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Optimal Location of Field Crops and Vegetables in California to Meet Projected 1980 Demand

By

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CHAPTER I

INTRODUCTION

The Problem

Agriculture in California is a complex, dynamic industry. There are many forces which have prompted constant adjustment and change in the past that will continue to shape the structure of agriculture in the future. The direction of these adjustments will depend on the nature and relative importance of these forces, which 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 [15, 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. In order to accomodate the influx of people and industry, about 54,000 acres of land per year have been converted during the past ten years from other purposes to urban uses. The capitalized value of land for traditional agricultural use cannot hope to compete with 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 accomodate 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 percent of this acreage will be taken from agricultural land.

Increasing Demand for Agricultural Products

These 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 consumer preferences for particular types of food shift as well. 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 [34, p.5] project that United States per capita consumption of these commodities in 1980 will be 6 percent higher than the average of the period 1959-61.

Crop production in California has increased significantly in the past fifteen years with no net increase in gross land resources used [104, p.14].[1/] 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

1/ However, from 1940 to 1954 the acreage of cropland harvested increased 27 percent.

rapidly as gross output levels. Since 1945 the per acre yield of some commodities has increased as much as 200 percent in California. 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 due to urban and industrial expansion, individual 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 unused 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 [60]. 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 land base by bringing additional land into production.

Governmental Farm Programs

Governmental programs are largely responsible for the year-to-year changes in the California crop acreage of rice and cotton and also affect the production of wheat and feed grains. However, the stability in the past decade of the distribution of State cotton acreage among counties has been due to the existence of an acreage allotment program with its accompanying restrictions on the transfer of such allotments.

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 enterprise 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 researchers 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 (e.g., King and Schrader [58]), conversion of agricultural land to nonagricultural purposes (e.g., Conservation Needs Inventory [9]), and water demands in specific areas (e.g., California Department of Water Resources [24, 26, 28]), 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 [41], has 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. In addition, these projections, published in 1961, were for the target date 1975. 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 is to provide a set of California agricultural projections which are for an intermediate time period (e.g., projection date of 1980), which are comprehensive in coverage of major products, primary resources, and geographic areas within the State, which are detailed in specific crop groups by area of the State, and which are internally consistent. However, since many years of research will be required before analysis of all the important variables shaping California agriculture can be completed and applied in detail to all major resources and products, the scope and methods used in this dissertation must be 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. Because the location of orchard and vineyard crops is essentially fixed for many years after planting, the detailed projections of this study will focus only on major changes in field and vegetable crop production within the State. Estimates of resource requirements should focus on land and water. Gross projections of orchard and vineyard crops and minor field crops and vegetables, though not covered in detail, should be included in order to project total resource requirements. In order to project product prices and total input costs, the cost of resources other than land and water will need to be estimated also.

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 will also be inventoried in areas where they may restrict production before the land resources become limiting. All other resources, (e.g., fertilizer, machinery, etc.) will be assumed available in unlimited supply at specified unit costs.

Specific Objectives

The impact of the natural resource endowment on the location of California's field and vegetable crop production will be analyzed with all other variables set at exogenously determined levels or unit costs. Rather than predicting the equilibrium conditions, the research conclusions will be of 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. Subject to the accurate estimation of the exogenous variables, to be discussed in succeeding chapters, answers to the following questions will be obtained for the target year 1980:

1. Will California have the productive capacity to retain its current share of the nations'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 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 the San Joaquin Valley come into production?

9. What would be the effect on optimum production locations and total cost of retaining the current cotton allotment program in force through 1980?

In addition, the locational structure, irrigated acreage requirements, and imputed farm product prices of field crops and vegetables which maximize profits to producers will be sought for average 1961-65 output levels and resource restrictions.

Further objectives of a methodological nature include:

1. Testing the applicability of a large scale programming model to use as the basis for detailed economic projections.

2. Exploring new ways of defining production areas, ways which are based on the production capabilities of multiple factors.

3. Investigating feasible methods of projecting urban acreage expansion by homogeneous resource unit for use in a programming model of agricultural adjustments.

4. Developing a basic model with which to analyze the effects of possible changes in yield, cost, demand, urban expansion, and governmental policies on agricultural production patterns in California.

It should be emphasized that although this study will provide some detailed areal projections, the purpose is to provide estimates for policy purposes and industry planning and not to serve as a planning model for an individual farmer.

Plan of Presentation

The remainder of the text falls naturally into three sections. The theoretical discussion is in Chapter 2, the development of model parameters in Chapter 3-6, and the results of analysis in Chapters 7-9.

In the first part of Chapter 2, an overview of general spatial equilibrium theory is presented as the more general type of theory encompassing the procedures of this research project. The specific simplifying assumptions for this study are there identified, and the model framework is presented in mathematical form in the latter part.

Chapter 3 clarifies methods of delineating "homogeneous production areas" as spatial units of analysis. The acreage restraints for the study crops in each production area are developed in Chapter 4, in which special emphasis is given to urban projections and to current land use inventories of orchard and excluded vegetable crops. Other important production area restraints are developed in the same chapter. Typical study crop yield and variable cost estimation comprises the body of Chapter 5. A brief analysis of past and projected future yields is also included in this chapter. Chapter 6 is devoted to estimating 1980 output parameters as a share of projected U.S. output.

The findings of the base period model are summarized in Chapter 7, where crop location, irrigated acreage, and product prices of the model solution are compared with the actual base period estimates, and possible reasons for observed differences are suggested. In Chapter 8, the 1980 model solutions are compared with the base period. The only difference between the first two 1980 models is in the output vector. In one, California output is projected as the base period share of 1980 U.S. output; in the second, it is projected as a changed share of U.S. output.

The output projections in the third 1980 model are the same as in the second; this model is developed to determine the least cost feed grain mix which would satisfy the total feed grain energy requirement. Two extensions to the third model provide tentative answers to the final questions raised in the previous section concerning 1) water pricing on the west side of the San Joaquin Valley and 2) the effect of the cotton allotment program on efficient production. In Chapter 9, the major findings and implication of the 1980 models are concluded, the methods of analysis used are evaluated, and a number of relevant areas meriting further investigation are suggested.

The actual parameters used in the study models, necessary supporting data, and detailed tables of the model results are confined primarily in the appendices.

CHAPTER II

FRAMEWORK OF ECONOMIC ANALYSIS

The relevant economic theory and tools of analysis for the projection of product location are discussed in this chapter. Because of the overall objective of making detailed projections for a broad spectrum of agricultural activity in California, this discussion will not be confined to the specific analytical framework required for the dissertation project. Rather, a theoretical and analytical base is established which subsumes the framework required for this study and into which possible additive research projects can also be incorporated in accomplishing that goal.

In the first section of this chapter, the development of general spatial equilibrium theory is discussed. In the second, a model for the solution of general spatial equilibrium type problems is described. Its mathematical development is included as an appendix to the dissertation. The simplifying assumptions required to make the dissertation project computationally feasible are then presented with the specific allocation model used.

General Spatial Equilibrium Theory in Review

The theoretical framework into which this study will be incorporated is that of general spatial equilibrium [57, 63]. This theory has developed through the fusion of two lines of thinking -- neoclassical and location theory. Walras was a master of the first line and provided an analysis for general equilibrium in a multi-product market. Space, however, was not considered variable in his approach. To fill in the spatial gap left by the neoclassical theorists, there evolved a group of economists who became known as location theorists. They considered economic activity in space, but generally in a partial equilibrium framework.

Location Theory

Von Thunen [107] is known as the father of location theory. He concerned himself with the theoretical considerations of the location of agricultural production around a single center of population. His market was treated as a unit isolated from the rest of the world. He made a significant contribution in turning economic thought to include costs of transportation as an important element in the determination of economic activity.

Weber followed Von Thunen with an analysis of spatial evolution from the primitive agricultural society to an industrialized nation. Lefeber [63] credits Hoover [53] with having provided the theoretical framework of the theory of the firm and partial analysis to make Weber's location analysis compatible with contemporary economic theory.

More than a century passed after Von Thunen first pioneered in location theory before any economic theorists made an earnest attempt to broaden location theory to the general case of multi-markets. Losch [65] was the first to create a general system through the fusion of general equilibrium analysis with location theory. Assuming a homogeneous spatial production plane, a uniformly distributed population, and a continuous transportation surface, he derived the concept of economic regions.

Isard [55] followed with a significant attempt to create an analytically useful "... general theory of location " through the synthesis of Weberian thinking with Losch's analysis of market space. He, like Losch, assumed a continuous transportation surface which proved to be a significant obstacle to computational analysis. Being continuous, it is difficult to estimate the transport plane with linear functions which would lend the problem to more convenient solution by electronic computer 1/ [63, pp. 3-6].

1/ For more detail of the contribution of location theorists to a general equilibrium see Isard [55, pp. 27-54].

Neoclassical Spatial Equilibrium

Several neoclassical theorists have likewise given serious attention to the problem of inter-spatial market equilibrium. Their attention has been motivated by the need to broaden the economic tools of analysis through the consideration of transportation between spatially separated markets rather than the derivation of market boundaries over a continuous spatial production plane.

Enke [46] defines the problem the neoclassicists have tackled very clearly: "There are three (or more) regions trading a homogeneous good. Each region constitutes a single and distinct market. The regions...are separated -- but not isolated -- by a transportation cost per physical unit which is independent of volume. There are no legal restrictions to limit the actions of the profit-seeking traders in each region. For each region the functions which relate local production and local use to local price are known and consequently the magnitude of the difference which will be exported or imported at each local price is well known. Given these trade functions and transportation costs, we wish to ascertain: 1) the net price in each region, 2) the quantity of exports and imports for each region, 3) which regions export, import, or do neither, 4) the aggregate trade in the commodity, [and] 5) the volume and direction of trade between each possible pair of regions." He develops a linear mathematical model capable of solution by electronic analogue. His equilibrium solution, however, while including multiple markets, is derived for a single homogeneous commodity only.

Samuelson [80] quickly followed Enke's analytical approach with a significant theoretical development to show that such an approach is consistent with the goal of maximizing "net social payoff". Assuming a constant marginal utility of money, he elegantly proves that for the single product case a static equilibrium can be found in which the "net social payoff" is maximized over all markets. The maximum can be approached by trial and error or by a systematic procedure of varying shipments in the direction of increasing social payoff. The transportation cost between any pair of markets per unit is defined as a constant, and the problem is expressed in a linear programming format. Samuelson points out that with regional supply and demand given, maximizing net social payoff simultaneously minimizes the sum of transport costs.

Beckmann [5] published an article the same year as Samuelson's extending the formulation to consider the case where production and consumption of a commodity take place in each infinitesimally small area over space. This case has much the appearance of the continuous spatial production surface derived by the location theorists. However, if the areas are taken as finite in number, the problem can be inserted into the Samuelson maximization framework. A solution could then be found simultaneously for both the geographic distribution of production and consumption and the geographic pattern of interregional flows.

General Spatial Equilibrium

Following these theoretical developments of single product partial analyses came Lefeber's general, multi-product, spatial equilibrium model in which he fused neoclassical general equilibrium with the contributions from location theory. He focuses "...on the problem of optimal resource allocation and commodity distribution over space, given prices of final goods in different markets or a welfare relation for spatially separated consumer groups " [63, p. 8]. He also develops a general equilibrium framework which determines market prices of final commodities within the system as well as optimality conditions for both producers and consumers.

Lefeber bases his development on the following set of assumptions: 1) There are a fixed number of discrete location points in which both production and consumption can take place, rather than a continuous plane of locational possibilities; 2) each point is endowed with an assortment of productive factors; 3) there is no transportation cost within the region; 4) production of any or all goods can take place at any point assuming that the necessary resources are available at that point or transportable to it; and 5) perfect competition is assumed-- no single firm can affect the price by adjusting its output placed on the market.

Lefeber presents a strong case for the inclusion of transportation as a separate industry into this general scheme. While most theoreticians have assumed that transportation costs per unit are dependent only on the distance between markets, Lefeber insists that transportation needs to be accorded the same respect as any other industry in the analysis. Transportation restraints are important in the short run, and in the long run transport cost per unit can vary significantly based upon the demands placed on it between pairs of regions. Depending on the relative cost of transportation to the value of product and on the cost of establishing new or enlarging old transportation networks, transportation treated as a fixed cost per unit between each pair of regions may be in significant error as a first approximation to the actual cost relationship.

Lefeber concerns himself with three levels of economic determination: 1) allocation of productive factors, 2) distribution of final goods, and 3) choice of production locations. He develops an internally consistent framework for the general equilibrium of a multiple product, multiple factor, and multiple region problem. This framework is finally simplified and expressed in a linear programming format.

A synthesis of various models used in the general spatial analysis of agricultural production and processing is presented by King [57]. The approach, which essentially parallels Lefeber's, is static with the important dynamic problems of growth and technological change bypassed in favor of concentration on spatial aspects. The agricultural sector is specified as to region and products within regions. A general spatial equilibrium framework is specified treating agriculture as if it were the entire economy and its products the various industries within the economy.

Basic assumptions include constant returns to scale for the industry and production points separated from consumption points. The reason for the first assumption is simplification. The size distribution of individual firms need not be considered if constant returns to scale hold because the size of firm is indeterminate. Also the production function can be expressed as a fixed input-output ratio which does not depend upon the output level. The latter assumption is introduced for greater realism. Since production of agricultural goods takes place in the area surrounding population clusters, it is a more reasonable first approximation to assume an intraregional transportation cost. By spatially separating production from consumption in each region, intraregional transportation becomes an explicit condition.

Non-transportable factors, transportable factors, and intermediate products are all introduced into the general framework. Final demand is a function of price. The general spatial equilibrium problem of agricultural products is then couched in an activity analysis framework. The objectives of the framework are to determine the equilibrium location of production and processing, shipments of primary, intermediate, and final products, demand for the non-transportable factors, and prices of each.

A Model of Location

A finite number of relatively homogeneous economic regions can be defined for California agricultural production. Therefore, in the development of the theoretical framework, the static neoclassical general equilibrium system will be generalized to encompass production and consumption in regions separated by transportation costs.

Further, since the location of primary agricultural production, not of processing plants, is the objective of this group of studies, the theoretical development in this section will bypass consideration of intermediate products in the general framework.1/

Agriculture will be treated as a distinct sector, and a general equilibrium will be derived for the products within that sector assuming ceteris paribus in all other sectors of the economy. Thus, the theory will be for a static general equilibrium within a partial analysis framework. The same thing can also be said for any national framework which does not take into account the effect on the national equilibrium of the exports and imports of other nations. Any time some relevant variable is assumed fixed, the result is a partial analysis framework, regardless of the number of variables whose impact is considered endogenously within the system. Therefore, this theoretical development for an intra-sectoral general equilibrium could just as easily apply to an entire economy.

First, the general spatial equilibrium problem will be specified in very general terms and then simplified as necessary to become computationally manageable.

The sets of equations needed include: demand for final products in each region, supply of resources in each region (including both domestic avail-

1/ The interested reader is referred to Lefeber [63, pp. 111-112] or King [57, pp. 36-38] for the inclusion of intermediate products in the framework.

ability and imports -- if applicable), transportation functions for final products and transportable resources, and production functions. Provided that this system of equations meets the requisite conditions for the existence of a unique solution, a general equilibrium theoretically can be found.

The word "theoretically" in the above argument should be emphasized. Even with such assumptions as homogeneous factors and products and well behaved supply and demand functions (i.e. downward sloping demand function, and supply function cuts demand function from below), it may be impossible computationally to determine the general equilibrium without other crucial assumptions such as perfect competition and a finite number of production processes with fixed factor proportions. Without such assumptions, the host of approximations and iterative procedures required to obtain the equilibrium solution in a single-region, single-product case cast doubts as to whether the equilibrium could be achieved in practice in a multi-region, multi-product case.

For the purpose of establishing an analytical framework for this type of study, the assumptions of perfect competition, a finite number of production processes, fixed factor proportions, and constant returns to scale[1/] will be accepted as sufficiently reasonable. The improvement in technical accuracy from relaxing these assumptions would probably not nearly outweigh the computational difficulty added (if the problem would be solvable at all).

With these assumptions, the extension of the Walrasian model by Lefeber becomes entirely adequate to handle the problem. However, since the only sector being considered endogenously within the system is agriculture, transportation costs will be assumed to be exogenously determined, and the quan-

1/ 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.

tity shipped will not affect the per unit cost of transportation.[1/]

Solution by Linear Programming

The location model in Appendix H is expanded from the Walras-Cassel general equilibrium system. The supply-demand equations and the relationship equations between resource and product prices in the original system are replaced by inequalities in the mathematical development. The inequalities place the system in a natural form to obtain the equilibrium solution through the technique of linear programming. This modification also makes the system somewhat more general, since the market will determine which goods are free and which are scarce.

In the linear programming framework indicated in Appendix Tables H.1 and H.2, the resource supply restraints, resource demand equations (derived from the production functions), product demand equations, transportation costs, and unit cost relationships would all be taken into account in deriving the equilibrium solution. The optimum solution of an LP model, based on a profit maximization objective function, is identical to the Walras-Cassel equilibrium solution derived from the same set of inequalities.

The basic primal and dual relationships of linear programming are developed in the appendix. Therefore, they will not be duplicated in this chapter.

An Alternative Method of Solution

The major alternative to linear programming as a method of solution for interregional supply problems is regression analysis. However, the size of this problem, with many production and resource interrelationships, precludes the use of regression analysis as a method of solution. A further feature

1/ It should be noted that this assumption is really made for simplicity sake. 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.

of regression analysis which would be a hindrance to the achievement of the current objectives is that it predicts based on relationships of past time periods, not on what could happen in the future. Policy changes, impact of water projects, and other structural changes which are extremely important in affecting the solution to the problem cannot be taken into account easily by regression analysis. While regression analysis may be a reasonable predictor of response under a continuation of current structure, it becomes a much less accurate predictor in the long run. It seems reasonable that, in the long run, changes in location will tend to approach the profit maximizing position. The linear programming formulation developed above has this optimum as its objective. As a forecaster of regional production and resource allocation, linear programming is often preferred for the long run solution, and regression analysis for the shorter run [4].

Linear Programming Spatial Allocation Models

Because of the very large data requirements and computer demands for a moderate-sized general spatial equilibrium model, some researchers have sought a first approximation through the use of an allocation model. An allocation model implies that either demand quantities are pre-estimated and the demand then allocated among production regions, or production quantities are assumed to be known and allocated among demand markets.

Interregional Grain Production Model

Earl Heady and colleagues have employed an allocation model of the first type in a number of interregional studies of major grain and field crops undertaken at Iowa State University. Because of the practical relevance to this project of the particular model used in the study, Regional Adjustments in Grain Production [44] by Alvin Egbert and Earl Heady, it will be discussed briefly here.

Their general objective was to determine the most efficient pattern of grain production in the United States which would satisfy annual requirements. The basic assumptions for the structure of the grain economy included the following: 1) production regions, with many individual producers having the same production alternatives, are spatially separated; 2) all producers in a region have identical input-output coefficients; 3) constant returns to scale exist; 4) the only restricting resource is land; 5) each producer seeks to maximize his profits; 6) quality is uniform; and 7) consumption requirements are exogenously determined by annual per unit requirements at a point in time [44, pp. 5-6].

It is the final assumption which dictates that an allocation model is to be used instead of a general spatial equilibrium framework. This assumption says that demand is independent of the prices that are generated by the allocation model solution (i.e., demand is assumed perfectly inelastic with respect to price).

Heady et al. generally use a cost minimization linear programming framework to simulate equilibrium production location conditions. With demand predetermined, solutions generated from a cost minimization model are identical to those of a profit maximization model [45, p.12]. The intuitive appeal of this argument is obvious. If the quantity of each commodity to be demanded at equilibrium prices is known before production occurs, minimizing total cost of production will simultaneously maximize total profits.

Egbert and Heady further simplify the general spatial equilibrium problem by assuming a single, central demand point, and, in most of their models, they assume zero transportation costs between points of production and point of demand.

California Spatial Allocation Model

Linear programming spatial allocation models similar to the Egbert-Heady model will be used to achieve most of the research objectives of this study. This section of the chapter will be directed to the specific models to be used. The mathematical framework is presented first, followed by the detailed model assumptions, and finally by the specific structural differences between the five analytical models of this form developed.

Mathematically stated. In mathematical form, the linear programming primal problem is as follows:

minimize total nonland cost of production =

$$\sum_{i=1}^{r} \sum_{j=1}^{s} \sum_{k=1}^{t} C_{ij}^{k} \; X_{ij}^{k} \tag{2.1}$$

subject to restraints on

(1) Output

$$\begin{aligned} &\sum_{j=1}^{s} \sum_{k=1}^{t} A_{1j}^{k} \; X_{1j}^{k} \geq D_1, \\ &\quad \vdots \\ &\sum_{j=1}^{s} \sum_{k=1}^{t} A_{rj}^{k} \; X_{rj}^{k} \geq D_r, \\ &\sum_{j=1}^{s} \sum_{k=a}^{d} A_{hj}^{k} \; X_{hj}^{k} \geq D_m^{a}, \\ &\sum_{j=1}^{s} \sum_{k=g}^{h} A_{nj}^{k} \; X_{nj}^{k} \geq D_n^{g}, \end{aligned} \tag{2.2}$$

(2) Production area acreage

$$\begin{aligned} &\sum_{i=1}^{r} \sum_{j=1}^{s} X_{ij}^{1} \leq L^{1} \\ &\quad \vdots \\ &\sum_{i=1}^{r} \sum_{j=1}^{s} X_{ij}^{t} \leq L^{t}, \end{aligned} \tag{2.3}$$

(3) Irrigated acreage

$$\sum_{i=1}^{r} \sum_{j=1}^{s-2} X_{ij}^{1} \leq I^{1},$$

$$\vdots \qquad (2.4)$$

$$\sum_{i=1}^{r} \sum_{j=1}^{s-2} X_{ij}^{t} \leq I^{t},$$

(4) Individual crop acreage (rotation requirements)[1/]

$$X_{11}^{1} \leq R_{11}^{1},$$

$$\vdots \qquad (2.5)$$

$$X_{rs}^{t} \leq R_{rs}^{t},$$

(5) Relative regional cotton acreage (in Model 1980D only)

$$\sum_{j=1}^{s} \sum_{k=1}^{b} X_{pj}^{k} + B \sum_{j=1}^{s} \sum_{k=e}^{f} X_{pj}^{k} = 0, \qquad (2.6)$$

(6) Nonnegative input usage

$$X_{ij}^{k} \geq 0; \qquad (2.7)$$

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 ($I^k \leq L^k$),

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1/ Also quality restraint on potatoes in the San Joaquin Delta.

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

B is $= \dfrac{\text{San Joaquin Valley cotton allotment}}{\text{Southern California cotton allotment}}$,

a, ..., b are San Joaquin Valley areas,

a, ..., d are Central Valley areas,

e, ..., f are Southern California areas ($0 \leq a, b \neq e, f \leq t$),

g, ..., h are mountain valley areas,

m is dry beans,

n is potatoes,

p is cotton,

1, ..., s-2 are irrigated production processes,

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

The objective function of each model is to minimize the total nonland cost of producing a minimum quantity of each output subject to the availability of nontransferrable resources in each production area. To minimize nonland production costs is to produce that minimum quantity most efficiently in the absence of transportation costs. In a perfectly competitive environment, profits to individual producers for supplying that specific level of output would be maximized simultaneously.

In addition to the requirement that the model allocate resources among production processes in nonnegative quantities, three types of production area resource restraints are identified in all models. These include total cropland, irrigated acreage, and individual crop acreage. Total cropland restraints limit the maximum aggregate acreage of all crops in a production area. Irrigated acreage restraints are the maximum acreage for which water is estimated to be available on a perennial basis and limit the acreage of all irrigated activities in an area. The restraints on individual crop acreage are specified because of the need to rotate crops.

In one of the projection models, Model 1980D, the relative distribution of cotton acreage among regions is specified. The purpose of this restraint is to estimate the effect on the model solution of continuing the current cotton allotment program.

The dual problem to the primal just specified appears as follows:

maximize returns to fixed resources =

$$\sum_{i=1}^{r} \sum_{j=1}^{s} \sum_{k=1}^{t} (U_i D_i + V^k L^k + W^k I^k + Y^k_{ij} R^k_{ij}) + Z_p \cdot 0 \qquad (2.8)$$

subject to

Imputed value per acre of output less rents to fixed resources equals per acre nonland costs

$$A^k_{ij} U_i - V^k - W^k - Y^k_{ij} + Z_p \leq C^k_{ij}, \qquad (2.9)$$

Imputed product price and resource rents are nonnegative

$$U_i, V^k, W^k, Y^k_{ij} \geq 0, \qquad (2.10)$$

Imputed value of an additional cotton allotment acre in the San Joaquin Valley is unconstrained (in Model 1980D)

$$Z_p \lesseqgtr 0; \qquad (2.11)$$

with additional notation required

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

Z_p is the imputed rent to an acre of cotton allotment in the San Joaquin Valley (in Model 1980D only).

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.

In setting up the dual form of this problem, the equal to or less than inequalities in the primal are multiplied by (-1). This transformation is required in order that the imputed value of each resource and product in the dual be nonnegative.[1/] However, there is no way to assure that the shadow price of an equality is nonnegative. For example, in the case of the cotton allotment equation, the imputed value will be positive if the next unit of cotton can be produced less expensively in the San Joaquin Valley than in Southern California, negative if the reverse is true, and zero if the marginal cost is the same in both regions.

Model assumptions. Although simplifying assumptions necessarily limit a model's usefulness as a simulation of the real world, certain assumptions are necessary to make the study computationally feasible. The particular assumptions upon which the programming models are developed may not exactly describe the field and vegetable crop industries in California. However, they permit the use of models which are sufficiently comprehensive and detailed to be consistent with the objectives of this study.

The following specific assumptions with regard to the structure of the field and vegetable crop industries in California were made:[2/]

1. There are N unique, spatially separated but interdependent production areas with many producers of field and vegetable crops.

1/ Actually, the specific computer algorithm used lists imputed product prices as negative values, as evidenced in Appendix Table G. 12.

2/ The reader may wish to compare these assumptions with those of Heady and Egbert [44, p. 6].

2. Unless exogenously projected to produce crops not included in the study, all producers in a specific area have only the choice of producing the same commodities, and quality is uniform between areas.1/

3. A finite number of production processes is specified for the production of any commodity.

4. All producers in a specific production area have identical input-output coefficients for each production process.

5. Input-output coefficients are constant within the relevant range.

6. Total production in each area is limited only by the net acreage available to the model crops.

7. Total production of irrigated crops in each area may be limited by a restraint on irrigated acreage.

8. Production of an individual commodity in any area may be limited by a rotational requirement.

9. Governmental programs, location of processing plants, and other institutional factors do not directly affect either California's

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1/ Two additional restraints will be imposed on all models due to evidence challenging the realism of the latter part of this assumption:

(1) The lower quality of potatoes produced on peat soils in the otherwise high yielding San Joaquin Delta area limits its disposition to the seed market. Acreage in this area is restrained at a maximum of 10,000 acres in all models.

(2) 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.

share of U.S. output or production patterns within California, with the exception of Model 1980D.[1/]

10. The economic objective of each producer is profit maximization.
11. The system is static in that consumption must be met from current production.
12. There is only one center of demand.
13. Transportation cost between points of supply and point of demand is zero.
14. All producers face the same set of product and resource prices, except that water prices vary by production area.
15. Total output requirements are exogenously determined.
16. One crop per year can be harvested on each parcel of land, with the exceptions that a crop of nonirrigated barley can be harvested only once in two years in some production areas, and certain double cropping activities (viz., barley-grain sorghum, broccoli-lettuce, and lettuce-lettuce) are possible in other areas.

Structure of alternative models. Five specific LP models will be developed for use in this study.[2/] One model is constructed to determine optimum locations of production in the base period, 1961-65, in the absence of governmental programs. The output levels, resources available after consideration of urban and excluded crop requirements, and variable cost and yield parameters for the model crops are estimated for this period. The other four models are for the projected year, 1980.

The differences between 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; viz., to minimize total nonland production

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1/ A regional cotton allotment restraint is imposed in Model 1980D.
2/ The abbreviation "LP" will be used periodically for "linear programming."

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 crop land in 1980.

In one of the 1980 models, minimum California output is projected to be the same share of U.S. output as in the base period. In another, historical trends in the share supplied by California are taken into account in projecting 1980 output constraints. In the third model, output levels are the same as in the second. 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. In the final model, the structure of the third is retained except for the addition of a regional cotton allotment restraint. With a continuation of the cotton allotment program, output levels of cotton and safflower projected for this model are different than those projected for the previous one. The basic structure of each model is summarized in Table 2.1.

The specific crops included in the study are the same in each model. Since there are more than 100 different field and vegetable crops grown in California with many thousand forms and varieties, it is clearly beyond the scope of this dissertation to consider each separately. Therefore, only those crops will be included which are most important in acreage or value of production to the economy of California. Those commodities which have sufficiently similar production requirements and/or demand structure will be grouped and represented in discussion by the most important crop.

TABLE 2.1

Structure of Alternative Dissertation Models

Model	Restraint					Yields	Production costs
	Total acreage	Irrigated acreage a/	Individual crop (rotation)	Regional cotton allotment	California output		
1961-65	Circa 1961-65	Circa 1961-65	Circa 1961-65	No	1961-65	1961-65	Circa 1961-65
1980A	1980	"	1980	"	1980 U.S.; 1961-65 California share	1980	1980
1980B	"	"	"	"	1980 U.S.; California share projected from recent trends	"	"
1980C	"	"	"	"	Same as Model 1980B except single feed grain restraint	"	"
1980D	"	"	"	Yes	Same as Model 1980C except for cotton and safflower	"	"

a/ Restraint imposed at less than total acreage only in those areas where water availability in 1980 is expected to be a primary restriction on agricultural expansion. In each such case, the restraint is set at recent irrigated acreage.

No distinction will be made between alternative marketing outlets, such as fresh and processing markets for vegetables. The crops to be included in the study represent 91 percent of 1966 acreage and 83 percent of 1966 value of production of field and vegetable crops [10, 14].

The specific crops included in this study, together with the representative crop of each group and the model crop activities, are identified in Table 2.2.

The parameters required in the various models are developed in the succeeding chapters. The production areas are delineated in Chapter 3, the model resource restraints relating to these production areas are developed in Chapter 4, the cost and yield estimates in Chapter 5, and the State output restraints in Chapter 6.

TABLE 2.2

Study Crops, Representative Crops, and Model Production Processes

Study crop	Representative crop	Model crop activity (production process)
I. Vegetable crops:		
Asparagus	Asparagus	Asparagus
Cole crops:		
Broccoli	Broccoli	Broccoli (single crop)
Brussels sprouts		Broccoli & fall or spring lettuce (double crop)
Cauliflower		
Lettuce, spring & fall	Lettuce, spring & fall	Lettuce, fall or spring (single crop)
		Lettuce, fall & spring (double crop)
		Lettuce, fall or spring & summer (double crop)
Lettuce, summer	Lettuce, summer	Lettuce, summer (single crop)
Lettuce, winter	Lettuce, winter	Lettuce, winter (double crop)
Melons, spring & fall:	Cantaloupes, spring & fall	Cantaloupes, spring & 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		

--Continued on next page.

