	0	6.0	143.0	0	47.1	0	316.1
Cotton.....	0	0	0	0	0	943.8	200.0	0	0	1,143.8
Total*.....	19.9	367.1	30.0	937.2	984.0	2,560.8	497.8	168.0	361.3	5,921.1

\* Computed from unrounded data.

† Alternative crop varieties, seasons, and activities are not differentiated. Activity acreage is converted to crop acreage harvested.

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