Table 2.2--continued.

Study crop	Representative crop	Model crop activity (production process)
II. Field crops:		
Corn:	Corn for grain	Corn
for grain		
for silage		
Small grains:		
Barley	Barley	Barley (fallow)
Oats		Barley (nonirrigated)
Wheat		Barley (irrigated, single crop)
		Barley & grain sorghum (irrigated, double crop)
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

CHAPTER III

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-- specifically soil and climate and, incidentally, 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.[1/] By stratifying the data according to resource endowment, attention is focused on spatial differences in nontransferable factors affecting yields and production costs.

This concept is similar to that used by Whittlesey and Heady in their national interregional competition model of seven field crops. They delineated 144 producing areas "... along county lines to form regions that are relatively homogeneous with respect to climate, historical yields, and production costs" [110, p. 103]. In one model, they also divided the cropland within each region into three groups reflecting differences in productivity. It is a desirable objective to follow such administrative boundaries 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. But while Whittlesey and Heady may have been able to achieve a degree of homogeneity in yields and production costs by adhering to county boundaries, it is not possible in this study. 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 or with deficit water supply. For example, San Diego County has land in four major plantclimate zones, ranging from

1/ The problem of aggregation bias is discussed in the next section.

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 much 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 will be sought through the analysis of general soils maps and plantclimate studies in the delineation of HPAs.

No other elements of the agricultural environment will be differentiated spatially.1/ It is for these areas that land, rotation, and water restraints and cost and yield estimates are relevant.

In the following section, the method used to delineate HPAs is defended as a means of effectively limiting aggregation bias. The remainder of the chapter 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 [36], Miller [66], Lee [62], and others [82, 49, 3] have dealt with the problem of aggregation bias in linear 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. They are the following: 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 in light of these criteria in the paragraphs below.

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

The unit price vector of nonrestrictive resources to one farmer in each HPA may not be greatly different than to another farmer. Farms within

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1/ Water availability is also considered indirectly in this delineation. See the last section of this chapter for an explanation.

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.1/ 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

1/ In several economies of size studies conducted on California field crop farms, it has been observed that few additional internal economies are possible as farms become larger than 600-1000 acres [38, 68, 47]. The 1964 Census of agriculture reports that two-thirds of field crop output in California is produced on farms which are larger than 700 acres in size [104, pp. 94-105].

resources are not normally restricting in actual practice. Adequate credit facilities are available, labor can be hired, and machinery often exists in excess capacity in relation to the amount of land available [40].1/ 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 micro-classification of soils by soil series.

In the early 1950's, Storie and Weir published a report entitled Generalized Soil Map of California [88] which depicted the general soil geography of the entire state. They based their report on an analysis of then current detailed and reconnaisance soil surveys and grouped individual soils into eighteen major categories. They rated each category according

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1/ 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 follows: 1) it should be possible to purchase adequate managerial talent if not already available on specific farms; 2) even if the current cotton allotment program is continued, allotments can be transferred from one HPA to another, through land sales or rentals, so that acreage allotments are not an effective restraint to production on individual units.

to its "...general land use suitability for commercial timber, grazing, nonirrigated field and truck crops, and irrigated field and truck crops" [88, p.1]. Subsequently, additional work was done on the general soil map, the number of categories were expanded, and the map, acreage, land use suitability, and Storie-Index rating were reported for each county in a manuscript as yet unpublished [87].

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 at the inception of this study. 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 Dr. Storie and Mssrs. Eugene Begg and Gordon Huntington,[1/] Storie's soil classes were grouped into thirteen agricultural soil categories. In terms of physiographic groupings, four alluvial (numbered 01, 02, 03, and 05), five basin (11-15), and four terrace soils (21-24) make up the thirteen categories.[2/] A description of typical soils in each category can be found in Table 3.1.

1/ Soils specialists in the Department of Soils and Plant Nutrition, University of California.

2/ With minor exceptions, upland soils are not suitable for cultivated agriculture; hence, they are excluded as a group from this study.

TABLE 3.1

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.

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Table 3.1 (continued)

Soil characteristic	Basin soil number				
	11	12	13	14	15
Typical soil series	Egbert	Sacramento Tulare Pit	Levis Willows	Fresno Traver	Fresno Traver Lahanton
Depth	Very deep	Very deep	Very deep	Moderately deep-deep	Moderately deep-deep
Profile development	Without	Without	Without-minimal	Minimal-medial	Minimal-medial
Texture: surface	Organic medium	Moderately fine-fine	Fine	Medium-moderately coarse	Medium-moderately coarse
subsoil	Organic	Fine-stratified	Fine	Moderately fine-medium	Moderately fine-med.
Drainage	Poor	Somewhat poor-poor	Poor	Moderately well	Somewhat poor
Salts or alkali	Free	Free-slight	Moderate-strong	Free-slight	Moderate-strong
Reaction: surface	Moderately acid	Varied	Slightly alkaline	Slightly alkaline	Moderately alkaline
subsoil	Slightly acid	Moderately alkaline	Moderately alkaline	Moderately alkaline	Moderately alkaline
Lime present? surface	No	No	No	Yes	Yes
subsoil	No	Yes	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

--Continued on next page.

Table 3.1 (continued)

Soil characteristic	Terrace soil number			
	21	22	23	24
Typical soil series	Ramona Tehama Rohnerville	Porterville Denverton	Huerhuero Hillgate Bieber	San Joaquin Redding
Depth	Deep	Deep	Shallow	Shallow
Profile development	Medial	Without	Maximal	Maximal
Texture: surface subsoil	Medium-moderately coarse Moderately fine	Fine Fine	Medium Fine	Medium-moderately coarse Fine
Drainage	Moderately well	Well	Moderately well	Moderately well
Salts or alkali	Free	Free	Free	Free
Reaction: surface subsoil	Moderately acid Slightly acid	Neutral Moderately alkaline	Moderately acid Moderately alkaline	Moderately acid Slightly acid
Lime present? surface subsoil	No No	No Yes	No Yes	No No
Storie Index rating	50-80	40-60	35-50	15-35
Occurrence	General	Central Valley and South Coast	General except Desert	General except Desert & Mountain valleys
Comments		Clay terrace soils	Claypan	Hardpan

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 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. SCS general soil reports [98] were used for Napa, Solano, Sonoma, Stanislaus, Yolo and Yuba counties. The general soil maps published in recent soil surveys were used for Glenn and Tehama Counties [7, 50] and a portion of Alameda County [109]. A reconnaisance soil survey was used for Sutter County [51]. Mr Alan Carlton[1] modified the map for San Joaquin County from more recent data. Mssrs. Begg and Huntington recommended modifications in several other counties. County farm advisors and agricultural commissioners provided estimates of the acreage of land classified by Dr. 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

1/ Soils specialist in the Department of Soils and Plant Nutrition, University of California.

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 of lesser importance, except where the seasonal distribution is such as to cause plant damage or where it is so sparse that the cost of irrigation water becomes prohibitive.

In a 1959 issue of California Agriculture, Kimball and Brooks published a preliminary mapping of sixteen plantclimate zones in California in which areas with similar effective day and night temperatures were grouped [56, pp. 9-10]. It should be noted that while 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 [43, p.8]. Several of these factors will be recognized as also affecting 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 in 1967 in Sunset Western Garden Book [43, pp. 17-27]. In that publication, the State was divided into nineteen zones for the benefit of the home gardener. In consultation with Mr. Kimball and Dr. DeWayne E. Gilbert, his successor, it was advised that the basic plantclimate delineations published in Sunset be 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 nineteen plantclimate zones which are depicted in Figure 3.1 and described briefly in Table 3.2.

For purposes of presenting the findings of this study, the nineteen climates have been grouped into nine regions (identified by the first digit of the climate code) which, with one exception, follow plantclimate 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 twenty, rather than nineteen, 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, which we shall refer to as homogeneous production areas.[1/] Their locations are identified in Appendix A. The acreage of each HPA was determined by planimetering.

After the projected 1980 acreage of land in urban, extra-urban, semi-agricultural and non-model crop use was calculated, twenty HPAs, including one entire climate, 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 ten thousand 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

1/ 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.

FIGURE 3.1

Plantclimate Zones

TABLE 3.2

Description of California Plantclimate Zones
[43, pp. 9-26; 56, p. 12]

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°; typical mean daily minimum in January, the coldest month, is 41°.
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°; typical mean daily minimum in January is 33°.
21	Marine influence dominates this Central Coastal climate 98 percent of the time. There are virtually no frosts. Typical mean daily maximum temperatures in September range from 67° to 72°; typical mean daily minimum in January is 42°. Fog reduces sunshine intensity. Humidity is high.
22	This Central Coastal climate is dominated by the ocean 85 percent 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° in different parts of the climate.
24	See climate zone 51 for description.
31	This mild South Coastal climate is almost completely marine dominated. Humidity is high. Record low temperatures range from 20° to 33° in different parts; record highs average 105°.
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 percent of the time. Record lows range from 17° to 20°.
33	Cold winter portions of the South Coast are included in this zone. Marine domination in this climate also varies from occasional to 85 percent of the time. Record lows range from 14° to 24°; record highs average 112°.
34	This climate comprises Southern California's interior valleys and terraces. The continental air mass dominates the climate at least 85 percent of the time. Humidity is low. Record lows range from 7° to 23°; record highs average 115°.

--Continued on next page.

Table 3.2 (continued)

Zone	Description
41	The Sacramento Valley floor is characterized by a long growing season and almost constant sunshine during it. The growing season is shorter, due to later spring and earlier fall rains, and the humidity higher than in the San Joaquin Valley (climates 61 & 62). Record lows for climates 41, 61, and 62 combined range from 13° to 18°; record highs range from 104° to 116°.
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°; 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 quite 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° 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°; record highs range from 114° to 117°. There are more than 110 days each year when the temperature exceeds 90° and 80 nights when the temperature drops below 32°.
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°; mean daily maximum temperatures in July range from 106° to 108°.

--Continued on next page.

Table 3.2 (continued)

Zone	Description
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°.
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.

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, nineteen HPAs would have been excluded. By applying the supplementary rules, three more HPAs were deleted and two of the nineteen 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. 3. 1/

With the HPAs identified, the next two chapters will deal with obtaining relevant resource restraints and cost and yield estimates for each of these areas.

1/ The climate zone dropped was zone 33 which had a projected 1980 acreage of less than 13,000 acres.

CHAPTER IV

LAND, WATER, ROTATION, AND ALLOTMENT RESTRAINTS

Five types of restraints are identified in Chapter 2 for inclusion in one or more of the LP models. The development of four of these, all of which restrict the acreage of all or part of the crop activities in specific areas, are discussed in this chapter. In the first section, the method of estimating the total acreage available in 1965 and in 1980 for model crop activities is presented. In the second, specific restraints on the sum of all irrigated crop activity acreage are developed. Rotation restraints on the acreage of individual crop activities are developed in the third. And the fourth section is devoted to the relative regional cotton allotment restraint to be used in Model 1980D.

Land Restraints

The procedure used to estimate the HPA acreage restraints on model crop activities may be referred to as residual resource inventorying. From the total inventoried acreage is subtracted acreage estimates for land uses assumed to return a higher marginal value product to a limited number of land units than the model crops. Land uses for which acreage is to be deducted from the total include all urban, extra-urban,[1/] and semi-agricultural uses,[2/] and production of orchard, vineyard, and excluded vegetable crops. Land required for each of these uses is exogenously estimated and subtracted from the total HPA acreage. The residual is

1/ The extra-urban category includes public roads, military reservations, parks, etc.

2/ Includes farmsteads, farm roads, canals, feedlots, typical crop failure, and forced idle land.

entered into the model as an upper acreage constraint on the sum of all model crop activities.

Urbanization

Recent estimates of urban land use in California vary from 2,000,000 [79, pp. 46, 48] to 2,400,000 acres [9, p. 46]. Projections from additional urban land requirements during the next decade range from less than 700,000 to more than 1,000,000 acres [79, p. 48]. In order to adequately assess the impact of urban expansion on agriculture, these projections must be disaggregated in terms of HPAs.

Urban economists have developed a number of theories for explaining the process of urban agglomeration and expansion [2, 78, 79]. While some emphasize transitions within the urban sector, others concentrate directly on the issue of expansion onto nonurban land. From the theories of urban expansion, a few points stand out which are of value in quantifying urban land requirement by HPA. Three theorists, Ruth, Krushkov, and Rao, agree that the primary variable determining total new land required is the rate of population growth [78, p. 21; 79, p. 17]. Ruth and Krushkov 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 [79]. None stress the alternative value of land for agricultural uses as a significant variable affecting which land is developed. Assuming that the value of land for agriculture is insignificant in determining urban expansion, the latter can be projected without consideration of any resultant agricultural adjustments.

Population projections have been published by the California Department of Finance [15, p. 3] for each county in California for five-year intervals to 1985. These projections are based on U.S. Bureau of the

Census fertility series D[1/] [103] and net in-migration to California of 300,000[2/] persons per year. There have been no comprehensive projections made for sub-county units in the State. The urban land projections used in this study will be based on the Department of Finance population projections.

Urban counties. Projections of gross urban land requirements in California, or a major subregion within California, have been developed by a number of researchers to target dates in the decade 1970-80 [9, 78, 79]. However, only one of these studies made projections for county and sub-county units within the State [79]. The authors, Ruth and Krushkov, undertook an elaborate and sophisticated study of urban land expansion in 25 urban counties of California between 1950 and 1964. The research procedure included measurement from aerial photographs of actual developed land for the two points in time, analysis of a host of general and local explanatory variables, testing of several alternative equations, and a projection of urban land requirements for the period 1965-75 for 188 urban submarkets. It is this study which will be used as the basic reference for projecting urban land requirements by HPA for 1980.

1/ Series D is the lowest of the fertility rates used in 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 U.S. However, in 1966 and the early part of 1967, actual performance in California fell somewhere between C and D [15, p. 1]. Reliance on Series D in these projections is based on the assumption that the fertility rate will continue to decline.

2/ During the decade 1950-1960, the annual net civilian in-migration to California averaged approximately 340,000 persons. Recently the rate has been lower. These projections assume that within a few years the level will converge to 300,000 persons [15, p. 1].

The authors employed preliminary Department of Finance 1975 population projections which allocate 92 percent of net population growth in the State to these 25 counties. The most important determinant of new land required per additional person during the period 1950-64 was found 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 and are shown below[1/] [79, p. 19]:

primary urban equation

$$\log_e dL_{10} = -4.51767 + .802238 \log_e dP_{10},$$

and extensive equation

$$\log_e dL_{10} = -5.76868 + .791069 \log_e dP_{10},$$

where

dL_{10} is land increase in ten years in hundreds of acres, and

dP_{10} is population increase in ten years.

The density of new persons per additional acre of land which was estimated by the sum of 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 Krushkov deviated about this "median" projection path when pattern variables were analyzed. With the inclusion of four pattern variables[2/] into the equations, R^2 values of 99.4 for the primary urban category and 97.4 for the extensive category were achieved.

1/ Primary urban uses include single and multiple family residential units, commercial, industrial, stock yards, docks, and related developments. Extensive urban patterns consist of highways, airports, cemeteries, schools, railroad yards, residential estates, parks, etc.

2/ The authors do not explain precisely what these pattern variables are.

<u>Extension of Ruth-Krushkov projections to 1980</u>. The only variable in the Ruth-Krushkov prediction equation for which county estimates could be obtained for 1980 was projected population growth. In the absence of data for the pattern variables, 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. The equation derived is:

$$\log_e dL_{15} = .26007 + .78845 \log_e dP_{15}, \tag{4.1}$$

where

dL_{15} is primary and extensive land increase in 15 years in acres,

and dP_{15} is population increase in 15 years.

The urban land requirements, 1965-80, estimated from the above equation, 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 4.1). 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 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 estimates projected 1) from the population growth variable only, and 2) from 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 Krushkov. Such a procedure rested on

TABLE 4.1

Comparison of 1965-75 and 1965-80 Urban Projections for 25 Urban Counties

Item	Unit	Ruth-Krushkov 1965-75	Extension of Ruth-Krushkov 1965-80
Total population growth	persons	5,526,963 a/	7,279,300
Average annual population growth	persons	552,696	485,287
Urban land requirements	acres	615,660 b/	830,086
Marginal population density	persons/acre	9.0	8.8
Ratio: 1965-80/1965-75 urban land requirements			1.348

a/ [79, p. 21] -- preliminary Department of Finance projections.

b/ [79, p. 3] -- corrected sum.

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, and 2) pattern variables in each county have the same relative effect on urban land required per person between 1975-80 as between 1965-75. The 1965-80 county urban land requirement was in turn distributed among the urban submarkets in the same proportion as in the 1965-75 period.1/

Generalization of urban projections to HPAs. A large percentage of the urban submarkets overlap HPAs. Since the urban submarkets are the smallest geographic units for which urban projections have been made, a working procedure for generalizing submarket projections to HPAs is required. This working procedure must include 1) a method of distributing urban projections among urban units in a submarket, and 2) a system for predicting where expansion will take place relative to the existing urban unit.

Maps were secured on which Ruth and Krushkov had delineated actual 1964 urban boundaries (as distinct from city limits) for each urban unit within a submarket. Current location, shape, and approximate size of each urban unit was thus available as data.

For the first part of the working procedure, the hypothesis is made that all urban units within a submarket encroach additional land at the same rate (e.g., 3 percent per annum) regardless of the absolute level of

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1/ The only exception to this procedure was faced when all of the developable land within five miles of the urban fringe [79, App. C-3] would be exceeded. In this case, the working assumption of the authors 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.

current urban land use. To see if the base period level of urban land use is a significant variable in explaining past rate of urban growth, county urban acreage data for 1950 and 1964 are used as proxy variables for the urban unit data. Two variables are defined: the independent variable, L_1, is 1950 county urban acreage, and the dependent variable, R, is the 1950-64 rate of expansion relative to 1950 urban land ($R = \frac{L_2 - L_1}{L_1}$, with L_2 being 1964 county urban acreage). A linear equation is specified:

$$R = a + bL_1. \tag{4.2}$$

The least squares estimates for a and b are as follows:

$$a = .3815,$$
$$b = 6.2 \times 10^{-7}.$$

The t value for b is .0708 which is not significantly different from zero at the 10 percent level. There is not a linear relation between 1950 county urban acreage and the rate at which additional land is urbanized between 1950-64 with respect to that acreage. Therefore, it seems appropriate to specify that urban units enroach additional land at a uniform rate in all regions.

For the second part of the working procedure, we will assume that all urban expansion is contiguous to existing urban units and that the relative propensity to develop is the same in all directions.[1/] These assumptions tie the expansion projection procedure employed in this study most directly to the concentric expansion model of classical urban development theory.[2/] Warren Farrell [48, p. 13] emphasizes that two alternative

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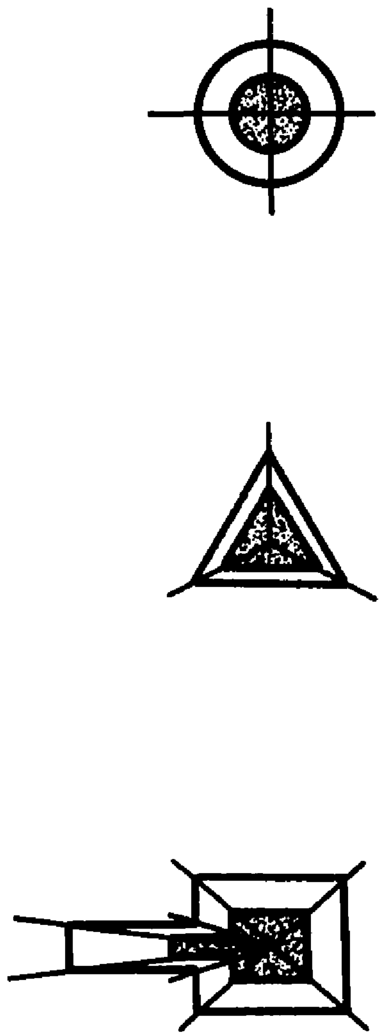
1/ This concept is illustrated in Figure 4.1.

2/ 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.

FIGURE 4.1

Basic Patterns of Contiguous Urban Expansion
With Equal Propensity to Expand in
All Directions



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" [48, p. 11].

Nonurban counties. Detailed urban land projections are unavailable for California counties not in the Ruth-Krushkov study. However, population has been projected to 1980 by the State Department of Finance [15, p. 3] for these counties also. In addition, the 1960 population and estimated acreage in individual cities, unincorporated towns, and counties has been published by the Bureau of the Census [102].

The following assumptions provide the framework for projecting 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 of unincorporated towns, reported by the Bureau of Census [102] are reasonable estimates of actual 1960 urban population and acreage in built-up uses.
2. Population in 1980 will be distributed among urban and rural sectors in the same proportion as in 1960.
3. The population in the rural sector is directly involved with farming.[1/]

1/ This assumption permits all developed land requirements for the nonurban sector to be accounted for in the semi-agricultural land requirements section to follow.

4. Urban population in 1980 will be distributed among towns (incorporated and unincorporated) in the same proportion as in 1960.
5. The urban density of people per unit of land in 1980 will be the same as the 1960 county average for towns having a population of at least 1,000 persons.
6. Urban expansion is contiguous to existing towns.
7. The propensity to expand on land is uniform in all directions.

Urban projections. Urban land in 1964, urban land requirements, 1965-80, and projected 1980 urban land for the State are recorded in Table 4.2. These figures are identified according to urban and nonurban counties. A detailed listing by HPA is provided in Appendix Table B.1.

Extra-Urban Land Uses

The term "extra-urban land use" is used in this study to refer 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 supplied 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.

TABLE 4.2

Urban Land Requirements (circa 1965-80)

Item	Circa 1964 acreage a/	Land requirements (circa 1965-80) b/	Projected 1980 acreage
	1,000 acres		
Urban counties	1,860	858 c/	2,718
Urban land in HPAs	1,455	747	2,202
Urban land not in HPAs	405	111	516
Nonurban counties	171	82	253
Urban land in HPAs	144	72	216
Urban land not in HPAs	27	10	37
State total	2,031	940	2,971
Urban land in HPAs	1,599	818	2,418 d/
Urban land not in HPAs	432	121	553

a/ Urban acreages for the nonurban counties and area outside urban submarkets in the urban counties are for 1960.

b/ Land requirements for the nonurban counties and area outside urban submarkets in the urban counties are for the period 1961-80.

c/ This figure is higher than the urban county projection recorded in Table 4.1; urban land requirements outside the urban submarkets are also included in this figure.

d/ Computed from unrounded data.

The current mileage in public roads outside of cities is published for each county in the California Statistical Abstract [31, 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 from the California Division of Highways [16]. Projected 1980 mileage of State highways was also obtained from the same source.1/ A 15 percent increase in State highway mileage between 1966 and 1980 is projected.

The 1980 acreage of roads by production area is projected according to the following set of assumptions:

1. The mileage of county maintained roads will remain constant between 1966 and 1980.
2. The mileage of State highways will increase consistent with the Division of Highways projection.
3. Acreage per mile of each type of road will remain constant.
4. Acreage per mile of each type of road is the same in each county.
5. Mileage of roads will be distributed among HPAs within a county in 1980 in the same relationship as in 1966.

Total 1980 extra-urban acreage in HPAs is projected at 804,000 acres. A detailed listing by HPA can be found in Appendix Table B.2. Acreage estimates were tabulated for 1966 also, but they differed very little from the 1980 projections.2/ Hence, only the latter are included in the appendix.

1/ Verbal estimation by Thomas E. Whaley, Supervising Highway Engineer.

2/ According to assumption, the only component that differs between 1966 and the 1980 projection is State highway acreage. Estimated differences for this component rarely exceed 1,000 acres for any HPA.

Semiagricultural Demands

Having inventoried the total land resources in each HPA and subtracted requirements for nonagricultural land uses, the residual may be termed "gross acreage for agriculture." It is apparent that 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 will be lost due to crop failure or ownership inflexibilities (i.e., estate transfer, operator illness, etc.). Since 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 [104, p. 7] reports that "Crop Failure" plus "Other Land"[1/] accounts for 11 percent of the total land available for agriculture. "Idle Cropland" accounts for nearly 5 percent more.

1/"Other land" in the 1964 Census includes the above stated uses plus wasteland and excepting crop failure and ownership inflexibilities.

The California Department of Water Resources assumes in their land use surveys that approximately 8 - 10 percent of gross field crop acreage and 4 - 5 percent of vegetable and orchard crop acreage is taken up by farmsteads, farm roads, and miscellaneous uses.[1/]

As an arbitrary standard in this study, 10 percent of gross agricultural land in each HPA is assumed to be required for uses incidental to net agricultural production. The circa 1965 acreage adjustments from gross to net agricultural acreage are recorded for each HPA in Appendix Table B.2. The 1965-80 change in semiagricultural land is grouped with 1965-80 urban and excluded crop requirements in a single category in that table also.

Orchard and Vineyard Crops and Excluded Vegetables

The final step in deriving net model acreage restraints is to subtract from net potential cropland 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 study crops.[2/]

The procedure involved 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.

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 emphasis

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1/ Verbal estimation by Fred E. Stumpf, Associate Land and Water Use Analyst.

2/ In deriving the net model acreage restraints, requirements for pasture and range are not also subtracted from net potential cropland. 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 study crop location patterns are determined.

on 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 has been inventoried.

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

These data, stored on some 170,000 computer cards, were secured and summarized by 7-1/2 minute quads within counties for the excluded crops. For a few counties, quad data could not be obtained. In these, the most detailed land use data available were used. A preliminary inventory for seven agricultural areas in Monterey County had been conducted by the Department of Water Resources. For four other counties, quad data were unavailable or unusable -- Imperial, San Diego, Modoc, and Lassen. County totals were used for these counties.

Because the quad and other areal boundaries do not correspond exactly with HPA boundaries, a set of decision rules is necessary to allocate crops when the inventory boundaries overlap HPAs. Refer to Table 4.3 for a listing of soil and climate priorities for the allocation of irrigated and nonirrigated excluded crop groups among HPAs. A maximum of two priority levels are listed for climates and five priority levels for soils. The following decision rules are made:

1. If climates from both columns exist within the inventory boundary, allocate total excluded crop acreage among those climates in the first column only.
2. Allocate the acreage among those soils in the highest priority

TABLE 4.3

Soil and Climate Priorities in the Allocation of
Excluded Crops Among HPAs

Crop group	Irrigation?	Resource type	Allocation priority: First	Second	Third	Fourth	Fifth
Excluded vegetables	Yes	Climate	All	------	-----	------	-----
	"	Soil	01, 02, 03, 05, 11	21, 22	12, 14	23, 24	13, 15
	No	Climate	11, 12, 21	All others	-----	------	-----
	"	Soil	01, 02, 03, 05, 11	21, 22	12, 14	23, 24	13, 15
Vineyard & noncitrus orchard crops	Yes	Climate	All	------	-----	------	-----
	"	Soil	01, 02, 03, 05	21, 22	11, 12, 14	23, 24	13, 15
	No	Climate	11, 12, 21	All others	-----	------	-----
	"	Soil	21, 22	01, 02, 03, 05	11, 12, 14	23, 24	13, 15
Citrus crops	Yes	Climate	22, 32, 34, 42, 63	All others	-----	------	-----
	"	Soil	01, 02, 03, 05	21, 22	11, 12, 14	23, 24	13, 15
	No	Climate	22, 32, 34, 42, 63	All others	-----	------	-----
	"	Soil	21, 22	01, 02, 03, 05	11, 12, 14	23, 24	13, 15

column which are combined with the selected climates.

3. The acreage in each crop group is to be allocated among the HPAs thus selected in proportion to their respective "total HPA acreage" within the inventory boundary.

The rationale behind this specification of priorities should be emphasized. While no extensive study was undertaken to determine the suitability of soils and climates for the excluded crops,[1] the following points of information were gleaned from production bulletins and university specialists.

1. Citrus production is essentially restricted to the thermal belts which comprise climates 42, 63 and parts of 22, 32, and 34.
2. Climates 11, 12, and 21 have the highest rainfall and are, therefore, more amenable to nonirrigated production than are the other climates.[2]
3. The alluvial soils are generally the most fertile and lack problems such as poor drainage, excessive salts, and extensive profile development which are present in some of the other soils. Therefore, they are best suited for all of the excluded crops, particularly deep-rooted orchard and vineyard crops.
4. Soil 11 is a peat soil and is particularly well-suited to vegetable production because of its texture.
5. Adequate drainage is possibly more important than level slope. Hence, soils 21 and 22 are given a higher priority than 12 or 14.
6. Shallow depth of soil is particularly restricting for orchard

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1/ Refer to Chapter 3 for the characteristics of each soil and climate.
2/ There is a wide range in annual rainfall and its seasonal distribution in the other climates also, but production is enhanced considerably by the application of supplementary water in all of them.

crops, but the presence of excessive salts is a serious problem to all excluded crops.

7. Outside of climates 11, 12, and 21, much of the nonirrigated production of orchard and vineyard crops is on sloping but relatively deep soil. This may be due to the higher cost of irrigating with sprinklers. Hence, soils 21 and 22 are assigned first priority in the allocation of nonirrigated orchard crops.

Updating to a common base period. The allocation of excluded crops among HPAs derived in the above fashion must be 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. County acreages for individual crops were obtained from the same source, where available, and also from the County Agricultural Commissioner's Reports.

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 recorded in Table 4.4. The acreage of all excluded crops in each HPA may be found in Appendix Table B.2.

1980 projections of State requirements for excluded crops. Aggregate California land requirements in 1980 for orchard, vineyard, and vegetable crop groups have been projected by Kenneth Farrell [1, p. 13]. Based on specified yield and share of market projections, he estimates the acreage required to meet 1980 demand as projected by Daly and Egbert [34]. The

TABLE 4.4

Average 1965-66 California Excluded
Crop Acreage

Crop group	1,000 acres
Orchard & vineyard crops:[a/]	
Deciduous tree	390
Citrus	264
Other tree fruits	78
Grapes	488
Tree nuts	319
Excluded vegetables[b/]	229
Total	1,768

a/ Source: California Crop and Livestock Reporting Service [11].

b/ Source: California Crop and Livestock Reporting Service [14].

Daly-Egbert estimates of U.S. production assume that Series B U.S. population projections will be valid through 1980 and that export levels will continue to increase at the same rate as during the 1950-60 decade [34, p. 2].

In recent years, a lower birth rate has prevailed causing the Series C population projections for the U.S. to appear more realistic than the higher Series B. Reduction factors [97] have been derived to convert a modified set of 1980 U.S. output projections [96, Appendix Table 1] from Series B to Series C population estimates. This same set of factors is used in this study to convert the Daly-Egbert projections.

In order 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. In order to have a conservative slant in the orchard and vineyard crop yield estimates in this study, it was decided to use a simple average of Farrell's projection and that projected by the 1930-66 linear trend.[1/] The rate of increase in yield between 1961-65 and 1980 for excluded vegetables is the same as Farrell's estimate for all vegetables.

1/ An exception to this rule applies to deciduous tree crops. A high degree of confidence could not be placed in the linear projection of peach and pear yields. Therefore, a nonlinear projection was used in the averaging process. The nonlinear projections were lower in both cases than the linear as the following table indicates.

Crop	Average yield, 1961-65 (tons)	Linear projection, 1980 (tons)	Nonlinear projection, 1980 (tons)
Peaches	11.43	16.10	14.00
Pears	8.92	13.88	12.50

Projected California share of U.S. output is estimated by different procedures for each crop group. The basis for each projection may be found in the footnotes to Table 4.5. Refer to Table 4.5 for the development of projected 1980 State acreage of excluded crop categories.

Total excluded crop acreage in 1980 is estimated to be 1,937,000 acres. 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 1980 projections for these crops total 1,957,000 acres.1/ An alternative set of projections using linear yield trends,2/ 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 assumes lower yields and generally larger shares supplied by California.

<u>Allocation of 1980 excluded crop acreage among HPAs</u>. The allocation of estimated 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 were optimal in the base period.
3. With the exception of urban expansion, no shocks, causing extensive shifting of acreage from one HPA to another, will occur between the time of the inventory and 1980.
4. A specific climate is more important than a specific soil to the production of excluded crops.

1/ This acreage 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.

2/ With the exception previously mentioned for deciduous tree crops.

TABLE 4.5

Projections of California Excluded Crops

Crop category	Projected 1980 U.S. output requirement		California						
			Yield per acre		Share of U.S. output		Cropland utilized		
	Series B population estimate a/	Series C as percent of Series B b/	Average 1961-65 c/	Projected 1980 d/	Average 1961-65	Projected 1980	Average 1961-65 a/ e/	Projected 1980 requirement e/ f/	Percentage change in 1980
	1961-65=100	percent	tons	1961-65=100	percent		1,000 acres		1961-65=100
Orchard crops:									
Deciduous tree	140	96.0	6.80	118	31.93 h/	35.00 a/	397	494	124.5
Citrus	168	95.8	9.00	122	23.52 i/	20.57 j/	240	277	115.4
Semitropical	125	96.0	2.44	123	92.85 h/	92.85 k/	81	80	98.4
Grapes	125	96.0	7.30	123	90.75 h/	90.75 h/	478	470	98.4
Tree nuts	130	95.9	.63	124	52.08 h/	64.19 l/	293	364	124.2
Excluded vegetables	148	95.9	g/	125 a/	g/	k/	221	252	118.8
Total							1,710	1,937	113.3

a/ Source: Farrell [1, p. 13].

b/ Source: U.S.D.A. [97].

c/ Yield calculated on bearing acreage only.

d/ The yield index for each crop category, except excluded vegetables, is an average of the index used by Farrell [1, p. 13] and the higher index derived from the linear trend on California yield for the years 1930-65.

e/ Includes bearing and nonbearing acreage.

f/ Acreage requirement to meet specified share of Series C U.S. output; ratio of bearing to nonbearing acreage assumed to equal average of 1961-65.

g/ Not derived.

h/ Source: Agricultural Statistics [91].

i/ Source: Agricultural Statistics [91] for U.S. production; California Crop and Livestock Reporting Service [12, 13] for California production.

j/ Estimated by the equation $Y = A + b \log T$ on 1930-66 data where Y = percent of U.S. output supplied by California and T is time ($T_{1930}=1$).

k/ Estimated to be the same as average 1961-65 share.

l/ California's share is projected to increase rapidly due to recent heavy plantings of new trees. Bearing and nonbearing acreage in 1967 had risen to 356,000 [13].

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

If the above assumptions are valid, 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 all counties having land in HPAs is 1.1073. See Table 4.6 for the development of this coefficient. Appendix Table B.2 records the estimates by HPA of additional land required between 1965-66 and 1980 for excluded crops.

In only five HPAs, all of which were in Southern California, did the estimates of urban land requirements limit the acreage of excluded crops to less than the acreage thus estimated.1/ 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 the most similar soil in the same climate.

<u>Land Restraints Recapitulated</u>

Two sets of upper limit parameters on total model crop activity acreage have really been developed in this section. One is the current land restraint,2/ which is equal to total inventoried acreage less circa

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1/ Although there is enough land 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. Industry sources project considerable shifting of orchard crops from Coastal valleys to the Central Valley [77].

2/ Identified as "circa 1965 net model acreage" in Appendix Table B.2.

TABLE 4.6

Current and Projected Excluded Crop Acreage by County Group

Crop category	Average 1965-66 excluded crops				Projected 1980 excluded crops		
	State total	Counties with land in HPAs	Excluded counties	State total less county allocations a/	State total	Counties with land in HPAs	Excluded counties
	1,000 acres						
Orchard & vineyard crops	1,539 c/	1,531 c/	7 c/	0	1,685	1,678	7
Excluded vegetables							
Total acres	229 d/	205 e/	f/	24	252	252	0
Acreage required b/	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	

a/ Residual of State acreage less that allocated to counties due to different sources of data.

b/ Double cropping in 1965-66 was estimated at 57.34 percent. The same percentage is assumed for 1980 projected acreage.

c/ Source: California Crop and Livestock Reporting Service [11]. Computed from unrounded data.

d/ Source: California Crop and Livestock Reporting Service [14].

e/ Sources: California Crop and Livestock Reporting Service [14] and Agricultural Commissioners [33].

f/ Negligible.

1965 urban land, extra urban land uses, semiagricultural requirements, and excluded crop acreage. The other is the projected land restraint,1/ equal to the current restraint less 1965-80 net urban and excluded crop requirements. The former will be used in Model 1961-65, and the latter in each of the 1980 models.

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

Water Availability

Annual rainfall in California is adequate to meet agricultural, industrial, and municipal requirements for many years to come. However, the spatial 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 the northern third of the State, while the greater requirements are in the central and southern portions [30, p. 25]. While most of the rainfall occurs between October and April, the bulk of the cultural 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. In very few areas of the State is water really a physically limiting resource for agriculture; but in several areas it is economically limiting.

1/ Identified as "projected 1980 net model acreage" in Appendix Table B.2.

The areas designated by Department of Water Resources engineers, Louis R. Mitchell and Helen Peters, as having water resources in effectively limited supply to agriculture and without prospects of importing additional water by 1980 include the coastal valleys of Santa Barbara County; Coastal terraces of San Mateo and Santa Cruz Counties; all of the high elevation mountain counties -- Mono, Sierra, Plumas, Lassen, Modoc, and Siskiyou; and the intermediate level desert -- Antelope and Owens Valleys. The maximum acreage in each of these areas for which water supplies are projected to be adequate for 1980 agriculture is current irrigated acreage. 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, it is estimated that 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 are currently available, this information has been taken into account in the development of typical water cost figures in the next chapter.

Rotation Restraints

Fixed agricultural rotation patterns are not the rule in California. Unlike Midwestern agriculture, many production possibilities are open to most California farmers. Therefore, the decision concerning which crops are to be included in the rotation is normally based more on the expected profitability and risk of alternative crops than on previous practice.

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.

Since rotation practices in the State generally are quite flexible, 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 is to be grown in that area for several years in a row. To obtain such restraints, commodity and plant pathology specialists at the university were consulted concerning the maximum proportion of acreage in a typical HPA that could be continuously planted to a specific crop activity. The following questions were asked of each specialist:

1. How many years in ten could ______________ 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?

The coefficients thus obtained are recorded in Appendix Table B.4. Acreage restraints on single crop activities may be 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.

Cotton Allotment Restraint

Since the mid 1950's the acreage of cotton in the United States has been subject to allotment restrictions. Allotments in any given year are distributed among states in proportion to historical planted acreage. The allotment to California is in turn distributed among counties and among farms within a county by the same criterion. Acreage allotments can be transferred from one farm to another within a county (if the same party owns or leases both), but can be transferred to another county only by referendum vote of the cotton farmers in the transferring county. Because the option to transfer allotments to another county has been exercised by the producers in only one county (San Diego), with a very small acreage, the relative cotton allotment distribution among regions in California has remained nearly constant in the past decade.

In Model 1980D, the effect on location patterns and production costs of continuing this relative distribution of cotton allotments will be analyzed. The distribution between major cotton regions will be determined by 1968 allotment levels. In 1968, California's cotton allotment was 738,639 acres, of which 671,421 acres was allocated to Region 6, 67,086 acres to Region 7, and 132 acres to other regions. Acreage in Region 6 was 10.0 times greater than in Region 7. The negligible acreage in other regions will be ignored, and the allotment restraint will assure that cotton acreage in Region 6 is 10 times that in Region 7.[1] While total California cotton acreage will be endogenously determined, its relative distribution among regions in Model 1980D will be thus fixed exogenously.[2]

HPA and Regional Restraints Concluded

Four sets of parameters, which limit the acreage of all or part of the crop activities in specific areas, have been discussed in this chapter. The actual parameters are recorded in Appendix B. The only other set of restraints to be developed are minimum output levels, which will be discussed in Chapter 6. Cost and yield estimates, which comprise the final model parameters needed, are developed in Chapter 5.

1/ Hence, the value of coefficient "B" in Equation 2.6 in Chapter 2 is 10.0.

2/ In the last few years, an export acreage reserve has been established under which producers can grow cotton in excess of their domestic allotments. Production from this reserve acreage can be sold only for export. No price support loans or payments are made, and in no year has the entire export acreage reserve been utilized by producers. A maximum of 30,000 acres has been produced in California in any one year under this plan. Therefore, its impact on cotton production patterns, if the current allotment program is continued, is expected to be of little importance.

CHAPTER V

YIELDS AND COST OF PRODUCTION

A Word of Caution

The most difficult task in setting up a linear programming problem may well be to obtain meaningful technical coefficients. Errors made in the development of yield coefficients and their respective unit production costs may have serious effects on the programming solution.[1/] In the dissertation models, if all costs are underestimated or overestimated by the same factor, the optimal production pattern will be unaffected. If all yields are under or overestimated by the same coefficient, more or less total land will be brought into production than would be required for a given level of production. But the most pronounced problem occurs if some costs or yields are overestimated while others are underestimated. In this case, the optimal location pattern obtained as a programming solution may be seriously biased.

A detailed survey of farmers to determine average cost and yield parameters in each HPA was clearly beyond the scope of this study. Instead, published data and the judgment of a small group of experts provided the basis for these estimates. As to the relative yields and costs between HPAs, the chief source of information has been expert opinion. No pretense was made at the time the data was gathered, nor is it made here, that these estimates are HPA averages. But they do reflect the thinking of some of the most knowledgable individuals as to what the typical farmer should expect on an efficient-sized farm with the specified soil and climate conditions in a year representative of the period 1961-65.

1/ The yield coefficients are the A^k_{ij} elements in the output equations (equation 2.2) of the model. The production cost estimates are the C^k_{ij} elements in the objective row (equation 2.1).

Yields

Estimation of Typical 1961-65 Yields

A questionaire was sent to each county director of the California Agricultural Extension Service requesting the best estimates of their staff of typical recent yields on harvested acreage by HPA. All but one county responded to the questionaire. Following the questionaire to the county directors, conferences were held with one or more University of California commodity specialists, a soils specialist, and a climate specialist.1/ The commodity specialists were asked to estimate typical yields of their respective crops for all soils in one climate and for one soil in all climates. The soils specialist estimated yields for all crops on each soil in one climate. And the climate specialist estimated yields on one soil in each climate.

Based on the premise that the characteristics of a given soil do not vary by climate zone and climatic qualities do not vary by soil group, relative yield between two soils in one climate should be the same as between two soils in any other climate. Therefore, the specialists' estimates were expanded to provide yield estimates in all HPAs not directly estimated by them. Two complete sets of yield estimates were compiled in this fashion: one from the commodity specialists and the other from the joint estimates by the soil and climate specialists.

The estimates from each county extension staff were normalized to center on average county yield per harvested acre. The normalized estimates were averaged over counties, with each county being given the same weight. The normalized averages which were derived from estimates in three or more counties, or a majority of counties if the HPA is confined in less than three counties, were compiled.

1/ The specialists involved are identified in the section "Personal Communications" following the Bibliography.

All three sets of yield estimates were independently normalized to weighted 1961-65 State average[1/] [10, 14] based on estimated distribution of production among soils and climates.[2/] The simple average of the nonzero elements in these three sets of normalized yields provide the yield parameters by HPA used in the 1961-65 model.[3/] These figures are recorded in Appendix Table E.1.[4/]

1/ Exceptions include the following:

(1) Cotton yields are based on solid plant production only and are normalized to a value 9.1 percent lower than State average gross yield. Gross weight includes bags and ties which average 22 pounds per 500-pound bale.

(2) Safflower yields are estimated for an irrigated culture. They are normalized to a value 10 percent higher than State average because of the sizable proportion of acreage historically not irrigated.

(3) Potato yields are for USDA No. 1 quality only. They are normalized to a value 25 percent lower than State average.

2/ Yields are not normalized with great precision since only the regional distribution of acreage in the base period is known. Judgment and some guesswork was used to estimate the distribution among specific soils and climates within a region.

3/ One yield estimate for each commodity in each HPA was estimated, except for barley. A nonirrigated barley yield and an irrigated barley yield were estimated for those HPAs in which both types of production are possible. But crop yields were not differentiated by season or single versus double crop culture. In those HPAs where a crop of nonirrigated barley must be preceded by a fallow year, the yield coefficients are one-half the yield estimated for the crop year. For the double crop activities involving lettuce, the yields of both harvested crops in the year are included. For a discussion of the special case of barley-grain sorghum double crop production, refer to the final section of this chapter.

4/ In general, if a double crop activity is specified for the production of a commodity in an HPA, a single crop activity is not also specified there. However, because of the fixed minimum output restraints for each commodity, it was observed in a preliminary model that total cost could be reduced if a single crop activity were added for summer lettuce in the Central Coast and for irrigated barley in the Central Valley. Rather than expanding these crop activities to all HPAs in those regions, the most efficient areas for such activities were determined by inspection. Hence, a summer lettuce single crop activity is identified for only a limited portion of the HPAs in Region 2, and an irrigated barley activity for only part of the HPAs in Regions 4 - 6.

Trends and Development of Yield 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. The question is, how much? Two point estimates for the 1980 yield of each crop have been obtained by statistical estimation of time trends in yields. The equation forms used include a linear equation

$$Y_1 = a_1 + b_1 T, \tag{5.1}$$

and logarithmic equation

$$\log\ Y_2 = a_2 + b_2\ \log T, \tag{5.2}$$

where T is year ($T_{1945} = 1$) and Y_i is average California per acre yield. They were estimated from annual California yield data for the years 1945-66 for each of the study crops.1/ Least squares estimates of Y_i were obtained for the year 1980. The estimated 1980 yields of each crop relative to average 1961-65 yield [10, 14] are reported in Table 5.1. The regression estimates of a_i and b_i, along with the t-values for b_i, are reported as inserts in Appendix Figures C.1 to C.15.

It may be observed that a relatively high t-value of both b_1 and b_2 is obtained for nearly every crop. In fact, for only one crop is a coefficient of regression insignificant at the 5 percent level. However, the 1980 yield estimates obtained from these two equation forms are often greatly different. As Stollsteimer, et al. [86, p. 87] concluded with regard

1/ [10] for safflower and for 1965-66 yields of all field crops;
[92] for all field crops, 1945-64, except safflower;
[14] for all vegetable crops except potatoes;
[94,101] for potatoes.

TABLE 5.1

Historical and Projected 1980 California Yield

Commodity	1961-65 weighted average a/		1980 linear projection	1980 logarithmic projection	1980 projection b/ by specialists
	unit	yield	1961-65=100		
Vegetable crops:					
Asparagus	cwt.	29.8	107	91	111
Broccoli	cwt.	63.4	122	99	122
Lettuce	cwt.	197.2	129 d/	108 d/	129
Cantaloupes	cwt.	136.4	122 e/	109 e/	115
Potatoes	cwt.	299.8 f/	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	135
Grain sorghum	bu.	70.4	142	109	142
Alfalfa hay	tons	5.36	115	101	118
Dry beans	cwt.	14.42	113	105	113
Rice	cwt.	48.0	140	108	135
Safflower	cwt.	19.8	152	131	141
Sugar beets	tons	20.5	115	106	115
Cotton	lbs.	1,097 c/	133	106	115

a/ Source: California Crop and Livestock Reporting Service [10, 14].

b/ Values used for projecting yields in this study.

c/ Net cotton lint yield -- does not include bags and ties.

d/ Regression estimates from fall lettuce data.

e/ Regression estimates from summer cantaloupe data.

f/ All potatoes marketed -- not just USDA # 1's.

to statistical cost functions, although the results are very dissimilar, respectable measures of correlation and reliability may be obtained from more than one equation. Therefore, absolute confidence was not placed in either of these sets of statistical estimates. Instead, these estimates were modified by the judgment of commodity specialists.

The table and graphs containing historical data and statistical estimates of trend were taken to conferences with the respective specialists. Using this information as reference material, the following question was asked for each crop: "What do you consider will be the most likely level of State average yield in California in 1980?" The background assumptions for these yield projections were as follows:1/

1. Yield estimates to be based on reasonable expected adoption of known technology;
2. Cost-price relations in 1980 similar to 1961-65;
3. No continued major wars and no depression;
4. Target year 1980 will be a normal year with no unusual weather conditions, disease problems, etc;
5. No shifts in production locations.2/

The specialists' estimates are also recorded in Appendix Figures C.1 to C.15, and their estimates relative to the weighted average 1961-65 yield are provided in Table 5.1.

The estimates obtained from the commodity specialists are the ones used to project yields in this study. It will be noted that, with three exceptions, their estimates coincide with either the linear or curvilinear

1/ The question and assumptions, except for the target year, are basically the same as those used by Dean & McCorkle [41, p.11].

2/ 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.

regression estimates or fall somewhere between these two extremes.

Two assumptions are critical for the application of these estimates to HPA yields: 1) yields in all HPAs will increase relatively the same for any single crop, and 2) yields of all crops in a commodity group will increase at the same rate as the representative crop. Therefore, crop yield in each HPA increases at the same rate as average State yield.[1/]

Cost of Production

The objective function to be minimized in this study is total variable (i.e., nonland) cost. Potential agricultural land is the only resource for which supply is considered inelastic in each HPA for 1980. Therefore, all costs of production, except rents on existing land, must be estimated and aggregated for one acre of land for one year. These include annual cash production expenses and annual charges for short and intermediate term investments and additional development of land.

This section is divided into two parts. In the first, the methods used in estimating relative base period cost among HPAs are explained. In the second, the development of a coefficient for estimating 1980 costs is discussed. This coefficient is used to update all cost categories for all crops in all HPAs.

Development of Representative 1965 Nonland Costs

The method used to estimate current costs is to develop a budget for a base area for each crop and then to estimate physical input requirements and unit costs for other HPAs in relation to the base area. A standard set of unit costs for several cost items is established. These are recorded in Appendix Table D.4. The cost of harvesting each crop is hypothesized to be

1/ Although 1980 HPA yields are not recorded, they may be computed simply by multiplying 1961-65 yield in Appendix E by the respective crop coefficient from Table 5.1.

a linear function of yield. That portion which varies directly with yield is recorded in Appendix Table D.5. Physical inputs and unit costs for most categories are estimated for a base area from recent Agricultural Extension Service sample cost studies. The specific county and year of the study used, along with the HPA it is judged to be applicable for, are recorded in Appendix Table D.8.

Basic assumptions made in the extension of these cost estimates to an entire HPA include the following:

1. All land in soil categories 01-15 is adequately leveled for flood or furrow irrigation; in categories 21-24, sprinkler or contour irrigation is necessary because of greater slope.
2. All land, except soils 13 and 15, is leached of excessive salts, and necessary drains are installed; Salts must be leached from soils 13 and 15, and artificial drainage may be required.
3. All land units in an HPA face an unlimited supply of all other resources at the specified prices, excepting the resource of water in those HPAs for which an irrigation restraint is imposed.
4. Tractors, equipment, and irrigation delivery systems depreciate as functions of time only.
5. In double crop activities, depreciable items used in the production of one crop can also be used in the production of the second crop.

A single total cost estimate applicable to existing developed agricultural land, except for soils 13 and 15, is made for each crop activity in an HPA. Step-cost functions within an HPA are thus ruled out by assumption. The annual investment cost in a double crop activity, based on the last two assumptions, is calculated as the sum of one-half the investment cost of each crop.

Differential physical input requirements were estimated for the non-basic HPAs from cost studies in other counties and from conferences with commodity specialists. The development of costs in other HPAs were guided by the following assumptions:

1. Investment cost does not vary by HPA;
2. Sprinkler irrigation is used for all crops, except rice, on soils 21-24;[1/]
3. The only unit costs which differ by HPA are water costs;
4. In the absence of specialist judgment or other evidence to the contrary, input requirements per acre are assumed to be the same in all HPAs.

Estimated 1965 total nonland cost of each model crop activity on one acre of HPA land in one year may be found in Appendix Table E.1.

Irrigation requirements. Consumptive water use, irrigation efficiency, rainfall and its seasonal distribution all combine to determine the total irrigation water that must be applied to a crop. Irrigation requirements for crops in many areas of California have been estimated by various researchers [17, 27, 30, 32, 105, 106]. These estimates have been sorted along climatic zone boundaries, averaged, and checked with University of California commodity, irrigation, and climate specialists. The best estimates so obtained are summarized in Appendix Table D.1.

Although specific studies comparing the irrigation efficiency on the different soil groups defined for this study were not found, the commodity specialists generally agreed that irrigation requirements on sandy soils are about 20% higher and on clay soils about 20% lower than on loam soils. Application efficiency with sprinkler irrigation is estimated to be 15%

1/ Although rice would not be irrigated by sprinklers, higher costs are also estimated for rice on these soils to account for additional leveling and contouring.

greater than with flood or furrow irrigation. Relative irrigation requirements on each soil group are recorded in Appendix Table D.2.

Water Costs. Estimated 1965 water cost per acre foot is recorded in Appendix Table D.3 for each HPA. These estimates are weighted averages of estimates derived for each county HPA. The sources of county HPA water cost data include previous water cost studies in the San Joaquin and Salinas Valleys [67, 71, 72], reported irrigation district charges [29], depth to groundwater maps and tables [18, 19, 20, 21, 22, 25], estimated future water costs by district on the Westside, San Joaquin Valley [74, 75, 76], Agricultural Extension Service sample costs sheets [106], and the judgment of engineering consultants, Louis R. Mitchell and Helen Peters, from the California Department of Water Resources.

An extensive study was undertaken by Moore and Snyder [72] to determine pumping lifts in the San Joaquin Valley. In reporting their conclusions, they defined areas of similar pump lift. Because surface water supplies a significant proportion of total irrigation water used there, they followed their initial study with an analysis of surface water costs for the same areas. They computed average water cost for each area based on relative shares supplied by surface and groundwater sources [67]. These latter figures were used exclusively in this study for the San Joaquin Valley, except for the Westside. Water cost per acre foot in each HPA is computed by weighting Moore and Snyder's figure by the proportion of the HPA in each of their areas.

For the Westside, cost estimates of water to be delivered from the California Aqueduct were obtained from the water agencies that will distribute this water [74, 75, 76]. Their cost estimates generally were for water at canalside. To these figures were added the estimated distribution costs.

The water costs at the headgate thus derived are averaged with Moore and Snyder's estimates weighted by the relative area of the HPA covered by each source.

In most other areas of the State, water cost is estimated by directly averaging costs from surface[1/] and groundwater[2/] sources. It is expected that irrigation districts provide virtually all of the water within their geographic boundaries, and groundwater sources supply the residual to each HPA. In those counties for which neither surface nor groundwater data are available, water cost is estimated from county Agricultural Extension Service estimates [106].[3/]

1/ The cost of surface water in irrigation districts was calculated by dividing total revenue received from farm deliveries by quantity delivered for agricultural use. This is an important difference from taking the reported cost per acre foot, because the latter often excludes charges levied per acre irrigated or per assessed valuation.

2/ The cost for groundwater was calculated by obtaining data on depth to the water table [18, 19, 20, 21, 22, 25], adding 40 feet to account for drawdown, and multiplying the sum by $.045/ft.

3/ The average of the sample cost sheet estimates is assumed to be the average water cost on all alluvial and basin soils in the county. An additional pump lift of 50 feet is added to estimate water cost on terrace soils.

Reclamation costs. Barley has the highest tolerance to saline conditions of any crop in the study [8, p. 10]. Even with its relatively high tolerance, barley yields are reduced by 10 percent at the estimated typical salinity levels of soils 13 and 15.[1/] The only crop activities permitted to enter the optimal solution on unreclaimed soils 13 and 15 are the nonirrigated barley activities. The rationale behind permitting only these activities is that if water is inexpensive enough to make irrigation profitable without reclamation, it would be more profitable to also reclaim the soil of excessive salts.

Virtually complete reclamation of the top three feet of soil is specified as prerequisite to the production of all other crop activities, except rice. For rice production, it is only necessary to remove salts from the top 3-6 inches of soil.

Reclamation costs, both one-time outlays and periodic costs, for each saline and alkaline HPA were estimated in consultation with university irrigation specialists Larry Booher and Robert Ayers and soils specialist Gordon Huntington. An annual charge using a 6% interest rate and straightline depreciation were computed and are summarized in Appendix Table D.6 for the alternative cropping activities.

1/ The salinity level of a soil is determined by measuring its electrical conductivity. The estimated typical electroconductivity of a saturated extract of soil 13 or soil 15 is 18 millimhos per centimeter.

Estimation of 1980 Nonland Costs

The discussion which follows explains the rationale behind the scalar estimation of 1980 nonland production costs relative to 1965 costs. Since a single coefficient is used to project total production cost of all crops in every HPA, it has no effect on the optimal location pattern. Its only function is to provide more reasonable estimates of 1980 total cost parameters so that the shadow prices derived endogenously from the 1980 models are also more realistic.

The unit price of all nonland agricultural inputs in the U.S. has increased 16.6 percent during the 15-year period between 1945-49 and 1960-64 [93, 100]. According to Farrell, "The [California] farm sector is now [year 1965] producing nearly one-third greater output, with only 3 percent more total inputs than in 1950" [1, p. 6]. Since cropland in California during the period 1950-65 actually decreased, the increase in nonland inputs was more than 3 percent. If 1) a 5 percent increase in nonland inputs between 1950 and 1965 was a reasonable estimate, 2) nonland inputs between 1965 and 1980 will increase at the same rate, and 3) unit costs will increase an average of 17 percent, then total nonland production costs will increase by 23 percent between 1965 and 1980.1/

1/ Since most of the base area budgets were developed from more recent data than 1965, 1980 costs may be biased slightly upward. But, in any event, the optimal location pattern will be unaffected. Because of the higher yield estimate, the actual cost parameters used in the 1980 models are more than 23 percent higher than the 1965 parameter. To calculate the 1980 cost parameter, multiply the differential yield between 1961-65 and 1980 by 1.1 times the unit 1965 harvest cost. Add this quantity to the 1965 total variable cost estimate and multiply the total by 1.23.

An alternative to the above procedure would have been to group inputs into several major categories such as skilled labor, unskilled labor, machinery, water, fertilizer and chemicals, etc. Then the cost of each category could have been projected at its own rate, based possibly on historical trends. Assuming that the input mix will remain constant to 1980, this procedure would provide more realistic estimates of actual 1980 costs.

For example, because labor costs have risen at a more rapid rate in the recent past than machinery prices, one might expect the 1980 nonland cost parameters in this study to be underestimated for the labor intensive crops or areas and overestimated for the capital intensive ones. However, it should be observed that there is considerable substitution of one input for another over time, especially between labor and capital. Rapidly increasing labor costs have been largely responsible for the trend to mechanize formerly labor intensive production practices. Therefore, the major problem in projecting the cost of input categories at different rates, if based on historical data, is failing to foresee the substitution that will take place between categories. Without further investigation, it would appear to the writer that the distortions caused by projecting all 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. The possibility of input substitution is a very real one.

A Note on the Barley-Grain Sorghum Double Crop Activity

Three basic double crop activities are specified in this study: lettuce-lettuce[1/], broccoli-lettuce, and barley-grain sorghum. For the first two combinations, the climate zones identified by the specialists as capable

1/ Three different seasonal mixes of a lettuce-lettuce double crop are possible.

of producing two crops in a year can normally produce two crops every year. For the barley-grain sorghum combination, this is not so. Fourteen climates are listed in which two crops can be harvested in a majority of years, but in only two of the fourteen can continuous double cropping be practiced.

The proportion of years in which two crops of feed grains can be harvested in each of the double cropping climates was estimated by the commodity specialists. The remaining years are assumed equally divided between the production of barley and grain sorghum.

Since resource restraints are specified in units of net agricultural land acres for a time period of one year, the model cost and yield parameters must be relevant for crop production on one acre of land in a year. Single crop activity estimates derived on this basis are the same as for one harvested acre. For the barley-fallow activity, the estimates per annual unit of land are one-half the cost and yield estimates per harvested acre. Lettuce-lettuce and broccoli-lettuce double crop activities include the cost of producing both crops and the yield estimates are for both on an acre of land in one year. A crop of barley and of grain sorghum cannot be harvested every year from the same land in all HPAs for which a double crop feed grain activity is specified. Hence, the cost and yield estimates per harvested acre of each crop must be reduced by the proportion of years in which each commodity is not grown in order to be representative of one acre of land.

Costs are further modified to reflect the ratio of double to single crop years for each commodity. The cost and yield estimates for both crops are treated alike since, by assumption, they are grown the same proportion of the time.

There is no difference in the crop yield estimates obtained between the single and double crop activities. The only difference in either crop's cost estimate is in the investment category, which in a double crop activity is equal to one-half the single crop investment cost. To illustrate for either barley or grain sorghum, define:

a = proportion of years the crop is grown,
b = proportion of years the crop is not grown,
a_1 = proportion of years crop is grown in double crop activity,
a_2 = proportion of years crop is grown in single crop activity,
I_c = investment cost in single crop activity for crop year,
C_c = total nonland cost for crop year,
Y_c = yield for crop year,
I = annual investment cost in amalgmated activity,
C = total annual nonland cost in amalgamated activity,
Y = annual yield;

then

$$a + b = 1, \tag{5.3}$$

$$a_1 + a_2 = a; \tag{5.4}$$

and

$$I = (.5a_1 + a_2)I_c, \tag{5.5}$$

$$C = a(C_c - I_c) + I, \tag{5.6}$$

$$Y = aY_c. \tag{5.7}$$

The total cost figure for the amalgamated double crop activity is obtained by summing Equation 5.6 for both crops. See Appendix Table D.7 for the values of coefficients a, a_1, and a_2 in those climates for which a double cropping activity is specified.

An alternative to this amalgamation procedure would have been to assume that in any climate where two feed grain crops can be produced in a majority of years, two can be produced every year. However, this alternative, although simpler, is a considerably less realistic method of determining actual feed grain land requirements.

Summary

The cost and yield estimates to be used in Model 1961-65 and in the 1980 models have been discussed in this chapter. Some published data have been used in the development of these estimates, but the judgment of farm advisors and university specialists has been the primary source of data. The reliability of the parameters derived in this chapter will be of basic importance in determining the reasonableness of the optimum production patterns for the output levels estimated in the next chapter.

CHAPTER VI

CALIFORNIA PRODUCTION PROJECTIONS

Development of 1980 Output Projections

This chapter is devoted primarily to a discussion of the demand restraint development for the 1980 models.[1/] Basically there are two sets of California output projections. Both are based on the same U.S. commodity output projections,[2/] but with different assumptions concerning the share to be supplied by California.[3/]

One set (for Model 1980A) is made on the premise that California producers will continue to supply the same share of U.S. output which they produced during the period 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 assumes 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 year and 2) in logarithms.[4/] These projections for Model 1980B are also used for Models 1980C and 1980D but with some modification in specific crop groups.

1/ These are the D_i^k values in equation 2.2.

2/ An exception to this statement affects one set of demand estimates for forage and feed grains. The second estimate for these two crop groups is based on projections of livestock and poultry fed in California, rather than on a specific assumption regarding the share of U.S. output supplied by California. For details, see the explanation in the next section of this chapter.

3/ The goal of achieving a certain share of the national and international markets is not based on an economic concept such as maximizing national welfare. It is a purely empirical question. There is no direct consideration given here to the relative advantage of regions outside of California, except as such advantage has affected California's historical share trends.

4/ A minimum of ten and a maximum of 37 years of annual data were used in each equation. The equation providing the highest degree of explained variance was used in the projections.

U. S. output projections for 1980 have been made by Daly and Egbert [35] for many of the crop groups in this study. Their projections are based on the following assumptions [34, pp. 2-5]:

1. U.S. population will reach 245 million by 1980 (Census Bureau Series B estimate);
2. Per capita consumption in the U.S. will continue to change generally according to recent trends;
3. Prices of farm products will be approximately the same as in recent years;
4. Exports will continue to increase by the same quantities as during the 1950-60 decade;
5. Per capita disposable income will show an annual gain of approximately 2.3 percent.

Their output projections, modified to the lower Series C population estimate of 235 million, are used in this study for potatoes and each of the field crops.

The output of U. S. vegetable crops, 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.

The California output projections for each crop under both sets of assumptions are recorded in Tables 6.1 and 6.2. U.S. output projections, California's past and projected shares, and other essential support data may also be found in these tables.

TABLE 6.1

Output of California Vegetables, 1980 a/

Crop	Projected 1980 U.S.:		U.S. production		California share of U.S. output		Projected California production, 1980	
	Per capita consumption	Output requirement b/	Average 1961-65 c/	Projected 1980	Average 1961-65 c/	Projected 1980	1961-65 share	Projected share
	1961-65=100		1,000 tons		percent		1,000 tons	
Asparagus	84	105	181.5	191	52.3	52.3 d/	100	100
Cole crops:								
Broccoli	104	130	114.3	149	74.2	90.2	110	134
Brussels sprouts	114	143	35.4	51	91.4	91.4 d/	46	46
Cauliflower	73	91	127.1	116	60.7	84.7	70	98
Lettuce:	113	141	1,947.7	2,746	58.6	58.6 d/	1,609	1,609
Spring & fall	NA	NA	NA	NA	NA	NA	544	544
Summer	NA	NA	NA	NA	NA	NA	518	518
Winter	NA	NA	NA	NA	NA	NA	547	547
Melons:								
Cantaloupes	78	98	633.9	621	54.9	54.9 d/	341	341
Spring & fall	NA	NA	NA	NA	NA	NA	54	54
Summer	NA	NA	NA	NA	NA	NA	287	287
Honeydew melons	78	98	66.7	65	78.0	78.0 d/	51	51
Spring	NA	NA	NA	NA	NA	NA	3	3
Summer	NA	NA	NA	NA	NA	NA	48	48
Watermelons	83	104	1,464.3	1,523	9.0	9.0 d/	137	137
Spring	NA	NA	NA	NA	NA	NA	54	54
Summer	NA	NA	NA	NA	NA	NA	83	83
Tomatoes:								
For fresh market	93	116	1,033.3	1,199	29.2	29.2 d/	351	351
For processing	124	155	4,551.6	7,055	59.2	62.2	4,177	4,386

a/ Except potatoes.
b/ U.S. population is projected to increase from 188.6 million to 235.2 million, a 25 percent change.
c/ Source: Agricultural Statistics [91].
d/ The t-values of the regression coefficients estimated from 1957-66 share data are too low to place confidence (at the 10 percent level) in a 1980 share different than the 1961-65 average.

NA - Data not obtained.

TABLE 6.2

Output of California Field Crops, 1980[a]

Crop	Projected 1980 U.S. output requirement: Series B population estimate [b]	Projected 1980 U.S. output requirement: Series C as percent of Series B [c]	U.S. production: Average 1961-65 [d]	U.S. production: Projected 1980	California share of U.S. output: Average 1961-65 [d]	California share of U.S. output: Projected 1980	Projected California production, 1980: 1961-65 share	Projected California production, 1980: Projected share
	1961-65=100	percent	1,000 tons		percent		1,000 tons	
Potatoes	121.01	97.0	13,626	15,994	11.14	11.14[i]	1,782[k]	1,782[k]
Russet burbank	NA	NA	NA	NA	NA	NA	149	175
Corn:								
For grain	155.91	96.5	106,523	160,264	.23	NA	369	325
Silage	NA	NA	NA	NA	NA	NA	1,903	1,903
Small grains:								
Barley	155.91	97.4	9,758	14,818	17.76	NA	2,632	2,323
Oats	155.91	96.4	15,417	23,172	.54	NA	125	110
Wheat	156.10	99.2	36,460	56,459	.72	.53	407	299
Sorghums:								
For grain	155.91	97.1	15,355	23,246	3.13	NA	728	642
Silage	NA	NA	NA	NA	NA	NA	367	367
Dry beans	126.56	97.7	938	1,159	17.48	15.18	203	176
Baby lima, kidney, blackeyes, & pink	NA	NA	NA	NA	NA	NA	110[l]	95[l]
Hay	117	95.9	120,113	134,767	6.17	NA	8,313	8,172
Alfalfa hay	NA	NA	NA	NA	NA	NA	7,313[m]	7,172[m]
Other hay	NA	NA	NA	NA	NA	NA	1,000	1,000
	1961-65=100	percent	1,000 lbs.		percent		1,000 lbs.	
Alfalfa seed	117[f]	95.9[f]	133,090	149,327	34.59	26.47	51,657	39,527
	1961-65=100	percent	1,000 bales [i]		percent		1,000 bales [i]	
Cotton	115.86	95.9	14,935	16,594	11.74	16.70	1,948	2,771
	1961-65=100	percent	mil. lbs.		percent		mil. lbs.	
Food fats & oils	187	97.2[g]	13,536	24,636	2.90	3.90	715	961
Cottonseed oil	115.86	95.9	1,937	2,152	11.62	16.52	250	355
Safflower oil	NA	NA	212[h]	NA	NA	NA	466	606

See footnotes at end of table.

--Continued on next page.

Table 6.2 (continued)

Crop	Projected 1980 U.S. output requirement		U.S. production		California share of U.S. output		Projected California production, 1980	
	Series B population estimate b/	Series C as percent of Series B c/	Average 1961-65 d/	Projected 1980	Average 1961-65 d/	Projected 1980	1961-65 share	Projected share
	1961-65=100	percent	1,000 tons		percent		1,000 tons	
Safflower seed e/	NA	NA	308	853	NA	NA	678	880

a/ Plus potatoes.

b/ Source: Daly and Egbert [35]; reported by Farrell [1, p. 13] relative to base period 1961-65.

c/ Source: U.S.D.A. [97].

d/ Source: *Agricultural Statistics* [91].

e/ Safflower oil is converted to units of raw safflower seed assuming that the average 1961-64 outturn of 34.4 percent oil remains constant to 1980.

f/ Assumed to be the same as for hay.

g/ Conversion factor for soybeans.

h/ Source: U.S.D.A. [95] -- average 1961-64 production.

i/ Bales average 500 pounds gross weight or 478 pounds of lint.

j/ Share of U.S. potato production supplied by California increased from 2 percent in 1930 to more than 12 percent in 1953. Since 1953 the share has fluctuated between 10 and 13 percent, with the average near the 1961-65 average.

k/ Estimated minimum Region 1 production.

l/ Estimated minimum Central Valley production.

m/ Production of nonalfalfa hay is projected to continue in a downward trend from 1,186,000 tons in 1961-65.

NA Data not obtained.

Special Situations

Alfalfa Hay

Alfalfa hay is readily substitutable for other types of hay in livestock production. The percentage of California hay which is alfalfa has been increasing steadily for many years. Therefore, the development of alfalfa hay projections involves 1) output projection of all hay, and 2) projections of alfalfa as a percentage of all hay. Alfalfa hay is projected to increase from 84 percent of all hay in the period 1961-65 to 88 percent in the first set of 1980 projections and 87.8 percent in the second set. This rate of increase corresponds favorably to recent trends.

Safflower

Cottonseed and safflower oil are the only vegetable oils produced in significant quantity in California. For projection purposes, it is assumed that 1) the outturn rate of cottonseed oil as a byproduct of lint production will remain constant to 1980, and 2) safflower will supply the remainder of California's vegetable oil. California's vegetable oil production is projected as a percent of U.S. food fats and oils.

Seasonal Demand

Most output restraints developed in this study are for annual production. However, for certain crops, there are seasonal demand aspects which are very important in determining production patterns. This is particularly true for perishable vegetable crops sold on the fresh market. For example, the Desert HPA 0372 has a relatively high cost -- yield ratio in comparison to other HPAs for the production of tomatoes. With only an annual output restraint specified, the tomato activity in HPA 0372 does not come into the optimal solution. However, if tomatoes could be produced there in an off-season when the price is substantially higher, it very well may be an economic allocation of resources to produce some tomatoes in HPA 0372.

It is recognized that seasonal demand characteristics play an important role in defining production patterns for several of the crops in this study. However, seasonal demand restraints are specified for only two: lettuce and melons. Virtually all the production of these crops is distributed for fresh market consumption.

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 also suitable 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 percent of California lettuce produced in 1961-65 was marketed in the spring and fall, 32 percent in the summer, and 34 percent in the winter. No strong trends in the share of California lettuce produced by season are discernable in the 1957-66 decade. Therefore, the distribution among seasons is projected to remain constant to 1980.

The harvest season 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 is also produced in this climate zone. Melon output restraints are separated into the spring-fall seasons and the summer season. In the base period, approximately 16 percent of the cantaloupes, 6 percent of the honeydew melons, and 40 percent of the watermelons were produced in the spring and fall seasons, with the remainder being harvested in the summer. These relative seasonal distributions are projected to prevail in 1980 also.

Varietal Restraints

In two cases the geographic adaptability of important commodity varieties are deemed to be sufficiently different from the rest to necessitate minimum varietal output restraints. The two instances are dry beans and potatoes.

So many varieties of dry beans are produced in California that a single yield estimate cannot represent all of them. The yield estimates used in this study are considerably higher for Region 2 (the Central Coast) than for Regions 4, 5, and 6 (The Central Valley). 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. It is expected that at least these varieties will continue to be produced in the Central Valley and will comprise at least their current percentage of dry bean production. Therefore, a minimum output restraint is imposed on dry bean production in this area at 54 percent of California dry bean output.

Potatoes produced in Region 1 are predominately of the Russet Burbank variety. This variety is a high quality potato for fresh consumption and is projected to retain at least its current share of total potato production. Therefore, a minimum output restraint on Region 1 potatoes equal to its current share, approximately 13 percent, of State output is imposed on all models.

Forage and Feed Grain Projections Based on Livestock and Poultry Numbers in California

In the second general set of 1980 output restraints, the output of forage and feed grains correspond to independent livestock and poultry projections made as a part of this study. Numbers of livestock and poultry fed in California are projected to change as follows between 1961-65 and 1980:

as follows between 1961-65 and 1980:

Type of animal	Percent change
Beef Cattle	+ 2
Dairy Cattle	+ 27
Sheep	- 9
Hogs	- 3
Poultry	+ 26

The forage-concentrate ratio is assumed to remain constant. Total hay supplies of 8,172,000 tons (up 10 percent from average 1961-65) are projected to come from California. Estimating that California will supply 58 percent (compared to 51 percent in the 1961-65 period and 65 percent in 1967) of its feed grain requirement, California feed grain production in 1980 is projected to be 3,400,000 tons (up 34 percent from 1961-65).

In both sets of output projections, the quantity of corn and sorghums produced for silage is projected to increase in proportion to the number of dairy cows in California. A 46 percent increase over average 1961-65 production is thus estimated.

Conversion of Output Estimates to Representative Crop Units

For the crop groups which are represented in the linear program by a single commodity, one demand value for the entire group must be obtained. It has already been 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. In order that the model solution accurately reflects the true 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 thus derived are recorded in Appendix Table F.1.

Feed Grain Output as a Single Restraint

One alternative to output projections by specified crop groups is analyzed in this study and incorporated into the output restraints for Models 1980C and 1980D. This alternative is to remove the minimum output restraints from each of the individual feed grains, specify a single minimum feed grain output, and solve for the minimum cost feed grain mix.

The yield and output estimates for 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[1/] weighted by the portion of 1961-65 feed grains fed to each class.[2/] The average relative net energy values are as follows:

Corn	1.00
Sorghum	.96
Barley	.93

The output projection 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, with the exception of the barley group. This last group includes the food grain, wheat, as well as feed grains, barley and oats. Its output, therefore, is set at the projected wheat output level multiplied by the relative 1961-65 yields of barley and wheat. Refer to Appendix Table F.1 for these minimum output restraints.

Imposition of Cotton Allotments

In Model 1980D the impact on production patterns of imposing a regional cotton allotment restraint is analyzed. If a regional cotton allotment restraint is imposed, total California cotton lint output projections must also be modifed. It is not realistic that under a continuation of current

1/ [64, p.25] for ruminants, [73] for hogs, and a verbal estimate by Wilbur O. Wilson, Chairman, Department of Poultry Husbandry, University of California, Davis for poultry.

2/ The breakdown of feed grains fed to each class has been estimated by King [84]: ruminants - 53.2%, poultry - 44.5%, hogs - 2.3%.

allotment programs, California's share of U. S. output will increase as projected.[1] The bulk of the historical increase in California's share came before the introduction of the allotment program. Since 1957 California's share has not increased markedly.

Assuming that cotton yields in California increase at the same rate as the rest of the nation and that the relative distribution of allotments among states will not change, the California cotton output restraint in Model 1980D will be the same as in Model 1980A.

If the projected share of U.S. food fats and oils supplied by California vegetable oils is not altered, the output restraint for safflower must be increased. With allotments imposed, the cottonseed oil output projection will be cut back from 355 to 250 million pounds. To meet projected vegetable oil requirements from California, 711 million pounds of safflower oil or 1,033,000 tons of safflower seed must be produced.

Model 1961-65 Restraints

Actual 1961-65 California production of each crop is used as the basis for the Model 1961-65 output restraints. The development of restraints in representative crop units is implemented in the same way as for the 1980 models. These restraints are also recorded in Appendix Table F.1. However, a different data series for 1961-65 production is used for the 1961-65 model than is used as the basis for the 1980 output projections. In order to estimate the share of U.S. production to be supplied by California in 1980, it was necessary to use a data series which records both California and U.S. crop production. The 1980 projections are based on 1961-65 output as reported

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1/ It is recognized that some increase in California's share may occur because of production exclusively for the export market. However, as explained in Chapter 4, production on this basis is not expected to be very substantial.

in Agricultural Statistics [91] and U.S. Fats and Oils Statistics [95]. But HPA yield estimates for the base period have been normalized to average State yield reported by the California Crop and Livestock Reporting Service. In addition, the base period model acreage will be compared with actual crop acreage from that source. Therefore, the Model 1961-65 output restraints are also devolped from California Crop and Livestock Reporting Service data.

Summary

The estimation of base period and 1980 output levels complete the elements required for the models specified in Chapter 2. Other elements were developed in the three preceeding chapters. In Chapter 3, homogeneous production areas were defined. In Chapter 4, the acreage in each HPA was computed. Estimates of acreage in nonfarm and excluded crop uses in the base period and conversions of model crop land to these uses by 1980 were also derived. In the last chapter, total nonland cost and yield per acre were estimated for both time periods.

The attention of the reader will be focused in the following three chapters on the analytical insights gleaned from the various model solutions. In Chapter 7, the Model 1961-65 solution will be compared with the actual base period patterns. The results of the 1980 models are contrasted with the base period in Chapter 8. Certain policy implications of the model solutions are suggested in the final chapter, together with a critical evaluation of the methods of analysis used and suggestions for further research.

CHAPTER VII

OPTIMUM CIRCA 1961-65 VERSUS ACTUAL PRODUCTION PATTERN

Introduction

Why This Model?

There are two primary purposes for including a 1961-65 model in the analytical section of the thesis:

1. To determine the differences between acreage and price levels in the real world and in the linear programming solution, with -- a) a given level of output, b) model yields normalized to 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.

The first purpose stated for including this model should be clearly distinguished from providing a validity test of the model. The model is normative and its value (or validity) is not measured by how closely it approximates the real world. There are several reasons that might cause the model solution to differ from the actual. These include the following:

1. Resources were not optimally allocated in the base period;
2. Farmers do not have the single objective of maximizing profits;
3. Not all of the relevant variables have been considered;
4. The data collected are incorrect or inadequate;
5. There is not a linear relation between variables over the relevant range;
6. The model is too aggregative -- i.e., there is a great deal of variation in cost and yield within an HPA, or seasonal or special

markets are much more important than assumed in the model development.[1/]

It is likely that all of the above possibilities are reflected in the model results. While a desirable goal of this type of model is to estimate the extent of resource misallocation, such an estimate must be tempered by due consideration for the other possible causes for the model solution differing from the real world. Analysis of other variables (e.g., transportation costs, location and economic life of processing plants, etc.) and further refinement of the data (more accurate estimation of average cost and yield and additional consideration of variance) may be quite important in explaining these differences. However, misallocation of resources is doubtless an important factor also.

The usefulness of the second stated purpose of the 1961-65 model is to allow a separation in the discussion of the 1980 model solutions between the effects of changing parameters over time and the effects of moving from a hypothetical or real state of initial disequilibrium to one of static equilibrium.

Matrix Size

The physical dimensions of the 1961-65 model activity matrix are 822 rows and 1102 columns. The matrix structure is block diagonal. Land, water, and rotation restraints each apply to crop activities in only one HPA. The output restraints tie the model together because demand for each commodity can be satisfied by production in any of a group of HPAs.

1/ It should be recalled that 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 the vector of farm prices in one area to differ somewhat from that in another.

Plan of Discussion

The remainder of this chapter will be divided into two sections, with the major insights from the primal linear programming solution being presented in the first and those from the dual solution in the second. In the first section, the optimal acreage and distribution of production among regions will be compared to the actual patterns. Because there are nonirrigated activities in the model, there are really three acreage comparisons of interest: land use (land resources required), irrigated acreage (portion of land resources requiring irrigation), and harvested crop acreage (output acreage of each crop). In the second section, derived model total product value and imputed product prices will be compared with actual value and prices.

It should be noted that the term "optimal" is applied to the model solution discussed in this chapter and to each of the model solutions in the next chapter. Each model solution discussed is optimal in the sense that for the output, cost, yield, and acreage parameters used in each model, it is the one for which total costs are at a minimum (and 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.

State and Regional Acreage Comparison

Estimation of Actual 1961-65 Acreage Data

To provide a basis for comparing the optimal model solutions, actual 1961-65 regional acreage of irrigated land and harvested acreage of each crop group was estimated.

Regional irrigated acreage. The 1964 acreage of irrigated land in each county is reported in the Census of Agriculture [104]. Maps depicting the location of irrigated land within counties are published by the Department of Water Resources [23]. County irrigated acreage was obtained from the first reference, while its distribution among regions within a county was estimated from the latter by planimetering. It is assumed that the data for 1964 are reasonable estimates for the period 1961-65 also.

Regional harvested crop acreage. The Department of Water Resources land use data, discussed in Chapter 4, was summarized by seven and one-half minute quadrangles for the model crops. This degree of areal breakdown was adequate to obtain reasonably accurate estimates of regional acreage.

For purposes of updating these data to a common base period, it was assumed that the relative regional allocation of acreage within a county at the time of the survey remained constant. Initially a 1965-66 base period had been chosen for crop acreage. County harvested acreage of crops in the study was obtained for the crop years 1965 and 1966 from Crop and Livestock Reporting Service and Agricultural Commissioner publications [10, 14, 33]. County data from the latter source were modified proportionately to correspond to the State totals reported by the Crop and Livestock Reporting Service. County crop acreage thus obtained was distributed among regions in the same proportion as in the Department of Water Resources land use survey.

However, when it was later decided to use a 1961-65 base period, county acreage for this period was not computed. Instead, total 1965-66 regional crop acreage was increased or decreased proportionately to correspond to 1961-65 State harvested acreage of each crop group.

Land Use Pattern

It is estimated that there are nearly 20 million acres in California which have potential for commercial agricultural production. Of this acreage, it is estimated that in the base period approximately 12 percent was actually required for urban and extra-urban purposes, 9 percent for semiagricultural uses, 16 percent for crops not in the study (consisting of irrigated pasture and nonalfalfa hay as well as orchard and excluded vegetable crops), and 30 percent for included crops. This left an estimated 33 percent of the inventoried acreage idle or used only for range purposes. In the model solution, only 26 percent of the inventoried acreage is estimated to be required for included crop production and 36 percent remains idle.1/ The breakdown of potential agricultural land in California according to major types of usage is recorded for the base period actual and model solution in Table 7.1.

The total model acreage required for the included crops is almost 800,000 acres less than actual requirements in the base period, but optimal irrigated acreage is 335,000 higher. One conclusion drawn from the model solution is that by shifting all production to optimal locations and increasing irrigated acreage by one-third million acres, total land requirements can be decreased by more than twice that amount. Such a conclusion is based on the premise that irrigated acreage in all regions (except possibly Regions 3 and 6) can be expanded at the same unit water cost in each HPA as is presently typical.

In Table 7.2, the model solution is recorded for each included crop activity by region.2/ 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. It will be recalled that net model acreage is equal to total inventoried acreage less urban, extra-urban,

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1/ Optimal requirements in all other categories are taken to be the same as actual.

2/ For easy reference, the production regions are delineated in Figure 7.1.

TABLE 7.1

Land Use in California in Base Period, 1961-65
Actual and Estimated Model Requirements

Land use category	Estimated acreage requirements	
	Actual	Model
	1,000 acres	
Nonagricultural land[a/]	2,403.2	2,403.2
Semi-agricultural land[a/]	1,722.5	1,722.5
Agricultural requirements		
Commodities not in study[b/]		
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	1,163.0	38.0
Subtotal	5,926.3	5,136.0
All commodities		
Irrigated	7,567.3	7,902.0
Nonirrigated	1,569.6	444.6
Total agricultural requirements	9,136.9	8,346.6
Idle land	6,362.7	7,153.0
Total land inventoried	19,625.3	19,625.3

a/ Source: Appendix Table B.2.

b/ Orchard and excluded vegetable crops, pasture, and nonalfalfa hay -- circa 1965-66.

FIGURE 7.1

California Production Regions

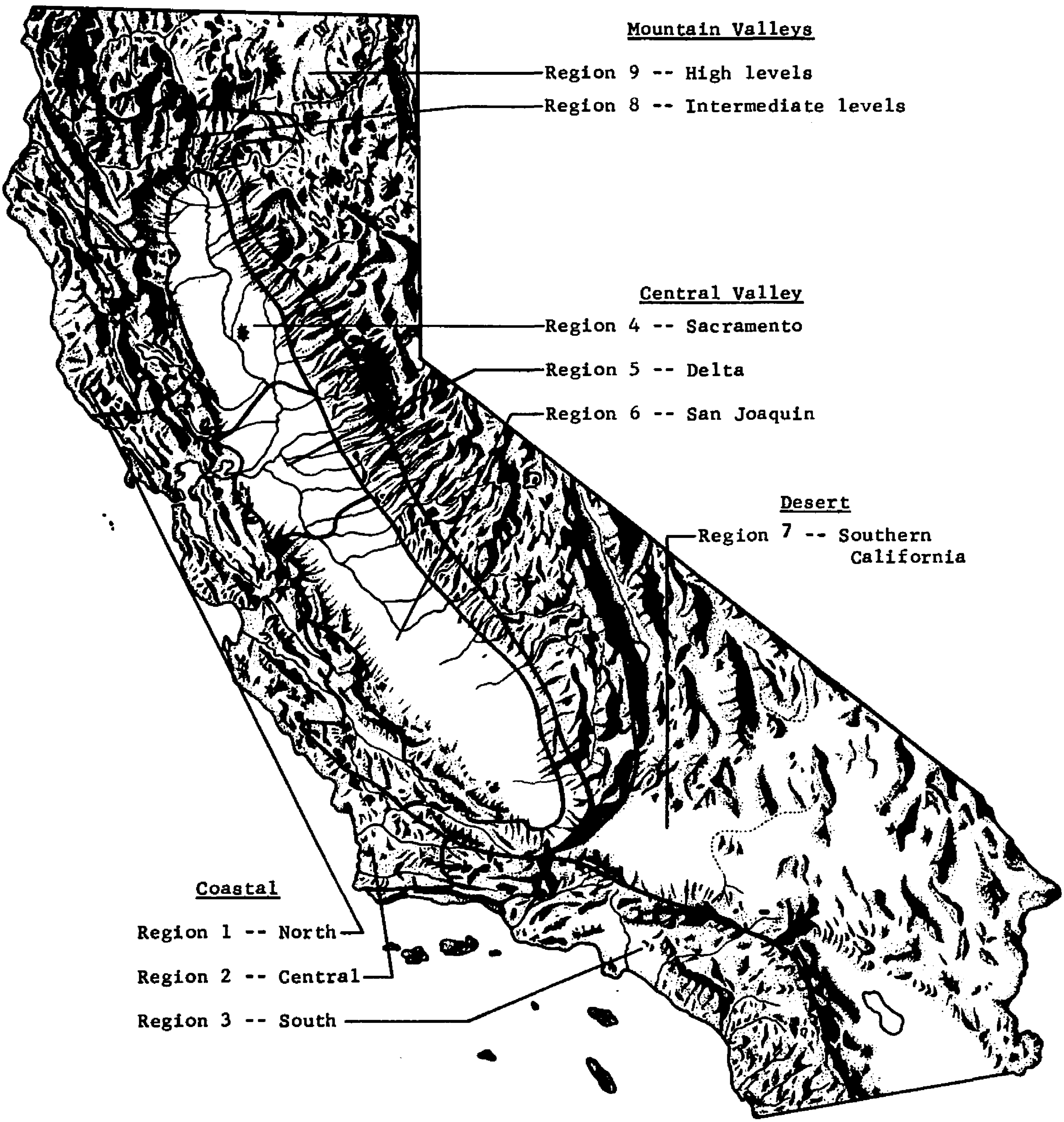

TABLE 7.2

Study Crop Land Use by Region in Base Period, Estimated Model Requirements

Crop activity	Region: Coastal 1	Coastal 2	Coastal 3	Central Valley 4	Central Valley 5	Central Valley 6	Desert 7	Mountain 8	Mountain 9	State[a]
	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 & 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 & spring (double crop)	0	0	0	0	0	0	0	0	0	0
Lettuce, fall or spring & 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	0	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 & 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	1,257.9
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	210.6	0	0	210.6
Sugar beets	0	72.0	72.0	0	0	96.4	0	16.0	0	256.4
Cotton	0	0	0	0	0	606.0	206.0	0	0	812.0
Total land utilized, Model 1961-65 optimal[a]	35.0	455.0	72.0	888.0	920.0	1,666.4	562.6	165.0	372.0	5,136.0
Residual land[b]	167	607	805	887	534	3,665	1,009	283	733	8,688
Net model acreage available, circa 1965[c]	202	1,062	877	1,775	1,454	5,331	1,572	448	1,105	13,828

a/ Computed from unrounded data.

b/ Includes acreage required for pasture and nonalfalfa hay.

c/ All figures except total are computed from unrounded data. Total is from Appendix Table B.2.

semiagricultural, and orchard and excluded vegetable crop requirements. Pasture and nonalfalfa hay were not introduced as model activities, nor were they inventoried and projected exogenously as were the excluded crops which generally return a higher marginal value product to land than the study crops. Therefore, the acreage required for pasture and nonalfalfa hay is included in the residual category in Table 7.2.

In no region do the optimal land requirements for the model crops equal the net model acreage available. In fact, not more than two-thirds of this acreage is so required in any region, and in many it is less than a third.

Irrigated Acreage -- Actual and Model Results

Of the crop activities in this study, all but two are specified as irrigated. Only 38,000 acres of nonirrigated barley enter the optimal solution. The remainder of the acreage would require irrigation. Optimal total irrigated acreage for all crops is estimated to be 4 percent higher than base period actual.

The largest percent increase in optimal regional irrigated acreage from the actual estimate is in Region 8. The largest increase in real terms is in Region 5. 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 7.3 presents the regional and regional group distribution of 1964 irrigated acreage, actual acreage used for excluded crops, and optimal requirements for the crops in this study.

Harvested Crop Acreage -- Model 1961-65 Optimal Versus 1961-65 Actual

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

TABLE 7.3

Irrigated Acreage by Region in Base Period, Actual and Estimated Model Requirements

Region	Region number	Included commodities		Commodities not in study		Base period total		Total model expressed as percent of actual
		Actual, circa 1961-65[a]	Model 1961-65 [b]	Irrigated pasture & nonalfalfa hay, circa 1965-66 [c]	Orchard & excluded vegetable crops, 1965-66[d]	Actual	Model[e]	
		1,000 acres						percent
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	206.4	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[f]		4,763.3	5,098.0	1,295.5	1,508.5	7,567.3	7,902.0	104.4

See footnotes on next page.

--Continued on next page.

Table 7.3 (continued)

a/ Computed as a residual: actual base period total less commodities not in study.

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

c/ Sources: 1964 Census of Agriculture [104] for irrigated pasture and proportion of nonalfalfa hay acreage which is irrigated; California Crop and Livestock Reporting Service [10] for 1965-66 acreage of nonalfalfa hay.

d/ All California vegetable crop acreage and 89 percent of the orchard crop acreage was reportedly irrigated in 1964 [104]. The approximate percentage of orchard and excluded vegetable acreage irrigated was estimated by region:

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

e/ Computed as the sum of commodities not in study and model included commodities.

f/ Computed from unrounded data.

is 5,369,000 acres[1/] or 11 percent less than actual acreage. 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 percent according to Model 1961-65 results. A similar shift from nonirrigated to irrigated safflower production[2/] (62 percent irrigated in 1964 and 100 percent in Model 1961-65 would cause a substantial decline in the acreage required for this crop.

The model results indicate that the base period output of several other crop groups could have been produced on considerably fewer land resources than were actually used. In addition to the three crops already cited, six groups are allocated by the model to less than 90 percent of

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1/ Harvested crop acreage differs from land requirements because of partial and complete double cropping activities on some land and a barley-fallow activity on other land. A summary comparison of base period actual and estimated model harvested acreage is recorded in Table 7.4 by region and by crop.

2/ 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 7.4

Harvested Study Crop Acreage by Region and Crop in Base Period, Actual and Estimated Model Requirements a/

Item	Region number	Actual	Model	Model less actual	Model as percent of actual
		1,000 acres			percent
REGION					
Coastal:					
North	1	6	35.0	29.0	583.3
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	42.9	-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		286	258.4	-27.6	90.3
Cotton		765	812.0	47.0	106.1
Total		6,019	5,369.0	-650.0	89.2

a/ Source: Appendix G.

their actual 1961-65 total acreage. Regional shifts in production are quite important in explaining the difference between actual and optimal acreage of some crops, but intraregional shifts between soils and climates are undoubtedly the more important for others.

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 less than 99 percent of actual acreage.

The model acreage of one crop, cotton, is actually 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 production. Marvin Hoover, University of California Extension Cotton Specialist, estimates that yields in this period were about 10 percent higher due to skip-row planting than they would have been from a 100 percent solid plant. Because only a solid plant activity is introduced in the linear programming models, 1961-65 acreage would have been exceeded by 10 percent if there 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 the small grains category, with optimal acreage being 452,400 acres lower than actual.

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 percent higher than actual, and model acreage in Region 3 (South Coast) accounts for only 33 percent of actual base period acreage.

Regional Shifts -- Individual Crop Harvested Acreage

Several very striking redistributions of the harvested acreage of individual crops are manifest between 1961-65 actual and optimum regional locations.[1/] Others are less pronounced. But if a general statement were to be made comparing the optimal to the actual patterns, it would be that regional shifts are the rule rather than across-the-board expansion or contraction of acreage in all major regions. The observations below emphasize this point:

1. Safflower production shifts from the Central Valley (Regions 4, 5 and 6) to the Desert (Region 7). The largest relative increase in a single regional crop acreage is safflower acreage in Region 7, with 1961-65 optimal being more than 200 times actual.
2. Asparagus acreage shifts from Regions 4 - 7, where the major concentration was in the San Joaquin Delta (Region 5), to the Central Coast (Region 2).
3. Sugar beet acreage is transferred from Regions 4, 5 and 7 to Regions 2 and 3, while the acreage in Regions 6 and 8 expand somewhat less.

1/ Appendix Tables G.1 to G.4 give the regional breakdown of harvested acreage by crop group:

Table G.1 -- 1961-65 actual
Table G.2 -- Model 1961-65 optimal
Table G.3 -- optimal less actual
Table G.4 -- optimal as a percent of actual.

4. Major grain sorghum production in the base period was actually in Regions 4 - 7. In the optimal solution, all production is concentrated in Region 5.
5. Corn production shifts northward in the Central Valley from Region 6 to Regions 4 and 5.
6. Optimal cotton acreage is higher in Region 7 and lower in Region 6.
7. Dry bean production in the South Coast (Region 3) moves northward to Region 2.
8. The only regions in which the small grain acreage increases are Regions 5 and 9.
9. Alfalfa acreage shifts northward completely out of Region 7 and partially out of Region 6 into Regions 4 and 5 in the Central Valley.
10. The dominant region for potato acreage is Region 2 in the optimal versus Region 6 in the actual pattern.
11. Tomato production in Regions 3 and 6 is moved to Region 2 while the acreage in Regions 4 and 5 remains quite similar to actual.
12. The concentration of production in the major producing regions is much greater in the optimal than in the actual pattern for rice, melons, lettuce, and the cole crops.

Synopsis of the Model 1961-65 Primal Solution

According to the model solution, the total cost of producing 1961-65 average output can be reduced by using fewer land resources. However, an increase in irrigated acreage would be necessary to partially offset the decrease in total land required. Some regional shifts are estimated to be optimal for all crops. Extensive relocations are indicated for several:

notably safflower, asparagus, sugar beets, alfalfa, and the feed grains. Significant declines in total harvested crop acreage are estimated for safflower, asparagus, and the small grains. The largest decline in both regional irrigated and harvested crop acreage is in Region 6, and the largest increase in both is in Region 5. Relative increases and decreases are significant for other regions also. In summary, the optimal production pattern is estimated to be quite different in all respects from the actual base period pattern.

Insights from the LP Dual Solution

The economic implications of the dual solution to a linear programming model are discussed in Chapter 2. In this cost minimization model, the dual includes the minimum total production cost, imputed price for each product, and imputed rent to each resource in fixed supply. Derived total product value and imputed price of each product are discussed in this section.

Production of Base Period Output at Least Total Cost

Total imputed value of production may be ascertained in either of two ways:

$$TV = \sum_j P_j X_j, \tag{7.1}$$

or

$$TV = TC + \sum_i V_i R_i, \tag{7.2}$$

where

TV is total imputed product value,

TC is total nonland production cost,

P_j is imputed price of 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.

It 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 nonland costs	935.0	Not available
Total rents	87.4	Not available
Value of production	1,022.4	1,133.3 1/

Imputed value of production is almost 10 percent lower than actual product value in the base period. 2/

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 exact long-run perfectly competitive equilibrium, the imputed price would be average market 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.
5. The price vector is not uniform in all areas because of the location of processing plants and commodity markets.

1/ Source: California Crop and Livestock Reporting Service [10, 14].

2/ With nonrepresentative crops in each crop group converted to units of the representative crop.

All of these factors would have some effect on the relative difference between imputed and actual price, but only the net is measurable in this study.

Imputed 1961-65 prices are generally lower than actual average product prices[1] for the same period (see Table 7.5). Of the 18 representative crops in the study, only five have an imputed price higher than actual price.[2] Eleven have imputed values between 70 and 99 percent of actual. The imputed price of safflower and grain sorghum are relatively the lowest at slightly more than 60 percent of actual. The imputed price of summer lettuce is relatively the highest at 113 percent of actual.

The imputed price for potatoes is 1 percent higher than actual. However, the imputed prices are 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 would be relatively lower.

One action taken in this study as a direct result of differences between Model 1961-65 imputed and 1961-65 actual prices was to add Model 1980C. This model was developed to force the relative imputed prices of the feed grain groups -- barley, corn, and grain sorghum -- to equal their relative feeding values.[3] 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.

1/ Actual weighted 1961-65 price is estimated as average price at the farm or at the first delivery point [10, 14]; it does not include government payments.

2/ The imputed prices average 88 percent of actual prices with an average deviation of 15 percent.

3/ Additional detail on the development of this model is given in Chapters 6 and 8, and the results are discussed in detail in Chapter 8.

TABLE 7.5

Crop Price, Weighted Base Period Actual, and Model Imputed

Representative crop	Price		
	Actual 1961-65[a]	Model 1961-65 optimal	
	$/ton harvested		percent of 1961-65 actual
Asparagus	273.18	249.10	91
Broccoli	160.60	137.12	85
Lettuce:			
spring & fall	81.92	65.03	79
summer	65.88	74.77	113
winter	77.70	74.97	96
Cantaloupes:			
spring & fall	111.44	82.48	74
summer	84.86	76.78	90
Potatoes	51.42[b]	51.85[c]	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	26.92	111
Dry beans	196.34	150.54[d]	77
Rice	99.06	81.25	82
Safflower	84.77	51.64	61
Sugar beets	11.66	12.55	108
	$/bale harvested		
Cotton	164.00	127.75	78

a/ Does not include any government payments

b/ Average price of all potatoes marketed.

c/ Imputed price of USDA No. 1's; imputed price per ton in Region 1 potatoes is $54.42.

d/ Imputed price per ton of Central Valley dry beans is $170.33.

If it can be assumed that the data used in the model are basically accurate and the model is adequate, the importance of this discussion of imputed and actual prices is to point out 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 in the production of summer lettuce, alfalfa hay, and sugar beets.[1/] While such a conclusion must be carefully qualified at this point, it is relevant to point out such observations that additional research may determine the 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 factor, then it becomes of economic (and possibly political) importance to find out 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? While definitive answers concerning the relative importance of each of these possibilities cannot be given by this study, the importance of raising relevant questions as a byproduct of analysis is not minimized either.

1/ In the absence of government payments.

Summary

In the introduction to this chapter, attention is given to the primary reasons for including a 1961-65 model in this study. The empirical discussion of this chapter has been developed exclusively to meet the first purpose -- a comparison of differences between the real world and the linear programming solution for the base period. The model solution suggests that the base period output might have been produced optimally on fewer land resources and at considerable saving to both producers and consumers. To do so, the acreage of irrigated land would have to have been increased, and extensive regional production shifts would have been necessary.

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

CHAPTER VIII

OPTIMUM LOCATION PATTERNS, 1980

This chapter is divided into four parts for the purpose of discussing the results of the 1980 models. The first section is devoted to a brief review of the alternative 1980 models. Secondly, the results of the primary 1980 models (i.e., Models 1980A and 1980B) are highlighted. A detailed discussion of regional production shifts and changes in product prices indicated by these models is bypassed in favor of focusing attention on the results of Model 1980C.[1/] The results of Model 1980C appear to be more realistic as to the feed grain production pattern than those of the primary models. Therefore, in the third section, the detailed results of Model 1980C are presented. Two additional issues, discussed in the fourth section as extensions to Model 1980D, are:

1. Demand for water at the farm level on the west side of the San Joaquin Valley with consequent implications to the California Water Project pricing policy, and
2. The effects of retaining the existing cotton allotment program (to include the findings in Model 1980D).

Brief Sketch of Alternative 1980 Models[2/]

The per acre cost and yield estimates are the same in all four 1980 models. Depending on the crop, the yield parameters range from 11 to 60 percent higher than in Model 1961-65. Nonland production cost parameters

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1/ Copies of the optimal cropping pattern and imputed product prices for any of the other models may be obtained from the writer.

2/ The structure of the various models was summarized also in Table 2.1.

are more than 23 percent higher than the base period estimates.

The irrigated acreage restraints are the same in all models. Although the land and rotation restraints do not vary between the 1980 models, they are lower than in the base period.

California output restraints are different in each of the models. Production levels of every crop are projected to be higher in each of the 1980 models than in the base period. In Model 1980A, minimum California output of each crop is projected to be the same share of U.S. output as in the base period. In Model 1980B, recent trends in the share supplied by California are used in projecting the 1980 California share of national production. Output restraints are the same in Model 1980C as in Model 1980B. However, an additional restraint is added to force selection of a least cost feed grain mix to meet aggregate feed grain output. This is in contrast to the previous models which specify a minimum output requirement for each feed grain. In Model 1980D, output restraints are the same as in Model 1980C, except for cotton and safflower. The cotton output restraint is the same as in Model 1980A, and the safflower restraint is higher than in any previous model. The final difference between Model 1980D and the other models is the imposition of a regional cotton allotment restraint in Model 1980D.

Highlights of the Primary 1980 Models

Between 1965 and 1980 nearly one million additional acres will be required for nonagricultural and excluded crop uses. The results from Models 1980A and 1980B indicate excess productive capacity in California although output levels for 1980 exceed those for the base period (see Table 8.1).

TABLE 8.1

Land Use, Harvested Acreage, and Product Value in California, Alternative Model Estimates and Base Period Actual

Item	1961-65		1980		
	Actual	Model	Model A, constant share	Model B, trend share	Model C, modified Model B
	1,000 acres				
I. Land use					
Nonagricultural land[a/]	2,403.2	2,403.2	3,221.3	3,221.3	3,221.3
Semiagricultural land[a/]	1,722.5	1,722.5	1,640.5	1,640.5	1,640.5
Agricultural requirements					
Commodities not in study[b/]					
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	5,122.4
Nonirrigated	1,163.0	38.0	52.0	35.0	26.0
Subtotal	5,926.3	5,136.0	5,501.3	5,702.0	5,148.4
All commodities					
Irrigated	7,567.3	7,902.0	8,413.0	8,630.7	8,086.1
Nonirrigated	1,569.6	444.6	478.5	461.5	452.5
Total agricultural requirements	9,136.9	8,346.6	8,891.5	9,092.2	8,538.6
Idle land	6,362.7	7,153.0	5,872.0	5,671.3	6,224.9
Total land inventoried	19,625.3	19,625.3	19,625.3	19,625.3	19,625.3
II. Harvested acreage, included commodities	6,019.0	5,369.0	5,740.8	5,924.0	5,827.8
	million dollars				
III. Product value, included crops					
Nonland costs	NA	935.0	1,275.4	1,381.8	1,354.6
Rents	NA	87.4	141.9	143.5	142.7
Value of production	1,133.3	1,022.4	1,417.3	1,525.3	1,497.2

a/ Source: Appendix Table B.2.
b/ Orchard and excluded vegetable crops, pasture, and nonalfalfa hay acreage.

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 remaining idle. However, more inputs of all resources would be needed than were required in the base period model solution. Land requirements for study crops are 7 percent higher, and irrigated acreage requirements for all crops are 6 percent higher. In comparison with the resources actually used in the base period, 7 percent less land for study crops and 11 percent more total irrigated land would be needed. Potential agricultural land remaining idle[1/] is estimated to be 8 percent lower than the base period actual and 18 percent lower than base period optimal. Although study crop land requirements in the Model 1980A solution are 7 percent lower than base period actual, harvested acreage of the study crops is only 5 percent lower because of a larger proportion of double cropped acreage in the 1980 model solution. The proportion of double cropped acreage is approximately the same in the model solutions of both time periods.

An interesting observation concerns the regional distribution of study crop harvested acreage in the two model solutions. In eight of the nine regions (Region 4 being the only exception), optimal 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 would

1/ Assumes that pasture and nonalfalfa hay acreage remains at the 1961-65 level.

be to partially offset the difference between the model solution and the actual pattern in the base period.

Imputed value. Imputed total product value[1/] is 25 percent higher than 1961-65 actual and 39 percent higher than the imputed value from the 1961-65 model. Similarly, nonland production costs are 36 percent higher than the base period model suggests, and imputed rents to fixed resources are 62 percent higher than the optimal solution in the base period model.

In general terms, it may be observed that 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 8.1 for two time periods for a case of a stepped supply curve and an inelastic demand curve. With a 40 percent 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 a 60 percent increase in quantity demanded (Q_1 to Q_{2b}), rents increase relatively less than the increase in value of production. There is some point, but 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 have equal step increments and 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

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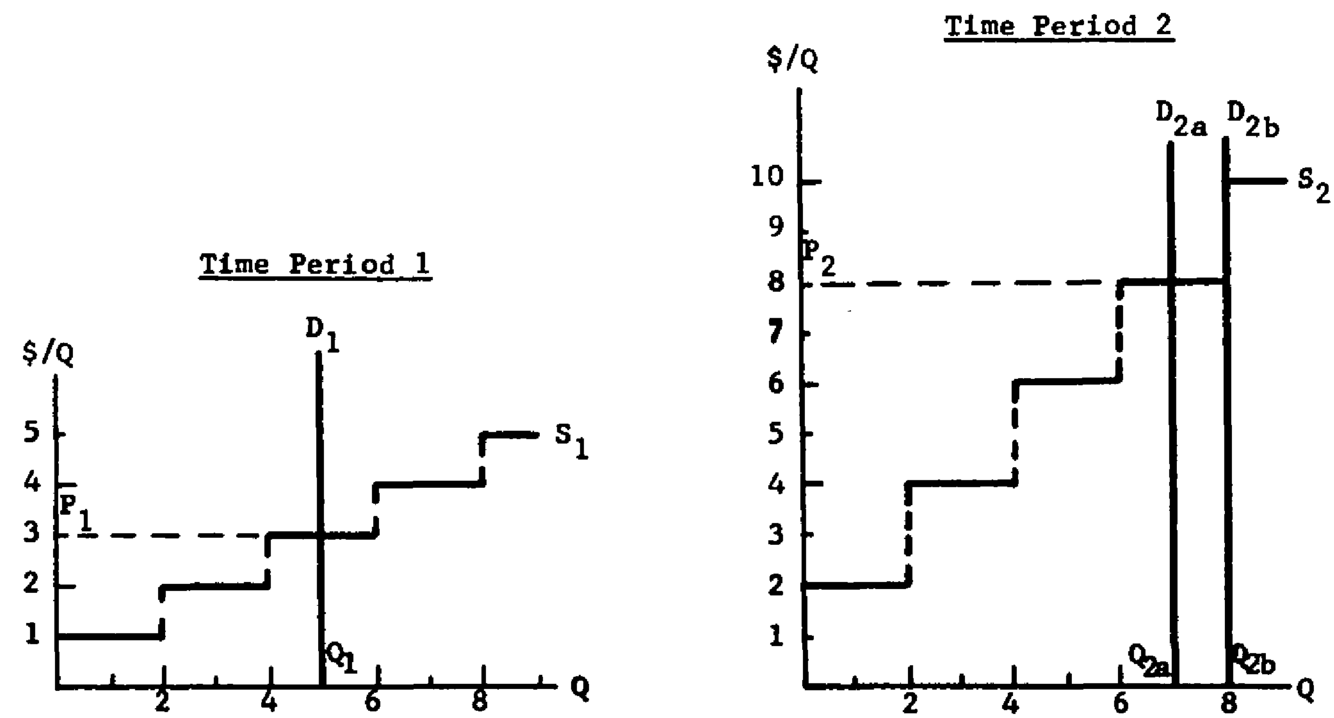
1/ In representative crop units.

FIGURE 8.1

Hypothetical Single Commodity Step Supply Curves and Inelastic Demand Curves in Two Time Periods Between Which Unit Costs Double and Quantity Demanded Increases Alternatively 40 Percent and 60 Percent



$TR_1 = 15$ $TR_{2a} = 56$ $TR_{2a}/TR_1 = 3.73$ $TR_{2b} = 64$ $TR_{2b}/TR_1 = 4.27$

$TC_1 = 9$ $TC_{2a} = 32$ $TC_{2a}/TC_1 = 3.56$ $TC_{2b} = 40$ $TC_{2b}/TC_1 = 4.44$

$R_1 = 6$ $R_{2a} = 24$ $R_{2a}/R_1 = 4.00$ $R_{2b} = 24$ $R_{2b}/R_1 = 4.00$

where

S_i is supply curve (or marginal cost curve) in time period i,

D_{ij} is demand curve in time period i and alternative j,

P_i is equilibrium price in time period i,

Q_{ij} is equilibrium quantity in time period i with demand curve j,

TR_{ij} is total value of production (PQ) in time period i with demand curve j,

TC_{ij} is variable production cost (area under supply curve) in time period i with demand curve j,

R_{ij} is rent to fixed resources (or producer surplus) in time period i with demand curve j.

greater than that of product value in all cases. Therefore, there is some justification for inferring that optimum capitalized land value for agriculture will likely increase proportionately more than value of farm production between the base period and 1980.[1/]

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 percent. The output of sugar beets, tomatoes, and 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 in Chapter 1, California has more than enough agricultural capacity to produce its projected share of 1980 U.S. output. More inputs of all resources would be required than were needed in the base period model solution. Land requirements for study crops are 11 percent higher and irrigated acreage requirements for all crops are 9 percent higher. In comparison with the base period actual requirements, 4 percent less land for study crops and 14 percent more total irrigated land would be needed. Potential agricultural land remaining idle is estimated to be 11 percent lower than the base period actual and 21 percent lower than the base period optimal.

The reduction in idle land reserves from the actual base period levels is due entirely to additional demands for land in the nonagricultural and excluded crop sectors. Although Model 1980B output projections of field

1/ If the interest rate on alternative investments does not increase between these time periods.

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 would have to be irrigated, two crops a year would have to be produced on a larger proportion of the acreage, and farmers would have to adjust their cropping practices to optimal production patterns.

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

Best 1980 Projections

At the inception of this study, only two 1980 models, possessing alternative demand assumptions, were planned. However, an unrealistic relationship was obtained between the relative feeding value of corn and grain sorghum and their imputed prices in Models 1961-65, 1980A, and 1980B.[1/]

1/ There was a significant disparity also between relative imputed and actual base period feed grain prices, although prices in the past decade have not correlated closely with scientifically estimated feeding values. Of the 20 annual price ratios of barley and grain sorghum to corn in this period, all but three have been lower than relative feeding value for major types of livestock and poultry. This observation is true when feeding value is computed as net energy only and also when digestible protein is assessed. The cause for this disparity has been attributed by some university specialists to old wives' tales, lower quality of sorghum inshipments, 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.

In addition, the imputed prices of corn and barley in Models 1980A and 1980B were not in agreement with their relative feeding values. Because of this disparity, 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.[1/] All other output restraints and parameters remain at Model 1980B levels.

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

To facilitate the orderly presentation of these results, this section is divided into six subsections. In the first three, the major insights apparent from the primal solution are discussed: land use, irrigated acreage requirements, and harvested crop acreage in that order. These insights are summarized in the fourth subsection. In the fifth, attention is focused on the dual solution. And the sixth is concerned with the sensitivity of the optimal solution to errors in parameter estimation.

Land Use Pattern

Land units required to produce Model 1980C output amount to 5,148,400 acres, as shown in Table 8.1. This is only 12,400 acres more than optimal acreage in Model 1961-65 and is the lowest of the 1980 models, being more than 1/2 million acres less than Model 1980B requirements.

1/ Detail on the development of this restraint is given in Chapter 6.

The minimum cost feed grain mix, which is comprised of 38 percent small grains,[1] 62 percent grain sorghum, and no corn, is produced almost exclusively in barley-grain sorghum double crop activities. An additional 652,200 acres of the double crop activity displaces 1,118,600 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 land requirements 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. However, projected idle land in Model 1980C is only about 140,000 acres less than actual idle land in the base period.

Regional study crop acreage requirements. Some production of study crops is projected by this model in all regions (see Table 8.2). 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 optimal acreage is anticipated. While the difference 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, the relative shifts between the optimal base period and Model 1980B solutions were almost as great. Regional adjustments both in individual and total 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 study crops.

Soil categories required for crop activities. From Table 8.3 it is observed that production is concentrated almost entirely on alluvial and basin soils. The only soil group entirely used for production is soil 11

1/ Oats and barley in units of barley, the representative crop.

TABLE 8.2

Study Crop Land Use by Region in Base Period, Estimated Model 1980C Requirements

Crop activity	Region: Coastal 1	Coastal 2	Coastal 3	Central Valley 4	Central Valley 5	Central Valley 6	Desert 7	Mountain 8	Mountain 9	State a/
	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 & 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 & spring (double crop)	0	0	0	0	0	0	0	0	0	0
Lettuce, fall or spring & 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	36.0	14.5	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	14.7	14.7
Barley & grain sorghum (irrigated, double crop)	0	4.0	0	249.6	314.0	335.8	0	0	0	903.4
Grain sorghum (single crop)	0	0	0	0	0	0	0	0	0	0
Alfalfa hay	24.0	16.0	0	207.8	340.0	267.0	0	61.3	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	266.4	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	36.0	0	311.4
Cotton	0	0	0	0	0	954.3	202.0	0	0	1,156.3
Total land utilized, Model 1980C optimal a/	24.0	366.7	53.0	843.0	855.0	2,082.4	477.9	119.4	327.0	5,148.4
Residual land, projected 1980 b/	172	546	415	870	502	3,094	1,062	323	777	7,757
Net model acreage available, projected 1980 c/	196	913	468	1,713	1,357	5,176	1,540	442	1,104	12,905

a/ Computed from unrounded data.

b/ Includes acreage used for pasture and nonalfalfa hay.

c/ All figures except total are computed from unrounded data. Total is from Appendix Table B.2.

TABLE 8.3

Total Land Use for Study Crops by Soil Category, Estimated Model 1980C Requirements

Soil type	Soil number	Net model acreage available, projected 1980 a/	Total land utilized by study crops, Model 1980C optimal b/	Residual land, projected 1980 c/
		1,000 acres		
Alluvial:				
Loam	01	1,377	981	396
Loam	02	956	834	122
Loam	03	2,384	774	1,610
Sandy	05	380	266	114
Subtotal		5,097	2,855	2,242
Basin:				
Organic	11	319	319	0
Clay	12	1,913	1,458	455
Clay with salts	13	479	247	232
Basin rim	14	301	119	182
Basin rim with salts	15	788	127	661
Subtotal		3,800	2,270	1,530
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	5,148	7,757

a/ 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.

b/ Refer to Appendix Table G.11 for detail.

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

(organic 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.1/

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 very 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 estimated 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 of them. 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 122 elements in the optimal basis, which includes acreage in 18 of the 24 different crop activities. The acreage of a crop activity is limited in 3 instances by irrigated acreage restraints, in 69 by rotation restraints, in 32 by net model acreage restraints, and the limiting restraint for 18 others is minimum crop output. The Model 1980C study crop activity acreage in each HPA is recorded in Appendix Table G.12 together with an identification of the variable which restricts production in each case.

1/ Refer to Appendix Table G.11 for the Model 1980C distribution of included crop activities by soil category.

Irrigated Acreage Required

All but 20,000 acres in the Model 1980C optimal basis are irrigated production activities. Irrigated acreage requirements for all crops are 7 percent higher than estimated base period acreage actually irrigated (see Table 8.4). They are only 2 percent higher than the base period optimal irrigated acreage and 6 percent 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 percent lower than base period actual rather than being higher as is the base period optimal solution. Region 8 shows the largest relative increase over the base period actual in this model as well as in Model 1961-65. The largest absolute acreage increases are in Regions 4 and 5, with almost equal changes in both.

The projected regional changes in total irrigated acreage are quite different when the comparison is between Model 1980C and the base period optimum. 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.

Harvested Crop Acreage

Optimal 1980D acreage of model crops harvested is 5,827,800 acres. While total land required for these crops in 1980 is projected to be very similar to the 1961-65 optimal, harvested crop acreage is 458,700 acres higher. This is an 8.5 percent increase. However, it is still 191,200 acres, or 3.2 percent, less than actual 1961-65 crop acreage. A similar contrast to that of the 1961-65 optimum is observed when Model 1980C is

TABLE 8.4

Irrigated Acreage by Region, Estimated Model 1980C Requirements

Region	Region number	Model 1980C optimal	Orchard & excluded vegetable crops, projected 1980 a/	Total b/	Projected 1980: Total as percent of base period actual	Projected 1980: Total as percent of base period optimal
		1,000 acres			percent	
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	1,294.9	124	98
Delta	5	855.0	226.0	1,318.6	124	97
San Joaquin	6	2,082.4	773.6	3,265.9	94	118
Subtotal		3,780.4	1,228.3	5,879.4	105	108
Desert:						
Southern California	7	477.9	58.4	586.3	94	88
Mountain Valleys:						
Intermediate	8	119.3	20.9	160.4	260	79
High	9	327.0	2.6	559.8	154	93
Subtotal		924.2	81.9	720.2	170	89
State c/		5,122.4	1,668.2	8,086.0	107	102

a/ See footnote "d" in Table 7.3 for the percentage of these crops irrigated in each region.

b/ 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.

c/ Computed from unrounded data.

compared with the Model 1980B optimum. Total land required is more than 1/2 million acres less in Model 1980C, but the difference in harvested crop acreage is less than 100,000 acres. The shift to much more double cropping of feed grains in Model 1980C is responsible for the increased disparity between relative total land and harvested crop acreage.

Major changes in crop acreage. As indicated in Table 8.5, the largest relative increase in the harvested acreage of any crop group between 1961-65 actual and Model 1980C is for sorghum, where acreage increases almost 190 percent. The acreage of safflower increases 96 percent and of cotton, 51 percent. 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 percent. Decreases include corn, 100 percent (no corn is projected for production by this model); small grains, 58 percent (due to a lower projected output and extensive conversion from dry land to irrigated production); asparagus, 32 percent (resulting from higher yields in the new production locations); and melons, 25 percent (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 percent of original acreage.

Harvested acreage of small grains shows the greatest 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 percent higher than in the base period, and output in 1980 is only 22 percent 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.

TABLE 8.5

Harvested Study Crop Acreage by Crop in Base Period and 1980, Actual and Estimated Model Requirements[a/]

Crop group	Base period		1980				
	Actual	Model	Model C	Model C less base period actual	Model C as percent of base period actual	Model C less base period model	Model C as percent of base period model
	1,000 acres				percent	1,000 ac.	percent
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	793.8	-1,077.2	42.4	-624.8	56.0
Sorghums	265	232.5	766.1	501.1	289.1	533.6	329.6
Alfalfa	1,276	1,259.9	1,294.1	18.1	101.4	34.2	102.7
Dry beans	217	194.2	192.9	-24.1	88.9	-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

a/ Source: Appendix G.

In comparison also with Model 1961-65 crop acreage, the largest relative and absolute increases in Model 1980C crop acreage are 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 1961-65 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 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.

<u>Regional shifts -- total harvested acreage.</u> Major regional acreage changes from 1961-65 actual include relative increases of 300 percent in Region 1 and 107 percent in Region 9 and decreases of 76 percent in Region 3 and 52 percent in Region 8, as recorded in Table 8.6. In absolute terms the largest increases are 269,800 acres in Region 5 and 169,000 in Region 9. The largest decrease is 340,200 acres in Region 6. Other regions with sizeable decreases include 3, 7 and 8.

When compared with the 1961-65 optimal, the largest relative change is a 40 percent increase in Region 6 acreage. The only other region with a projected increase in Region 4. Declines are greatest in Regions 1, 3 and 8 with 31, 26 and 28 percent 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 7 of the 9 regions.

TABLE 8.6

Harvested Study Crop Acreage by Region in Base Period and 1980, Actual and Estimated Model Requirements[a/]

Region	Region number	Base period		1980				
		Actual	Model	Model C	Model C less base period actual	Model C as percent of base period actual	Model C less base period model	Model C as percent of base period model
		1,000 acres				percent	1,000 ac.	percent
Coastal:								
North	1	6	35.0	24.0	18.0	400.0	-11.0	68.6
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	1,074.8	269.8	133.5	-34.6	96.9
San Joaquin	6	2,679	1,666.4	2,338.8	-340.2	87.3	672.4	140.4
Subtotal		4,406	3,663.8	4,406.4	0.4	100.0	742.6	120.3
Desert:								
Southern California	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	72.3
High	9	158	372.0	327.0	169.0	207.0	-45.0	87.9
Subtotal		407	537.0	446.3	39.3	109.7	-90.7	83.1
State		6,019	5,369.0	5,827.8	-191.2	96.8	458.7	108.5

a/ Source: Appendix G.

<u>Regional shifts -- individual crop harvested acreage.</u> Several major shifts in the regional distribution of individual crops are noted between the 1961-65 optimal and the Model 1980C solution:[1/]

1. Grain sorghum production is expanded mainly in Regions 4 and 6, from which production was originally shifted to Region 5 in the base period model solution. It is interesting to note in Table G.7 that as output expands, sorghum acreage in Regions 4, 5, and 6 increases almost proportionately from the actual base period acreage.
2. Some of the bean production returns to Region 3 such that 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. The major increase in safflower acreage is in Region 6. Approximately 53 percent 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.

1/ Appendix Tables G.5 to G.9 record absolute and relative acreage comparisons of regional harvested acreage by crop group between Model 1980C optimal and 1961-65 actual and optimal patterns:

Table G.5 -- 1980C optimal,
Table G.6 -- 1980C optimal less 1961-65 actual,
Table G.7 -- 1980C optimal as a percent of 1961-65 actual,
Table G.8 -- 1980C less 1961-65 optimal,
Table G.9 -- 1980C as a percent of 1961-65 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 percent of the State's optimal base period alfalfa acreage shifts from the Central Valley to the mountain valleys (particularly to Region 9).

6. Major declines in small grain acreage occur in Regions 6-9. The only region with a projected increase in optimal acreage is Region 4.

7. All expansion of cotton acreage takes place 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 percent 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 Region 5, giving the latter the largest share of the total in 1980.

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

<u>Synopsis of the Model 1980C Primal Solution</u>

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 due to increased demand. Included crop land requirements 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, the land requirements in all of the 1980 models are lower than actual requirements in the base period.

Harvested study 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 contrasts also can be observed between the 1980C solution and any of the other model solutions.

In the following part of this section, the imputed product value and rents to fixed resources as obtained from Model 1980C will be presented.

Insights from the Model 1980C Dual Solution

The imputed value of Model 1980C output is nearly $1.5 billion. This figure is 32 percent higher than the actual value of base period output and 46 percent higher than the imputed value of Model 1961-65 production. The increase in imputed product value over the base period is due to 1) generally higher unit costs, 2) higher output requirements, and 3) less land available in 1980 in HPAs on which production was allocated by the base period model. Nonland production costs are 45 percent higher than suggested by Model 1961-65, and imputed rents are 63 percent higher (see Table 8.1).

Least cost feed grain mix. Output requirements and all other parameters in Model 1980C are exactly 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 study crops is approximately $28 million lower than the Model 1980B imputed value. Shifting from a 1980 feed grain mix in which the percentage of individual feed grains in the mix remains the same as during the base period to a least cost mix results in a saving of 2 percent in imputed value of study 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 $31 million less. This relative saving in imputed feed grain product value over Model 1980B rations amounts to 18 percent. If production occurs under perfect competition, this is the saving that would be passed on to the feeding industry.[1/] 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 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.

1/ California is a deficit region in the supply of feed grains (i.e., demand has historically exceeded production within the State). This situation is projected to continue to 1980, so that feed grains will still be shipped into California. Hence, if the imputed value of feed grains produced in the State is lower than the cost of feed grains shipped in, under equilibrium conditions the production of these crops would be increased within California, and inshipments would be decreased.

<u>Imputed value of restricting Variables.</u> 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 G.12.

The highest imputed rent to an additional acre of land is $61.25 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 $40.83 in the Central Coast HPA 0222 and $26.64 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 $87.69 could be spent on nonland resources to relax by one acre the rotation restraint for cotton in the Desert HPA 0372. Similarly, $73.69 in HPA 0572, $61.00 in the San Joaquin Valley HPA 1362, $60.00 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.

Model 1980C representative crop imputed prices (or the marginal costs of production expressed as positive values) average 4 percent lower than actual 1961-65 prices and 10 percent higher than imputed 1961-65 prices (see Table 8.7). The average deviation of 1980C imputed prices as a percent of base period actual is 19 percent. 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 percent of base period imputed is lower at 11 percent. There are at least two obvious implications of the relative magnitude of these deviations:

1. The impact on the relative product price vector is due less to changing cost, yield, and output parameters between the two time periods than to the net effect of: 1) higher price-cost ratios in the base period for some crops than for others, 2) the possibility for decreasing costs by moving to optimal locations, and 3) 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 1980Cimputed prices which are the largest relative to 1961-65 actual prices are for summer lettuce (+31 percent), alfalfa hay (+24 percent), and sugar beets (+24 percent). The lowest relative to the base period actual are for safflower (-34 percent), barley (-28 percent), tomatoes (-26 percent), and corn (-24 percent). The highest 1980C prices relative to 1961-65 imputed prices are for grain sorghum (+26 percent), asparagus (+21 percent), dry beans (+21 percent), and cotton (+20 percent).

TABLE 8.7

Crop Price, Model 1980C Imputed

Representative crop	Model 1980C imputed price	Percent of 1961-65 actual[a]	Percent of Model 1961-65
	$/ton harvested	percent	
Asparagus	302.22	111	121
Broccoli	146.47	91	107
Lettuce:			
spring & fall	76.90	94	118
summer	86.26	131	115
winter	85.38	110	114
Cantaloupes:			
spring & fall	97.06	87	118
summer	90.84	107	118
Potatoes	58.45[b]	114[f]	113
Tomatoes, processing	21.26	74	95
Corn for grain	38.99[c]	76	78
Barley	33.47[d]	72	71
Grain sorghum	34.55[d]	79	126
Alfalfa hay	30.17	124	112
Dry beans	181.97[e]	93	121
Rice	78.07	79	96
Safflower	55.81	66	108
Sugar beets	14.48	124	115
	$/bale harvested		
Cotton	152.92	93	120

a/ 1961-65 actual price does not include any government payments.

b/ Imputed price of USDA No. 1's; imputed price per ton of Region 1 potatoes is $60.77.

c/ No corn activities entered the optimal basis. The imputed cost of producing a ton of corn is $3.00 more than producing a ton equivalent of barley or grain sorghum.

d/ Estimated from imputed price of feed grains which is $35.99. Imputed price of barley is 93 percent of feed grain price, and grain sorghum is 96 percent.

e/ Imputed price per ton of Central Valley dry beans is $195.12.

f/ 1961-65 actual potato price is the average for all potatoes marketed.

The lowest are for barley (-29 percent) and corn (-22 percent). Each of these crops whose 1980 to 1961-65 imputed price ratio is at one of the extemes 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 in the paragraphs below.

There are 122 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 percent. In a second mutually exclusive subset of 18, underestimation of between 1 and 2 percent would cause an incorrect solution; in another of 31, 2-5 percent, in a fourth of 27, 5-10 percent, and in 16 the underestimation would have to be greater than 10 percent. Some of the changes so prompted in the basis would amount to only a few acres of a crop shifting location and others to more than 10,000 acres changing. No summarization has been made of the effect of data errors in the nonbasic 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 solution 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 percent 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 percent and in the other it is raised 25 percent. The imputed price of feed grains in corn ton equivalents is $35.94 in the first and $36.55 in the latter as compared to $35.99 in Model 1980C. When output is decreased 25 percent, imputed price decreases only .14 percent; when increased 25 percent, imputed price increases 1.55 percent. The only other crops for which the imputed price varies between models are alfalfa (-.07 percent in the former and +.07 percent in the latter) and rice (+.81 percent in the latter).

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.

No general comment can be made concerning the sensitivity of the production pattern to possible data errors. The solution is sensitive to extremely minor data errors in some elements and insensitive to sizable errors in some others. The direction of the error, as well as its magnitude, is important.

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.

The remaining sections of this chapter will be devoted to a discussion of two extensions of this model:

1. In the first extension, a demand function for water on the west side of the San Joaquin Valley is derived.
2. In the second, the extent of resource misallocation from continuing the current cotton allotment programs is suggested.

Westside San Joaquin Valley Water Pricing

Relevance of the Parametric Pricing Problem

Not all alluvial soil in the San Joaquin Valley enters the optimal solution of the base period or 1980 models. Because of high water costs on the Westside, only a portion of the acreage in HPAs 0362 and 0363 is used for production in any of them. 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, the Westside area has been only partially irrigated by deep wells which are steadily exhausting the ground water sources. It has been a land of cotton fields, ranches, oil fields, and tumbleweed. So the optimal model patterns are not dissimilar to the current pattern.

However, beginning in 1970 the California Aqueduct, a part of the comprehensive California Water Project, will begin delivering millions of acre feet annually to a large share of HPA 0362 and 0363 land. In fact, it is anticipated in the planning of the California Water Project that more than 1/2 million acres of this land will be irrigated in 1980.[1/] But given the currently estimated cost of water and the production

1/ Verbal estimates of idle land in this area in 1980 include: Fresno County - 125,000 acres, Kings County - 160,000 and Kern County - 190,000. The sources of these estimates were David De Bruyn, Hydrologic Engineer, U.S.Bureau of Reclamation, and Glenn Sawyer, Senior Land and Water Use Analyst, California Department of Water Resources.

alternatives considered in this study, less than 1/3 of the 1 million acres in this area enters any of the optimal solutions.[1/]

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 the Westside. Since the California Aqueduct is a joint State and Federal project, 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 Westside. This programming method is a modification of the

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1/ 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 orchard and excluded vegetable crops. Even if a major portion of the projected net acreage expansion of these crops between 1961-65 and 1980 were to occur on HPA 0362 and 0363 land, it would require less than 100,000 additional acres. 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.

standard simplex linear programming model.[1] 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, it may indicate the optimum quantity of water to be purchased at each possible unit cost. In this case, the optimum acreage of land to be irrigated in relation to water cost is determined simultaneously.

Solutions are obtained at 1965 water cost increments of $2 per acre foot in HPAs 0362 and 0363. For each crop activity in these HPAs, the estimated nonland costs of production for 1980 are systematically reduced by a reduction in the cost of irrigation water. Because of the method of budgeting and projecting costs used in this study, a $1 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 $ 1.353 in the 1980 cost. Therefore, in the discussion to follow, when a $2 decrease in the 1965 water cost per acre foot is mentioned, it really refers to a $2.706 decrease in 1980 nonland production cost.[2]

Demand for Irrigated Land on the Westside

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 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 417,000 acres is brought into production. Hence, the marginal cost of water to the farmer would have to be reduced between

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1/ See Heady and Candler [51A, Chapter 8] for a discussion of variable cost programming.

2/ The irrigation requirements for each crop are recorded in Table D.1. The 1965 cost per acre foot is $14.70 in HPA 0362 and $19.36 in 0363. The total generated nonland production cost in 1980 per acre foot of water applied is $19.89 in 0362 and $26.19 in 0363.

$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 acreage in these two HPAs at each incremental price level are recorded in Table 8.8.

Westside 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 that which is delivered via 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:

$$\log_{10} Q = 3.64 - .052\, P_{0362},$$
$$\log_{10} Q = 3.89 - .052\, P_{0363},$$

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,

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

It is observed that the regression coefficient is the same in both equations. The difference in the intercept value is due to the average water cost differential of $4.66 between the two HPAs.

The demand equation is plotted on a semilog scale in Figure 8.2. The 1965 price of water in each HPA is identified on the horizontal axis and the combined quantity demanded in both HPAs on the vertical axis.

TABLE 8.8

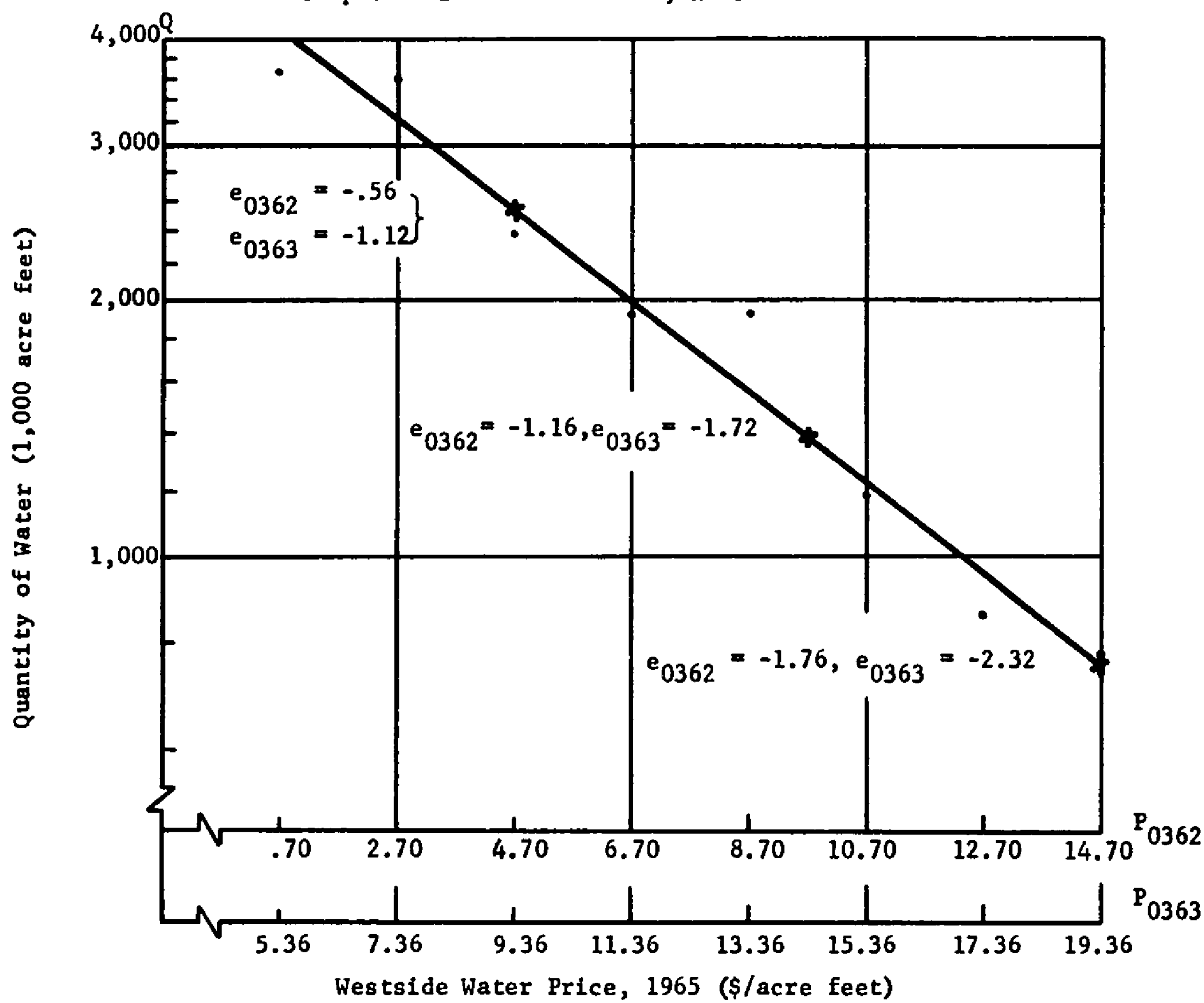
Model 1980C Crop Activity Acreage in HPAs 0362 and 0363 at Alternative 1965 Prices of Water

HPA 0362								
1965 water price per acre foot	Alfalfa hay	Barley-sorghum	Cotton	Dry beans	Safflower	Cantaloupes	Potatoes	Total
dollars	acres							
14.70			166,000			40,936		206,936
12.70			166,000			40,936		206,936
10.70			166,000	46,694		40,936		253,630
8.70			166,000	64,872	220,188	40,936	12,003	503,999
6.70			166,000	64,872	220,188	40,936	12,003	503,999
4.70	58,725	28,540	166,000		220,188		30,547	504,000
2.70	293,489	44,511	166,000					504,000
.70	338,000		166,000					504,000

HPA 0363						
1965 water price per acre foot	Dry beans	Cotton	Safflower	Sugar beets	Cantaloupes	Total
dollars	acres					
19.36		65,329				65,329
17.36		94,742				94,742
15.36		163,000				163,000
13.36		163,000				163,000
11.36		163,000				163,000
9.36	64,872	163,000			41,319	269,191
7.36	61,394	163,000	185,628	43,659	41,319	495,000
5.36	35,756	163,000	196,628	58,297	41,319	495,000

FIGURE 8.2

Composite Demand for Water, HPAs 0362 and 0363



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 8.2. 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. The total quantities on the Westside demanded at the low, medium, and high prices in HPA 0362 are the same as at the respective HPA 0363 prices.

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 maximized 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 Westside of the San Joaquin Valley is the inelastic demand for water on Tulare County farms estimated by Moore and Hedges [628, p. 133]. At a 1965 water price per acre foot of $9.70 in HPA 0362 or $9.36 in HPA 0363, the Westside demand for water is elastic. A 1 percent decrease in price would result in more than a 1 percent increase in quantity demanded, so total revenue 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 percent decrease in price would result in only a .188 percent 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 sets of demand curves for water were derived by a similar procedure. Parametric programming was used in both studies. However, certain differences are apparent in the underlying assumptions and technique, as well as the area of analysis. Moore and Hedges derived their aggregate demand function from an individual farm approach for different sized farms. Based on a single set of typical production conditions and unit costs in each HPA, a more aggregative approach is used in this study. The demand curve of Moore and Hedges included the water demanded for orchard and vineyard crops, whereas in this study it does not. Such crops make up a significant portion of the agricultural acreage in Tulare County and are higher valued crops than most of those in this study. Because water costs comprise a smaller portion of nonland production costs for orchard and vineyard crops than for the field crops and vegetables which are projected fcr production on the Westside, one would expect the water demand for the former to be less elastic than for the latter.

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 Westside for which water is expected to be available in 1980.

2. Annual revenues to suppliers of water on the Westside may be increased by lowering the unit price of water sufficiently to irrigate all of the land which the water agencies have estimated will be irrigated in 1980. There are important implications, however, for other producing regions in the State if such a policy were adopted.

Impact of Imposing a Regional Cotton Allotment Restraint

Although only one model is identified in the previous chapters with a regional cotton allotment restraint, the question about cotton allotments raised in Chapter 1 really requires answers from two slightly different models. The first issue is to estimate the effect on cost and production locations from imposing an acreage allotment restraint without changing anything else in Model 1980C. The second model (1980D) is needed to project production patterns and provide related information when output levels are also affected by the acreage allotments. The allotment restraint in both cases distributes cotton acreage regionally in the same proportions as did 1968 allotments - 90.9 percent to the San Joaquin Valley and 9.1 percent to the Desert.

Allotment Restraint without Modifying Output Levels

Model 1980C nonland production costs are increased more than $27 million by imposing current relative regional allotments. Cotton acreage is increased 26,900 acres, with Region 6 increasing 121,300 acres and Region 7 decreasing 94,400 acres. With the exception of a small acreage of sugar beets and alfalfa shifting from Region 6 to Regions 2 and 8 respectively, no other regional crop shifts are prompted by the transfer of cotton to Region 6.

Cotton production replaces 19,200 acres of alfalfa and 4,400 acres of sugar beets in HPA 0161 and expands by 97,700 acres in HPA 0363. HPA 0572, with 43,000 acres of cotton, is removed from production, and the cotton acreage in HPA 0372 declines by 51,400 acres.

The only imputed price which is different because of the cotton allotment is for cotton itself. Another bale of cotton can be produced for \$151.50 versus \$152.92 in Model 1980C. In Model 1980C the imputed price is the marginal cost of producing one more bale in HPA 0363. Here it is the marginal cost of producing part of the bale in Region 7 and the rest of it in Region 6.

Although the LP solution does not indicate the imputed rent to the transfer of an acre of cotton allotment from Region 6 to Region 7, this value can be estimated. If another bale of cotton were to be produced in Region 7, it would be grown in HPA 0372 at a cost of \$123 per bale. Neither land nor the cotton rotation restraint are restricting resources in this production area. The only cost incurred in expanding cotton production is its nonland cost of production indicated above. If another bale were to be produced in Region 6, it would be grown in HPA 0161. Because land is a restricting resource in this area, an acre of a crop already being produced there would have to be shifted to another HPA to make room for an additional acre of cotton. Hence, the marginal cost of producing more cotton in HPA 0161 is greater than its nonland production cost. The nonland production cost is \$136 per bale. The increase in total cost, however is $156 per bale.[1/] The imputed rent to the transfer of allotment acreage from Region 6 to Region 7 is $32.22 per bale or $96.02 per Region 7 acre. In other words, if one additional bale of cotton is to be marketed, it can be produced in Region 7 for $32.22 less than in Region 6.

1/ Set of equations for estimating real marginal cost per acre of cotton in Region 6:

$$C_6 = \frac{Ca - C_7 S_7}{S_6}$$

$$C_a = P_a Y_a$$

$$Y_a = Y_{0161} S_6 + Y_{0372} S_7$$

where

C_6 is marginal cost per acre in Region 6;
C_a is marginal cost per acre ($315.13) produced in fixed proportions between Region 6 and Region 7;
C_7 is marginal cost per acre ($368.00) in Region 7;
S_7 is Region 7's current share (.091) of the allotment;
S_6 is Region 6's current share (.909);
P_a is imputed price of bale ($151.50) produced in fixed acreage proportions between regions;
Y_a is marginal yield of an acre (2.08) divided between the regions in fixed proportion;
Y_{0161} is yield in HPA 0161 (1.99);
Y_{0372} is yield in HPA 0372 (2.98).

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Allotment Restraint with Output Levels Modified Also

Acreage allotments not only affect the regional distribution of acreage, but also the total acreage in the State. Although California's share of U.S. output is projected in Models 1980B and 1980C to increase in the absence of acreage controls, it has not increased markedly during the decade that allotments have been in force. In Model 1980D it is assumed that cotton yields in the rest of the U.S. increase at the same rate as in California and that allotments are distributed among states in the same ratio as in 1961-65. Therefore, California cotton output in Model 1980D is projected to be its base period share of 1980 U.S. output.

One other change was also made in the output vector. Cottonseed oil comprises a part of California's vegetable oil output. Safflower oil makes up the remainder. The California output estimates for safflower are derived as the residual source of vegetable oil production to that of cottonseed oil. Because vegetable oil production in California has increased steadily as a share of U.S. production during the period that cotton allotments have been in effect, the total vegetable oil estimate used in Models 1980B and 1980C is not altered for Model 1980D. The output estimate for safflower is consequently higher in Model 1980D. Thus, the impact on the Model 1980C optimal solution is the net effect of a regional cotton allotment restraint, a lower cotton output restraint, and a higher output restraint for safflower.

Model 1980D output can be produced at a total cost of $1.25 billion on 4,903,800 acres of land. Production costs are 9 percent lower than in Model 1980C and land requirements are 5 percent lower. Harvested crop acreage, 5,586,800 acres, is 4 percent lower than in Model 1980C.

The imputed product price of cotton is $142.62, or 7% lower than in Model 1980C; imputed price of safflower is $61.37, or 10% higher. No other significant changes in imputed product price are observed. The imputed rent to the transfer of cotton allotment acreage from Region 6 to Region 7 is $21.51 per bale or $64.10 per Region 7 acre.[1/]

There is less than 200,000 acres in production in HPA 0362 and none in 0363 which together comprise the Westside, San Joaquin Valley. Hence, with cotton allotments continuing in force, the extent of idle land there at current water prices could be greater than under free market conditions.

Harvested crop acreage of cotton would decline 337,000 acres, or 29 percent, from the Model 1980C level. The decrease comes 209,500 acres from Region 6 and 127,500 from Region 7. Safflower acreage increases by 92,000 acres with an expansion of 48,400 in Region 6 and 43,600 in Region 5. The only other significant regional crop shifts affect tomatoes, alfalfa, barley, and grain sorghum. Tomato acreage in Region 4 shows an increase of 36,600 acres with a decrease in Region 5 of 43,600. Region 6 alfalfa acreage increases 15,700 acres, and other regions decrease 10,000. Barley and grain sorghum acreage both go up 29,100 acres in Region 6 and down 27,900 acres in Region 4. Total harvested crop acreage decreases in all regions except Regions 1 and 9, but the only important ones are 127,600 acres in Region 7, 84,200 acres in Region 6, and 20,900 in Region 4. In percentage terms, the decreases amount to 26 percent in Region 7, 4 percent in Region 6, and 2 percent in Region 4. Model 1980D regional distribution

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1/ The marginal HPAs for cotton production in this solution are 0362 and 0372. Other than the different HPA in Region 6, the method of estimating imputed rent to allotment acreage is the same as that used in the last section. Imputed rent per bale is computed as the difference between marginal cost in Region 6 of $144.99 and that in Region 7 of $123.48.

of harvested crop acreage is recorded in Appendix Table G.10.

Several secondary crop acreage shifts between HPAs are prompted by this modification in the cotton and safflower output levels and regional distribution of cotton acreage, but they are minor compared to the primary cropping pattern changes in these two crops.

The major observations gleaned from the 1980 model results are summarized and some apparent implications are discussed in the first section of the following chapter.

CHAPTER IX

IMPLICATIONS AND ASSESSMENT

This concluding chapter will be devoted to 1) summarizing the results of the study and their major implications, 2) critically evaluating the methods used in the analysis, and 3) suggesting areas for further research.

Empirical Summary and Implications

Agriculture in California is a complex, dynamic industry. There are many forces that will shape it in the future. These 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 will be significant changes in diet, relative prices, resource use, and the organization of agriculture.

No one can exactly predict future changes in demand, technology, production, and prices of farm products. Nevertheless, farmers, processors, legislators, and administrators are forced daily to make decisions on the basis of future expectations. Hence, those researchers who would aid such people to make rational decisions must make economic projections, even though the multitude of variables at work make such projections conditional.

The projections in this study are subject to: 1) the fulfillment (or effectively offsetting influence) of the assumptions spelled out in the second chapter, 2) accurate data, 3) realistic exogenous projections of state output, yield, cost, and land availability, and 4) an adequate mathematical model. Several alternative assumptions affecting the model structure have been evaluated following the research. In the absence of governmental programs, the assumptions of Model 1980C appear to be the most reasonable. This model includes elements of changing output shares and a minimum cost feed grain mix. It is recognized that an almost infinite number of other alternatives leading to quite different results could have been considered. However, the unexplored areas yield little tangible insight for immediate answers to pressing problems. Therefore, the focus of this section will be to extract from the models actually solved the major findings and implications of interest to decision makers.

Aggregate Land Resources Restricting?

There is no apparent prospect for a stress on available California land in the aggregate by 1980. All model solutions contained substantial amounts of idle land. It is estimated that in the base period there were more than 6 1/3 million acres of potential agricultural land actually idle. Less idle land is projected in each of the 1980 models, but it is never lower than 5.6 million acres.

Although there is no indication that agricultural land needed in the near future will run out, as some vocal proponents of the governmental regulation of urban sprawl proclaim, the rate at which the optimum acreage of surplus land is projected to decline between the two time periods is of economic and political importance. The following discussion should illustrate this point.

Between the base period and 1980, at least two adjustments in agriculture are possible to allow more efficient production and to reduce the total agricultural requirements for land resources. They are: 1) to shift production from nonoptimal to optimal locations, and 2) to produce the least cost feed grain mix rather than the base period proportions. Therefore, it is estimated that net requirements of idle land for agricultural and urban uses between the base period and 1980 will be equal to the difference between the base period actual uses and Model 1980C land uses. This amounts to only 138,000 acres.

If the entire adjustment from nonoptimal to optimal locations occurs before 1980, all adjustments after 1980 would be optimal responses to changes in technology, demand, or nonagricultural competition for resources used in agriculture. Hence, annual requirements for additional land would be higher than that estimated between the base period and 1980. Additional land requirements similar to those between the base period model and one of the 1980 models would be realistic for the period following 1980.

To extend the aggregate land use projections beyond 1980, assume that:

1. The annual increase in net urban and extra-urban acreage requirements after 1980 is the same as between 1965 and 1980, or an estimated annual average of 54,500 acres, and
2. The annual increase in agricultural requirements after 1980 is the same as between the base period model and the Model 1980A inventory, or about 32,000 acres per year over the 17 year mean period.

The first assumption above would be valid under these possible conditions: 1) population in California increases at a linear rather than a geometric rate after 1980, and 2) the population density on urban and extra-urban land remains constant after that date.

The second assumption would be valid under at least this set of circumstances: 1) in the aggregate, U.S. output and California crop yields increase by the same annual amounts after 1980 as between the base period and 1980, 2) California's share of U.S. output remains constant, and 3) the productivity of additional land brought into production remains the same as that already in agricultural usage.

Based on the above premises, total agricultural and urban land requirements would increase by approximately 81,000 acres per year after 1980. With an estimated 6,225,000 acres of idle land available in 1980, this reserve would be depleted in 77 years. In the year 2057, the land use inventory might look something like this:

	(1,000 acres)
Nonagricultural land	7,410
Semiagricultural land	1,215
Total agricultural requirements	11,000
Idle land	0
Total land inventoried	19,625

This view of future land requirements is probably conservative in at least two respects: 1) urban land requirements have been growing at an increasing rate in the past several decades, and 2) the highest yielding land is projected to be used for production in 1980 -- in the absence of policies controlling urban sprawl, additional units of lower productivity land would have to be brought into agricultural production.

Even taking this conservative view, the availability of potential agricultural land could become a serious restraint to the production in California of current shares of U.S. output during the 21st century. It will become an effective economic restraint to the production of a number of individual commodities long before it is restricting in an aggregate sense. So long as unused land is available in other parts of the U.S., the output share of particular crops supplied by California will decline as the stress on better land increases. For example, there are many other places where urban pressure is less and where feed grains can be produced to be shipped to California for about the same cost as the current marginal cost of producing it in California. However, for other crops, particularly certain fruits and vegetables, California seems to have a strong comparative advantage in production. To estimate responsibly the California land use pattern in the mid-21st century, competition from regions outside the State will have to be assessed.

While the above discussion may be overly simple, it does point to the following conclusion. No panic is warranted over land becoming a physically restricting resource to agriculture during the time span of this study. However, taking a longer perspective, such an issue may become important.

Reclamation of Saline and Alkaline Soils

In general it is more profitable to expand production on the better soils and also to reclaim saline-alkaline soils than to expand on terraces requiring sprinkler irrigation. Higher yields are generally produced on reclaimed saline-alkaline soils than on the terrace soils, and total costs are often no higher. In each of the models, considerable production is projected to occur on level soils reclaimed of salts, but very little is projected on terrace soils.

Prospects for Expansion of Irrigation Facilities

The profitable expansion of irrigation on level soils from the base period actual acreage is suggested by Model 1961-65. Further expansion by 1980 is indicated by each of the 1980 models. Most of this expansion is projected in the Central Valley from Merced County north, but some is projected also in the North and Central Coast and in the mountain and intermediate level valleys.

Considerable redistribution of currently irrigated acreage is indicated in the Model 1961-65 solution. However, the Model 1980C solution projects an offsetting influence on the regional distribution. In none of the regions is the difference between base period actual and Model 1980C optimal irrigated acreage greater than between the base period actual and optimal. The difference is smaller in seven regions.

Optimal Changes in Crop Acreage

The optimal allocation of land resources among crops in the base period and in the "best" 1980 projection are quite different from actual base period allocation. There are significant differences also between the two optimal solutions. Production patterns are projected to be in a state of dynamic flux between the two time periods, both because of the initial misallocation of resources and because of the changing parameters between the time periods.

In altering the total crop acreage distribution among regions, the effect of adjusting to the optimal allocation of resources in the base period is relatively more important than adjusting to the changing parameters between time periods. For the distribution of total land among crops, the effect of the changing parameters is more significant. In the base period, some increase in the efficiency of land for the production of every crop is possible if the production pattern is altered. 1/

Imputed Rent and Product Price

The imputed 1980C rent to fixed resources varied from a high of nearly \$88 per acre to a low of \$0. The high in the base period model was only \$50. In both cases the cotton rotation restraint in the Desert HPA 0372 commanded the highest rent. It is anticipated that as output requirements increase and land resources decrease in the future, the rents to particular resources will be even higher than in the 1980C model. The most valuable resources to the production of model crops are those with the highest imputed rent. If one more acre of the cotton rotation restraint in HPA 0372 could be added, total production costs would be reduced by \$88. If another acre were added to the same restraint in HPA 0561, costs would decline by only \$.12.

1/ This is true with cotton also, even though the optimal 1961-65 acreage is higher than actual acreage. Total acreage required for skip-row planting is considerably higher than that for solid plant, although the official crop acreage is lower.

Imputed product prices in both Models 1961-65 and 1980C are relatively quite different from the base period actual. In these models there is no interplay (or functional relationship) between output projections and price. Output projections were made independently of the imputed prices obtained endogenously from the models. Because of the difference in relative 1980C imputed prices from actual and imputed 1961-65 prices, the equilibrium output projections are somewhat suspect. Estimating 1980 output levels as a function of price would enable the use of imputed prices in approaching iteratively, or through quadratic programming, the equilibrium output and price levels.

Imputed product prices have been used in this study to estimate imputed value of production. An imputed product value which is lower than actual value for the same output quantities implies that greater efficiency is possible by shifting production to optimal locations. Though the 1961-65 imputed value of production is 10 percent lower than its actual value, it is of interest to note that the increased efficiency in the use of land resources is almost the same, slightly less than 11 percent. Whether we refer to imputed savings in dollars to the consumer or to a decrease in land units optimally required for production, the estimated gain in base period efficiency is similar.

Land and Cost Saving by Production of a Least Cost Feed Grain Mix

It is possible to decrease the acreage of total and irrigated land required for Model 1980B output levels more than 1/2 million acres. By allowing a shift to more sorghum production, nearly all feed grains are produced as double crop activities in Model 1980C. Hence, land requirements for feed grains in the least cost mix are 33 percent lower than in Model 1980B, and imputed product value (cost to feeders) is 18 percent lower. Because the imputed product price of feed grains is very stable for large variations in output, the supply elasticity with respect to price of feed grains is extremely high. 1/

Westside San Joaquin Valley Water Price

The estimated cost of water to farmers on the west side of the San Joaquin Valley is too high to irrigate optimally all the land projected by other sources for irrigation in 1980. The cost per acre foot would have to decrease $12 (in the 1965 estimate) to irrigate all land on the Westside, or $6 to irrigate the 1/2 million acres projected for irrigation in 1980. Even with a possible expansion of excluded crop acreage, the cost of water appears too high to irrigate optimally all the projected 1980 acreage.

Efficiency Cost of Cotton Allotments

Given the output projections in Model 1980C, the imposition of relative regional allotments results in a misallocation of resources in the magnitude of $27 million. Imputed product value is nearly $4 million less, so aggregate profits to farmers are $31 million lower if they receive the same average price in both cases. In making policy decisions, the value of increased stability in production should be carefully weighed against such increases in resource inefficiency.

Critical Evaluation of Method of Analysis

In drawing conclusions from a piece of research, the basic limitations and weaknesses of the study which would restrict the useful scope of the results should be recognized. The statedprimary objective of this study is to provide aggregate projections of areal production which will be of value to governmental and industry decision makers. This study provides answers to each of the specific questions raised in Chapter 1, questions about future agricultural production in California. The major conceptual

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1/ However, in an interregional analysis of major field crops in the U.S., Skold and Heady [83] project that no feed grains will be produced in California optimally in 1975.

and practical problems which may limit the confidence placed in the conclusions for macro-level purposes are discussed below in four sections: 1) aggregation of data, 2) objective function, 3) delineation of HPAs, and 4) other major limitations of the models used.

Aggregation of Data

Typical (or representative farm) cost and yield data were used to estimate average HPA production relations. Because of the variance in parameters involved within an HPA, production locations in reality should not be as polarized to individual HPAs as is estimated by the models. Although macro estimates of production location are the goal of this study, extensive variation of the production relations within an HPA will alter the macro conclusions.

Because of the degree of aggregation necessary to simplify the project to manageable proportions, such considerations as quality of product, manager's capital position, risk, managerial capacity, economies of scale, and external economies within regions are ignored. It should be recognized that these elements do vary and sometimes vary widely. Although most of these factors are bypassed directly, it is assumed in this study that average management is employed on specialized farms which are large enough to receive much of the benefit from economies of size.

The impact of external economies is probably a little more crucial in a short run analysis than in the long run. Location of production for many commodities is determined in large part by the location and capacity of processing facilities. In the short run, processing plants are usually assumed to be fixed; but for the long run projections, it is assumed that they can be relocated and/or expanded and will move to optimum locations. Consequently, if an HPA has a relative cost advantage in supplying a market with a significant portion of a particular commodity, we can expect the location and size of processing plants to be nonlimiting in the long run. Because an intermediate planning horizon is used in this study, inclusion of the long-run assumption that processing plant location is not restrictive may limit the usefulness of the study results for intermediate planning. However, in pointing out the direction of long-run adjustments, this assumption is justified.

Nonhomogeneity of prices, production functions, inputs and outputs make any aggregation an abstraction from reality. However, the research decision is not to choose between <u>aggregation</u> or <u>no aggregation</u>, but rather to minimize the "errors" by following appropriate and consistent aggregation procedures.

<u>Objective Function</u>

Under conditions of perfect competition, an objective function which maximizes aggregate profits also maximizes profits to each unit in the aggregation. If each atomistic producer maximizes his profits, the allocation of production will be exactly the same as if a central planner had sought to maximize profits to the State (assuming the same information were available to the central planner as to the producers). In addition, Henderson and Quandt state that "in the absence of external economies or diseconomies, a perfectly competitive equilibrium satisfies the conditions of Pareto optimality ... [i.e., economic efficiency]." 1/ [52, p. 208] This is true both when aggregate sectors are considered and when atomistic elements are analyzed.

Since agricultural producers very nearly meet the conditions for being perfect competitors, the allocation of production by maximizing profits for the State will closely approximate the allocation by maximizing the same

1/ The conditions of Pareto optimality are based on the assumption that resource ownership is given, thus bypassing any consideration of increasing social welfare through the redistribution of income.

goal for each producer. Although there are some exceptions even in agriculture (i.e., large specialized units and contract arrangements), the assumption of perfect competition appears to be a reasonable approximation of reality. One would expect that the solution obtained by maximizing such an aggregate function would be a reasonable estimate of the solution if all of the individuals' objective functions were maximized.

Minimizing aggregate costs to the State of producing and transporting given demand quantities has no such logical appeal. There is no inherent reason why minimizing aggregate costs will minimize individual costs. To minimize individual costs of production and transportation would lead to extensive agricultural production in virtually all cases. The quantity of products to be produced by each individual farm would have to be specified.

However, if the vector of demand quantities is specified exactly as it would be at equilibrium prices, the allocation of production to minimize aggregate production and transportation costs would be exactly the same as if each farmer maximized his profits [45, p. 12]. Hence, the degree of reality in the production allocation obtained from minimizing production costs in this study depends 1) upon how nearly the specified demand quantities facing California farmers approximate those which the equilibrium set of prices would actually dictate, and 2) how closely the goal of maximizing profits approximates the producers' true goal functions. Because demand functions facing California agriculture have not been estimated for all crops in the study, the proximity of the projected output levels to equilibrium 1980 output remains speculative at this point. With regard to the personal objectives of individual agricultural producers, maximization of profits is of central importance. However, additional goals may also be involved in the decision making of individual farmers -- viz., maximize capital gains, minimize risk, or maximize after-tax income from both farm and nonfarm sources. A multiple objective function in which one seeks to maximize some combination of several parameters, or maximize one subject to minimum constraints on the others, may be more realistic than one in which only gross profits are maximized. If the alternatives are limited to single objective functions, maximization of profits is undoubtedly the most relevant, but it is recognized that other goals may also be important.

Delineation of HPAs

The purpose of following major soil and plantclimate boundaries in the delineation of HPAs is to reduce the variance about the average cost and yield estimates. Although no attempt was made to determine scientifically the delineative variables which would reduce variance the most, spatial differences in the natural resource complex are considered to be of primary importance for a long-run analysis. Other important delineative variables for intermediate and long-run analyses which are not measured in this study are suggested in Chapter 3.

The practical problems inherent in grouping areas along other than administrative boundaries are significant. It is extremely difficult to check adequately the reliability of the data or results in this study. Data are not compiled by other sources according to soil-climate groups. Yield data are published for individual counties; production costs are estimated sporadically but usually represent, at least in title, individual counties also.

It is hoped that any practical difficulties resulting from county boundaries not being followed will be more than offset by the virtue of the variation about estimates obtained being lower. However, confidence in the average cost and yield estimates must be carefully qualified because of this inability to verify their accuracy.

Other Major Limitations

General equilibrium solutions have been precluded in this study by the nonfunctional relationship between demand quantities and imputed prices. These are allocation models. Location of production and imputed prices of factors and products are the only model conclusions. The output vector is not endogenously determined.

Several important crops which would interact with study crops for the optimal allocation of resources have been excluded from the models. Their locations are projected exogenously. Some of the major orchard and vineyard crops each demand more than 100,000 acres of land resources. Although they are projected to expand in the HPAs where they are now located, which mainly consist of the best soils, shifts to more optimal locations have not been evaluated.

The problems are set up as spatial allocation models, but with no transportation cost between any HPA and the consumption market. This simplification is not of critical important when relatively concentrated, high-value crops which are marketed mainly outside of California are concerned. But for low-value, bulky items marketed exclusively within the State, the effect of this omission may significantly distort optimum location patterns.

Local and regional demand may be quite important for some of these very bulky, low-value products. Inclusion of such demand estimates, along with a consideration of transportation costs, could markedly alter the optimum production patterns obtained for such crops as alfalfa and sugar beets. 1/

1/ Sugar is marketed extensively outside of California, but the effective demand point to sugar beet producers is the location of the processing plant.

Different rates for projecting individual cost components to 1980 are not introduced into the budgeting procedure. However, the unit cost of labor has been increasing recently at a faster rate than that of water (and of most other inputs also). Thus, to assume a single rate of increase on total cost may cause the solution to be 1) unduly sensitive to current water cost and requirement differentials between activities and 2) too insensitive to differential labor requirements.

An alternative argument may also be hypothesized. If the cost of one component increases at a faster rate than another and the two are somewhat substitutable, the latter will be substituted for the former. It is hard to conceive of extensive substitutability between labor and water, although it may be possible to save on labor at the expense of some water by particular irrigation techniques. However, a more pertinent interchange would probably be that between labor and capital investments. Given the state of American technological ingenuity, additional labor saving equipment can be expected to enter into economic use whenever there is a significant change in the labor market. Witness the advent of the mechanical tomato harvester. Bringing water back into the comparison, both labor and water can be conserved for many crops by investing in sprinklers. Presently, only a very small acreage of sugar beets are projected to be optimally irrigated with sprinklers in 1980; however, if the cost of labor increases at a more rapid rate than the cost of sprinklers, or if some technological development reduces the cost of sprinkler irrigation, there may be a pronounced shift to sprinkler irrigation on level as well as on sloping soil.

There is no way to validate effectively the models used. Linear programming models are normative. They predict according to what should occur given an underlying set of assumptions. In this case one of the basic assumptions is that all farmers seek to maximize their individual profits. If the assumptions are valid and the data are correct, the model results are valid. If not, the results may be suspect. 1/ The use of a normative instead of a positive model implies that the researcher hypothesizes that historical behavior will not explain future behavior well. He may want to assess the impact of policy decisions or variables that were not as important in the past as they might be in the future. Or he may want to consider alternative decisions, as in this study. If he is able to determine what causes producers to respond as they do, then he can build this information into a decision model.

It is impossible to estimate the degree of confidence that should be placed on the results of any of the models in this study. One reason is that the models are normative. The second is that error coefficients in a strict probability sense cannot be assigned to the model parameters. It has not been possible, with limited finances and time, to develop a statistical sampling procedure for the collection of the data.

Concluding Remarks

As a simulation of the real world, the results obtained from these models have a multitude of limitations. They are not definitive predictions of the future. The probability that the exact production patterns projected by Model 1980C will actually occur is as close to zero, or for that matter -- as close to one, as for any other single set of projections. The only way these projections might become accurate predictions of the future would be for them to be used by a central planning agency that has absolute control over production decisions, and then they would be plans rather than projections.

1/ Actually, so far as the mechanical model itself is concerned, it can be said with certainty that it is valid. It provides an optimal solution subject to the assumptions and data on which it is based. The data and assumptions are what the researcher is concerned about in validation.

However, the usefulness of this study is equally significant. It points out:

1. Likely aggregate possibilities for California agriculture,
2. Major production shifts that could increase farming efficiency,
3. Certain limitations of commodity control policies,
4. Important considerations in planning water needs, costs, and location,
5. Areas that need further research, and
6. The need for gathering more extensive data and compiling them according to different geographic units than they have been in the past so that this sort of research can be more meaningful than it has been.

A basic model has been developed which is very flexible. With a minimum of effort, the impact of alternative yield, cost, demand, urban expansion, or governmental policies on optimum production locations and expected prices can be determined. In addition, it is possible to estimate these optimum conditions in considerable detail with regard to commodity and production location. Although the importance of some variables in affecting production patterns has been minimized, more emphasis has been given in this study than in any previous study to the interrelationships between specific crops in demanding spatially fixed resources in California. Such a large scale model which considers competitive relations in alternative production areas and commodities seems to be a necessary tool in making sound economic projections for a particular area or crop.

Problems Meriting Further Investigation

There are far more questions raised by this research project than answers it has provided. Some of these questions might be answered with only a moderate amount of additional research effort. Others would require major research. Because of the breadth of problems warranting additional investigation, only the highlights will be touched on in this section.

Nonrestrictive Resource Adjustment

Because major production shifts are projected by the model solutions, extensive shifting of transportable resources is also implied. In Chapters 7 and 8, the relocation and expansion of regional irrigated acreage dictated by Models 1961-65 and 1980C are discussed. Possibly a further discussion should center on the change in acre feet of water required in each region. One might ask how this adjustment would affect the unit cost of water in each HPA. The marginal cost of water, rather than average cost, is really the relevant issue when expansion is contemplated.

Economic and social analyses should focus on adjustments in the labor market which correspond to major changes in regional production patterns. What is the impact on the local labor force? Will basically different work functions be required? Can the local labor force adjust? From whence will additional labor or a different type of labor be obtained? What about those people in the declining regions? Economic and sociological issues relating to labor movements, community services, and regional development and decline are raised by these questions. In this economic analysis, only nonhuman factors of production are considered to be restrictive in the relocation of production. Attention needs to be given also to the economic and social cost of moving, readjusting, and retraining the human resources.

An analysis of changes in the demand for nonrestrictive physical resources would also be pertinent. Where will additional fertilizer, seed, and machinery outlets be needed? Given the basic supply sources, what long-run differentials, if any, are expected in the unit cost of resources between regions. If the regional adjustments projected in this study were to occur, what are the direct and indirect effects on all resources?

How much more water would be required for agriculture? How much would be required for the additional labor force, fertilizer companies, processing plants, etc.? Additional water requirements for agriculture would be a direct effect of the production adjustment. Water required for production factors used in primary agriculture, etc. would be an indirect effect. An input-output model can be used to estimate both the direct and the indirect effects of a production adjustment on the demand for resources and also for the services of other sectors.

Alternatives with Existing Models

Preliminary estimates of current and future urban land acreage have been made by County Conservation Needs Committees 1/ as a part of revising the Conservation Needs Inventory which was published in 1961 [9]. Total State urban acreage in 1967 is tentatively estimated by these sources to be 65 percent higher [99] than the 1965 estimate used in this study. Conversions of nonurban to urban land uses between 1967 and 1980 are estimated by these committees to be 121 percent higher [85] than the 1965-80 urban requirements projected in Chapter 4. Although there are differences in the urban land definition used in this study and that used by the conservation committees, it would be of interest to analyze the impact on agriculture of such an alternative rate of urban expansion.

What would be the impact on production patterns if the cost budgeting were handled differently? How sensitive is the solution to the method used to project costs? Would the result be very different if labor costs were projected at the rate indicated by recent trends? Varying degrees of risk may be a result of climatic differences. It should be possible to include in the cost estimates a measure of relative risk associated with an enterprise in a particular area.

1/ Under the chairmanship of the U.S.D.A. Soil Consevation Service.

A modification of current HPA delineations might be warranted for one of two reasons: 1) refinement, or 2) generalization to correspond to boundaries used by some data sources. The variance about average cost and yield estimates should be reduced if such considerations as water availability, water quality, currently irrigated land, typical size of farm, and/or proximity to a major urban center affected HPA delineation. On the other hand, the Department of Water Resources has gathered land use data by 7½ minute quadrangle and irregularly shaped resource areas. The Bureau of Census uses sub-county units in compiling some unpublished yield estimates. Although one would expect the variance to be increased by modifying HPA boundaries to correspond to data groupings, the practical advantage of being able to verify the accuracy of certain mean data used would also be important.

Possibly the largest single boon to this type of research would come by such data collection agencies as the California Crop and Livestock Reporting Service compiling cost and yield data by natural resource area in addition to administrative units. Then all yield and cost estimates in this study based on historical production could be verified. Extensive generalization of HPA boundaries may then be unnecessary also. Using the raw data from which averages are compiled for natural resource areas, it would be possible to estimate standard deviations. Much more confidence could be placed in the results of this study if the data could be adequately verified. It is the opinion of this writer that the most important limitation to accepting the model results as optimum production locations is the set of cost and yield estimates used as model parameters. Of all the criticisms raised in the previous section, none seem to be as important as the lack of confidence in the data. But to improve markedly the data used would require extensive resources and could probably be handled only by a data collection agency.

If only a partial check on the data were to be made, this check should focus first on the crops for which the optimal 1961-65 regional acreage distribution or imputed price are most different from actual acreage or price. The regions that should receive primary attention are those in which the shift is the greatest.

Extensions of the Existing Models

All of the suggestions below require an increase in the model size or complexity, unless some compensating simplification is introduced. However, so far as computer capacity is concerned, the size of the existing models can be reduced considerably with no loss of detail on the IBM 360 computer. 1/ The number of rows is the critical restraint on computer capacity. The number of rows in each of the existing models could have been reduced by more than 75% had the rotation restraints been imposed on columns. 2/ All of the rotation restraint rows can be dropped by adding one row with upper limits on each activity.

The impact of important local demand, inflexible processing plant location over the projection period, or a continuation of certain governmental programs might be assessed by adding minimum or maximum regional output or acreage restraints.

The interaction of all major crops for the allocation of resources could be judged by adding important orchard and vineyard crop activities to the existing production possibilities. It may be important to introduce the livestock industry as another production alternative. However, this would also pull in an intermediate industry which purchases some agricultural outputs for inputs to its own production process. While no theoretical problem is raised by such an intermediate process in the model, the empirical ones are important.

1/ On which the Mathematical Programming System (MPS) software has been implemented.

2/ This is an option of the MPS when a restraint affects only one column.

A general equilibrium model could be developed in one of two ways if demand functions of the following form were estimated for each crop: $Q = f\ (P)$. The existing model could be used to approach iteratively the optimal solution. Or, quadratic programming could be employed to solve directly for the optimum. In the latter case, the objective function would have to be changed to maximize aggregate profits. An additional row would be added to relate demand quantities to imputed prices. The existing models would become general spatial equilibrium models with a single demand point by merely including transportation costs in the objective row. For many crops (particularly vegetable crops, dry beans, cotton, and rice) the inclusion of transportation costs may be irrelevant. The incremental cost of shipping one of these from one HPA to the major demand point as compared to shipping from another HPA is probably negligible.

For some other crops, multiple demand points (including local demand) may be quite important also. In this case the matrix would be expanded to include an extra row for each additional demand point for a crop and an extra column for each HPA that can supply one crop to an additional demand point. While the columns may be expanded greatly, the lid could be kept on the model because the number of rows increases at a much slower rate.

The final area to be suggested for additional research involves the expansion of this static model into a dynamic one in which the time path of adjustment, as well as the terminal equilibrium, is projected. There are basically two common dynamic linear programming models. In one, a single objective function is maximized for the entire planning horizon. A discount or interest rate is attached to profits in each time period and compounded to the initial or terminal period or to obtain an income flow. Capital and other resource restraints may be transferred within the system from one time period to the next. Changes in the resource levels in different time periods can also be implemented exogenously. The most significant use of this type of model to date has been with firm growth studies. [42, Chapter 12; 54].

In the second dynamic model, the Henderson - Day recursive programming model [37], economic plans are determined by a sequence of optimizing decisions. A separate problem is defined for each time period, and expected net returns (or other goals) are maximized for that period independently of all others. However, production in one time period is recursively related to production in previous time periods. The usual procedure is to specify flexibility restraints on the maximum allowable changes between two time periods. Regression analysis and other techniques may be used to estimate the flexibility restraints. For a study of production adjustments, such restraints might be imposed on the rate at which land can enter or leave production in any HPA or on the rate at which crop land can be transferred from one use to another. Exogenous projections of urban expansion or cost and yield increase could also be included. Recursive programming has been used previously in similar regional production adjustment studies [81].

Recapitulation of Problems Meriting Further Investigation

No attempt has been made in this section to be comprehensive in the coverage of areas deserving additional research. The field is really wide open. Relevant problems cover the spectrum from purely data needs to those which can be handled with the existing models to those which require some model extension and finally to those which require altogether different tools and include social as well as economic ramifications. It is hoped that this study has made a substantive contribution to the analysis of one subset of problems concerned with the efficient use of resources for agricultural production in California.

APPENDIX A

MAPS

FIGURE A.1

Guide to Detailed Regional Maps

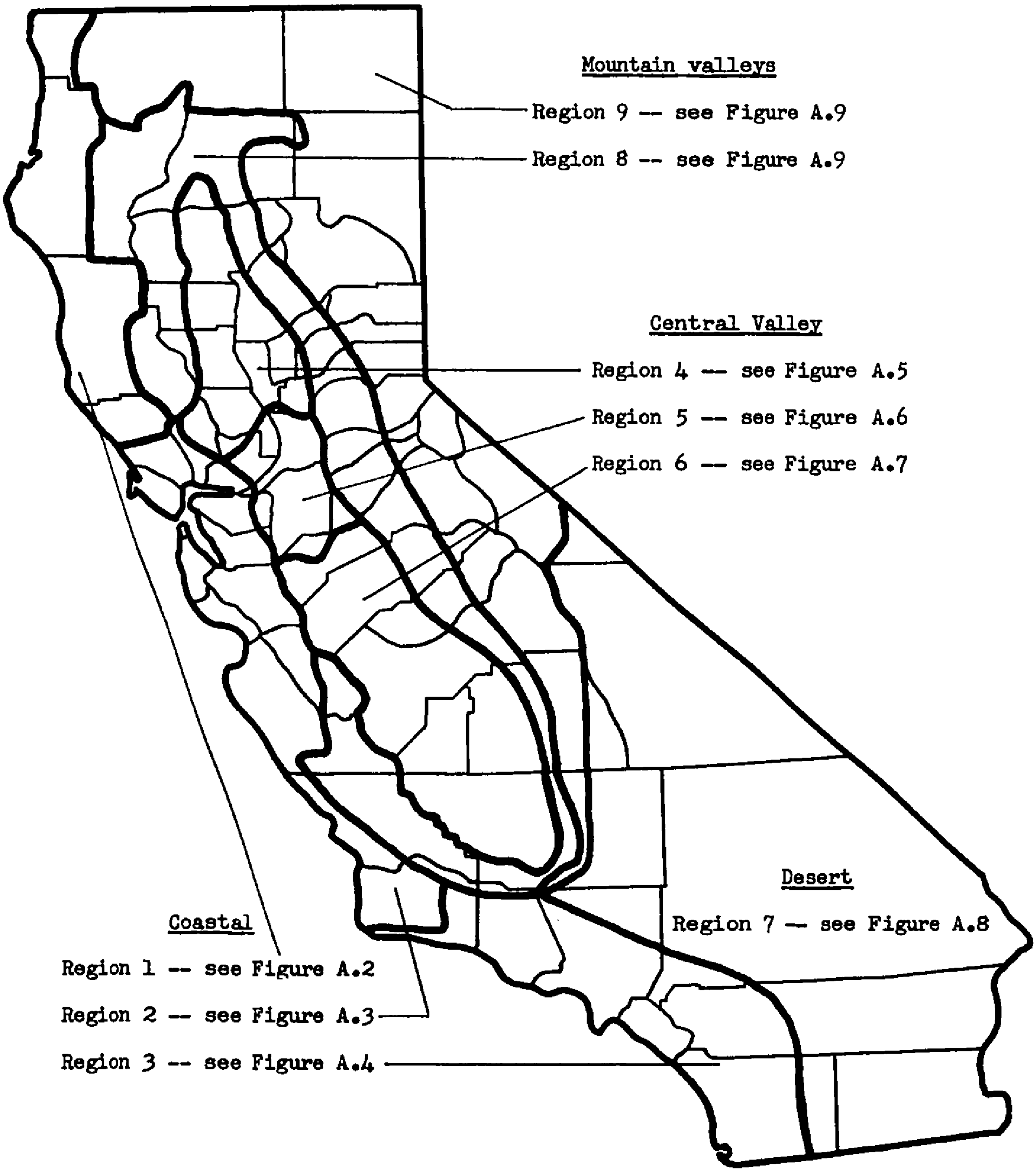


FIGURE A. 2

Region 1 – North Coast

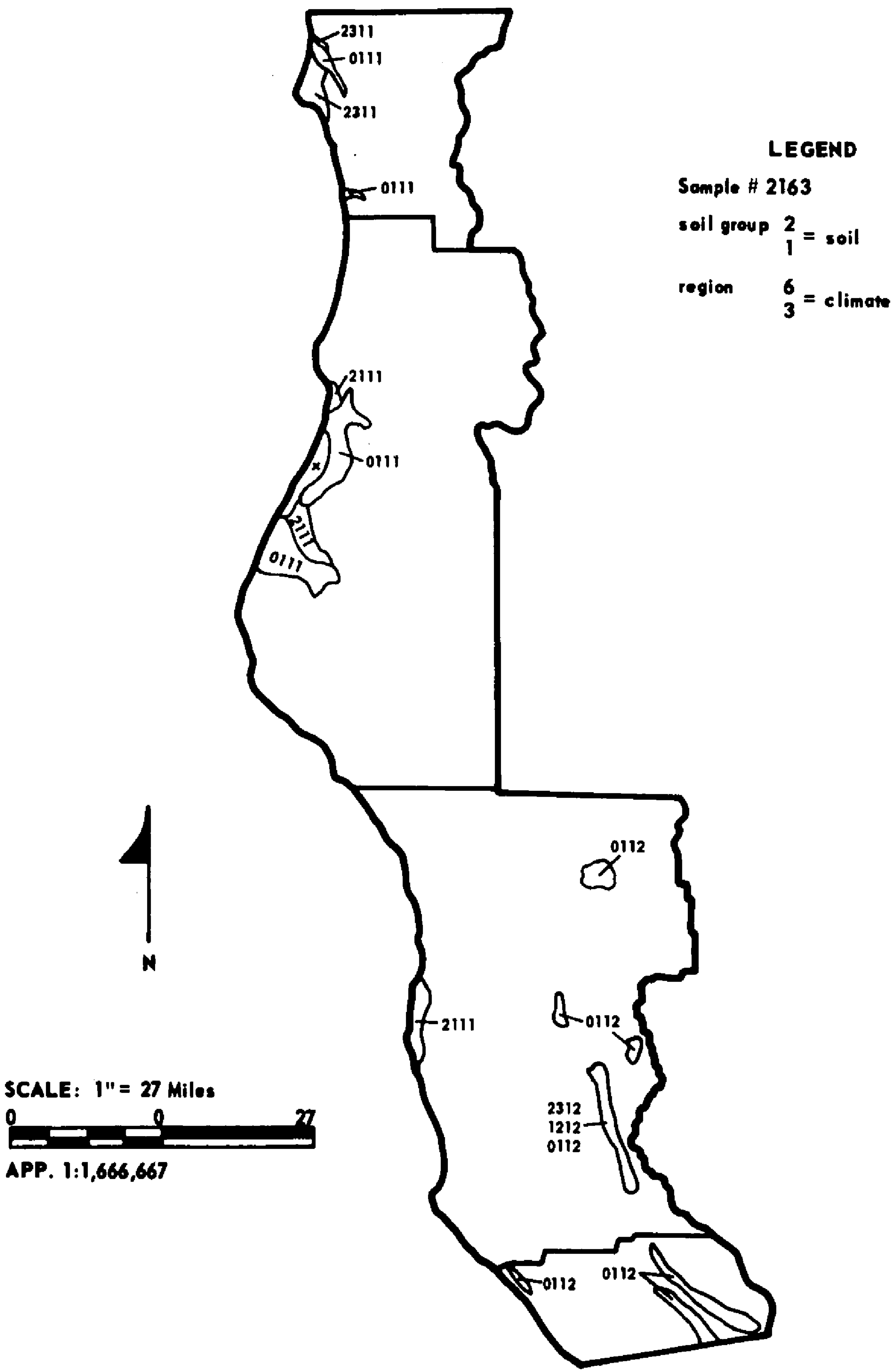


FIGURE A. 3

Region 2 – Central Coast

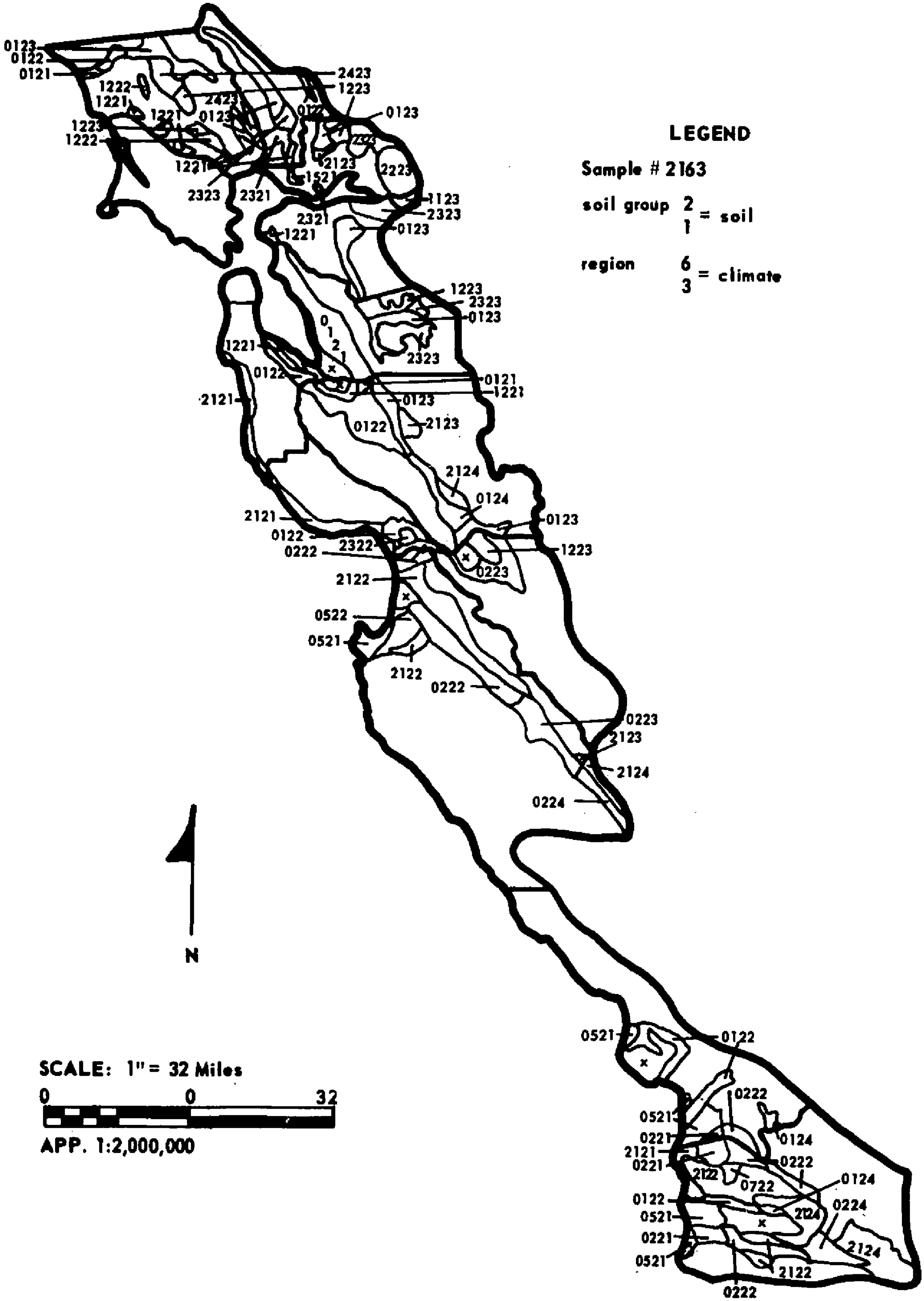


FIGURE A. 4

Region 3 – South Coast

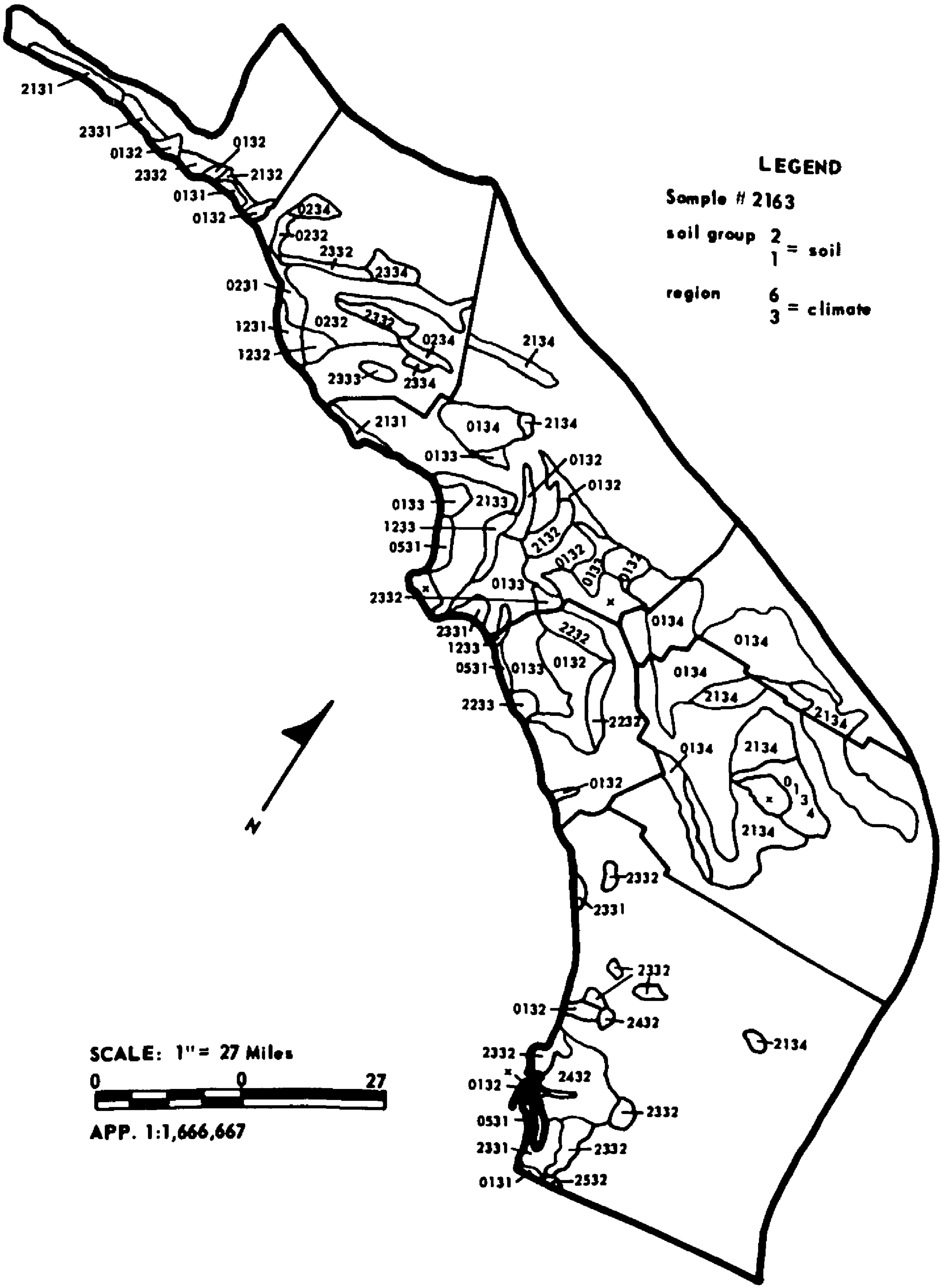


FIGURE A. 5

Region 4 – Sacramento Valley

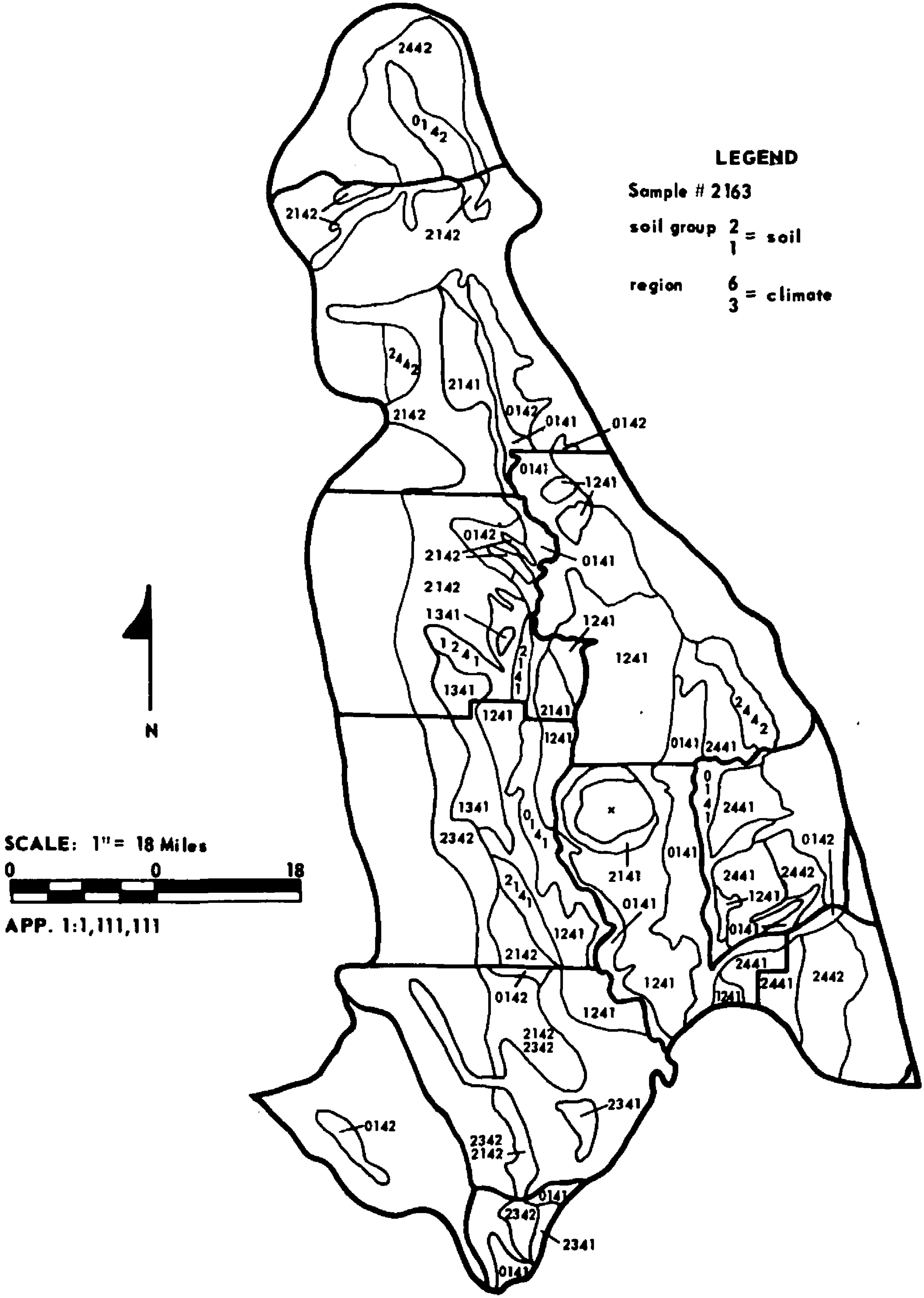


FIGURE A. 6

Region 5 – San Joaquin Delta

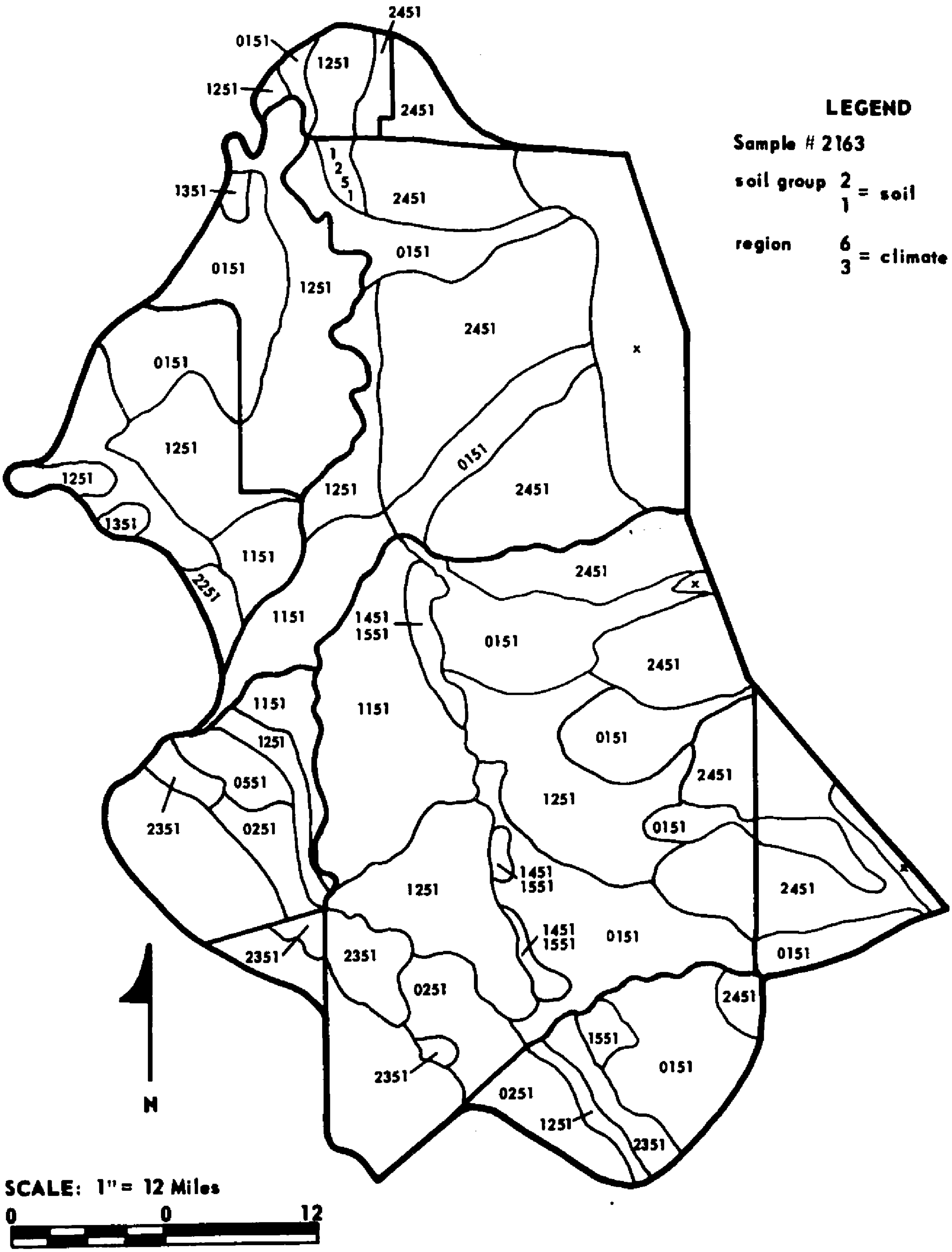


FIGURE A. 7

Region 6 – San Joaquin Valley

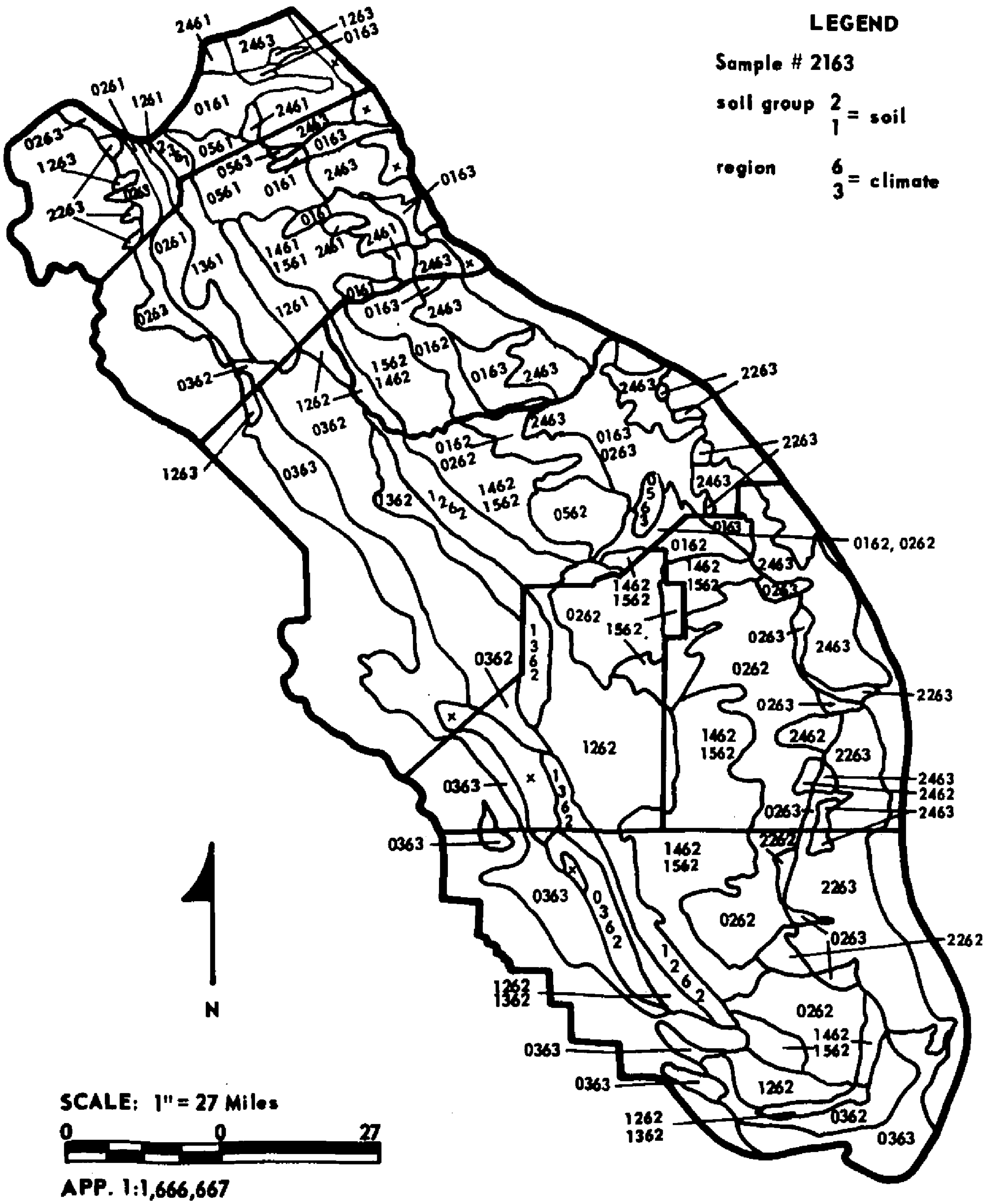
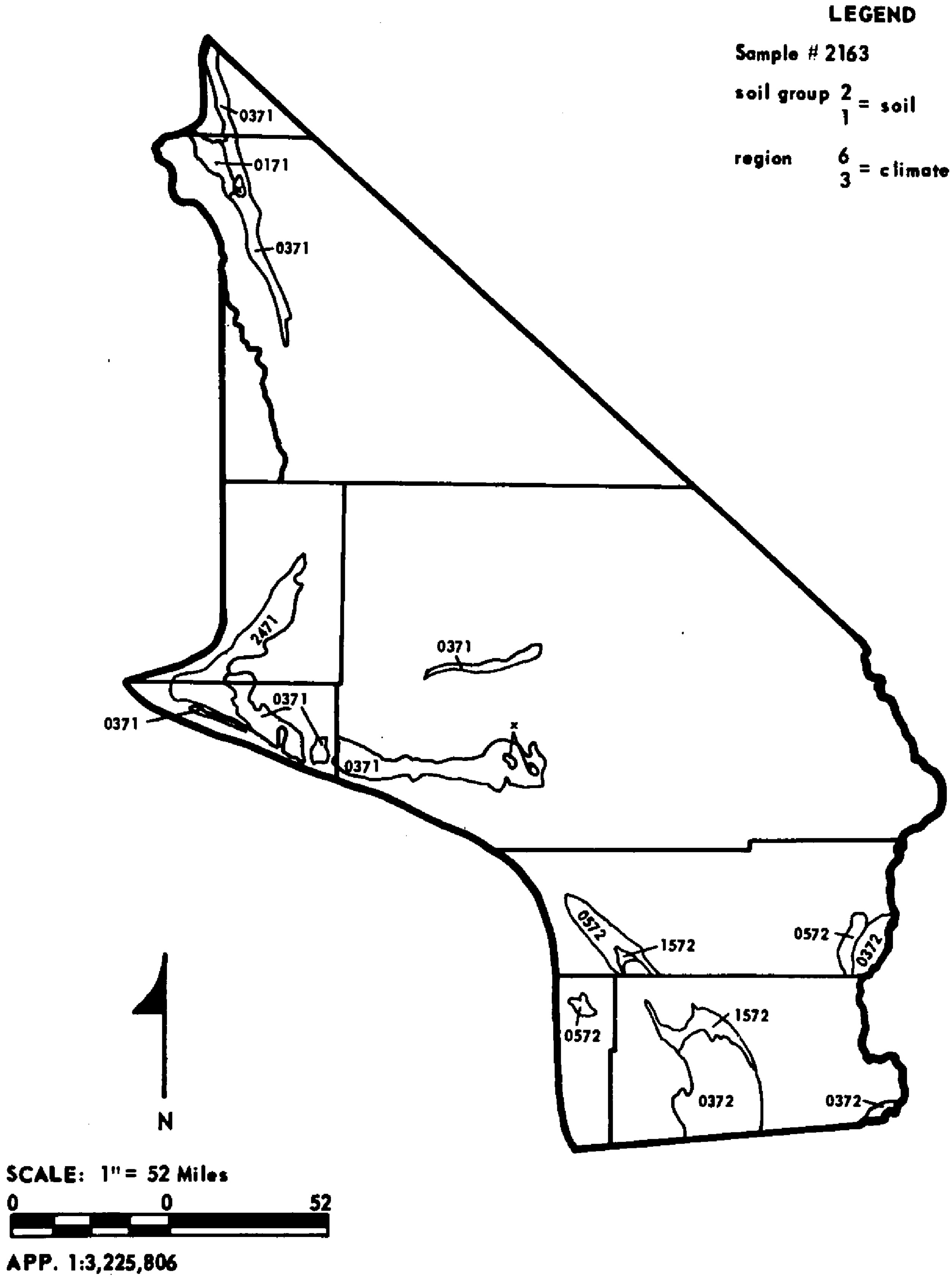


FIGURE A. 8

Region 7 – Southern California Desert



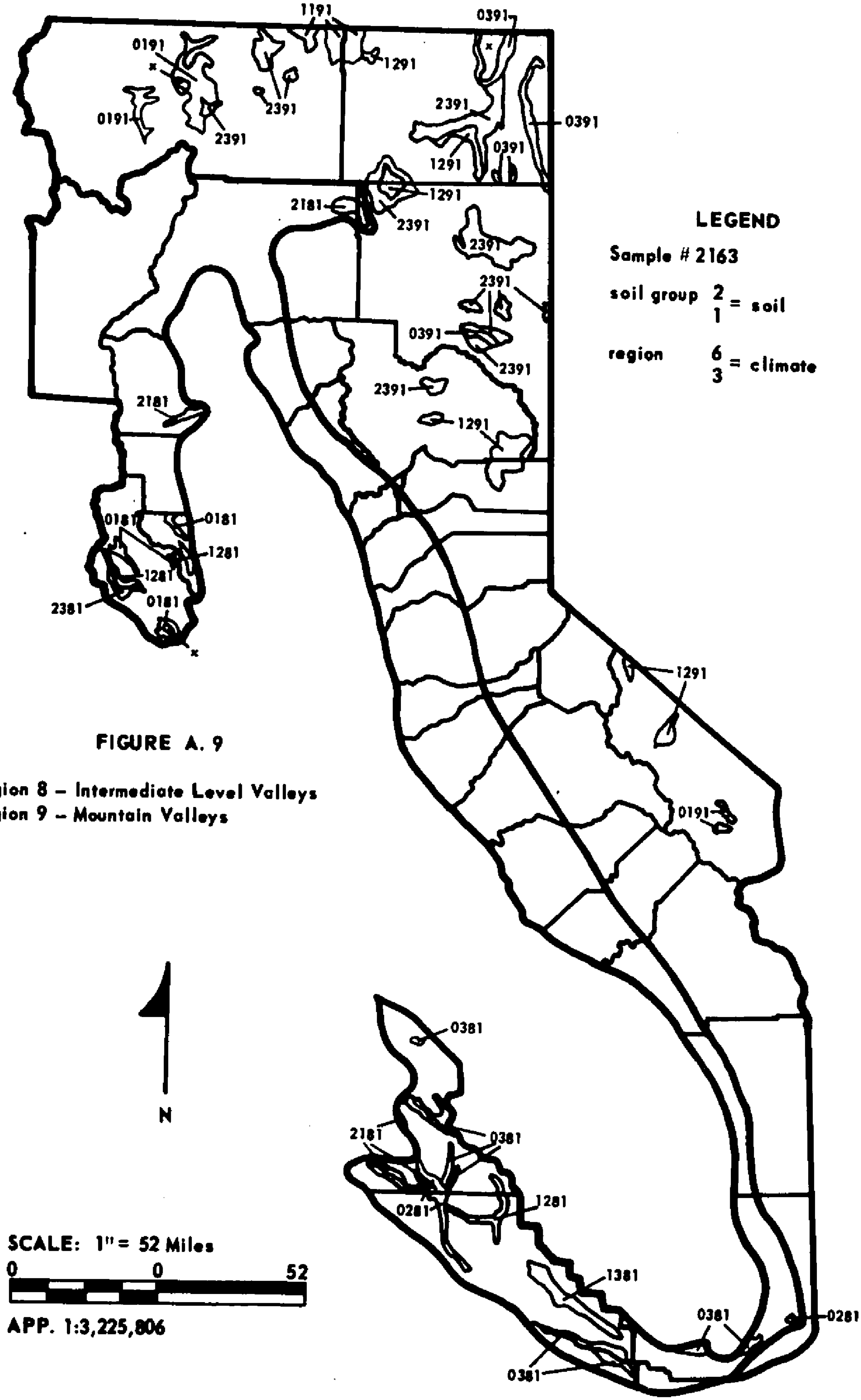


FIGURE A. 9

Region 8 – Intermediate Level Valleys
Region 9 – Mountain Valleys

APPENDIX B

LAND, IRRIGATED ACREAGE, AND ROTATION RESTRAINTS

TABLE B.1

Urban Land in California

HPA[a]	Urban land, 1964	Urban land requirement, 1965-80	Urban land, projected 1980
	1,000 acres		
111	4.7	.6	5.3
112	2.9	2.1	5.0
121	50.9	15.0	65.9
122	66.8	35.8	102.6
123	32.1	24.8	56.9
124	5.7	5.8	11.5
131	1.9	1.1	3.0
132	166.9	55.5	222.4
133	156.3	48.1	204.4
134	192.5	70.9	263.4
141	28.1	19.4	47.5
142	4.8	4.2	9.0
151	65.5	28.6	94.1
161	3.7	1.7	5.4
162	12.1	6.2	18.3
163	12.0	7.1	19.1
171	.9	.7	1.6
181	1.2	1.0	2.2
191	1.1	.1	1.2
221	3.0	2.6	5.6
222	16.7	9.5	26.2
223	2.0	1.0	3.0
224	0	0	0
231	8.8	9.7	18.5
232	9.4	13.2	22.6
234	5.0	7.2	12.2
251	6.6	1.7	8.3
261	2.8	1.6	4.4
262	54.2	26.9	81.1
263	21.0	7.0	28.0
281	4.4	3.2	7.6
362	3.4	.8	4.2
363	4.6	2.2	6.8
371	10.5	16.8	27.3
372	9.3	4.5	13.8
381	0	0	0
391	0	0	0
521	11.2	8.0	19.2
522	5.6	4.1	9.7
531	30.0	8.6	38.6
551	2.0	1.7	3.7
561	4.9	2.5	7.4
562	1.9	.6	2.5
563	1.4	.5	1.9
572	4.1	6.3	10.4

See footnote at end of table

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Table B.1 (continued)

HPA[a]	Urban land, 1964	Urban land requirement, 1965-80	Urban land, projected 1980
	1,000 acres		
1123	0	0	0
1151	1.9	.6	2.5
1191	0	0	0
1221	25.0	8.4	33.4
1222	4.1	1.7	5.8
1223	10.7	6.7	17.4
1231	3.8	5.5	9.3
1232	0	0	0
1233	22.2	7.5	29.7
1241	2.2	1.0	3.2
1251	39.9	23.3	63.2
1261	.5	.3	.8
1262	1.4	.9	2.3
1263	0	0	0
1281	0	0	0
1291	3.1	.5	3.6
1341	0	0	0
1351	0	0	0
1361	0	0	0
1362	.6	.2	.8
1381	0	0	0
1451	0	0	0
1461	0	0	0
1462	4.0	2.2	6.2
1551	0	0	0
1561	0	0	0
1562	8.5	4.8	13.3
1572	0	0	0
2111	2.9	.3	3.2
2121	10.1	4.1	14.2
2122	10.5	4.5	15.0
2133	0	0	0
2124	0	0	0
2131	0	0	0
2132	22.0	7.8	29.8
2133	81.6	18.7	100.3
2134	49.2	33.3	82.5
2141	.3	.1	.4
2142	2.1	1.0	3.1
2151	0	0	0
2181	0	0	0
2223	0	0	0
2232	21.3	8.2	29.5
2233	9.8	4.1	13.9
2251	.5	.3	.8
2262	0	0	0
2263	5.8	6.9	12.7
2311	3.4	.2	3.6

See footnote at end of table.

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Table B.1 (continued)

HPA[a]	Urban land, 1964	Urban land requirement, 1965-80	Urban land, projected 1980
	1,000 acres		
2312	0	0	0
2321	.7	.3	1.0
2322	1.5	.9	2.4
2323	18.2	8.9	27.1
2331	14.0	12.2	26.2
2332	39.8	42.9	82.7
2333	1.4	1.8	3.2
2334	.2	0	.2
2341	.7	.8	1.5
2342	1.2	.8	2.0
2351	8.1	3.9	12.0
2361	0	0	0
2381	0	0	0
2391	1.4	.2	1.6
2432	32.6	71.4	104.0
2441	2.8	2.3	5.1
2442	18.7	12.4	31.1
2451	55.1	22.3	77.4
2461	4.8	3.2	8.0
2462	2.4	1.1	3.5
2463	15.8	10.5	26.3
2471	0	0	0
Total	1,599.3	818.2	2,417.5

a/ Last two digits identify climate; first two digits identify soil. On a three digit HPA, a zero is assumed before the first digit recorded.

TABLE B.2

HPA Land Restraints

HPA	Total acreage	Urban land 1964	Extra-urban land	Semi-agricultural land	Excluded crop acreage, average 1965-66	Net model acreage, circa 1965	Land requirement 1965-80 a/	Net model acreage, projected 1980
	1,000 acres							
111	122.0	4.7	4.7	11.3	0	101	0	101
112	77.0	2.9	4.2	7.0	27.6	35	5	30
121	90.3	50.9	.1	3.9	6.6	29	14	15
122	173.4	66.8	11.4	9.5	35.2	50	36	14
123	201.3	32.1	2.5	16.7	63.4	87	30	57
124	41.2	5.7	.1	3.6	21.6	← Grouped	with HPA	0224 →
131	12.1	1.9	0	1.0	2.0	← "	" "	0132 →
132	274.5	166.9	2.6	10.5	36.4	137	117	20
133	222.8	156.3	0	6.6	4.8	← Grouped	with HPA	0132 →
134	475.3	192.5	0	28.3	72.3	187	78	109
141	607.8	28.1	10.8	56.9	178.9	333	37	296
142	137.1	4.8	2.0	13.0	23.0	94	6	88
151	489.5	65.5	12.3	41.2	167.1	203	43	160
161	213.6	3.7	4.9	20.5	94.0	90	11	79
162	211.9	12.1	8.7	19.1	93.2	79	16	63
163	221.9	12.0	2.5	20.7	109.8	77	18	59
171	70.0	.9	8.9	6.0	0	54	0	54
181	81.6	1.2	4.4	7.6	18.5	50	3	47
191	211.0	1.1	4.4	20.6	0	185	0	185
221	41.5	3.0	7.8	3.1	3.8	24	3	21
222	160.0	16.7	2.7	14.1	23.3	103	11	92
223	99.6	2.0	4.8	9.3	27.9	56	4	52
224	54.5	0	3.5	5.1	2.3	54	8	46
231	25.9	8.8	0	1.7	7.6	← Grouped	with HPA	0132 →
232	140.2	9.4	0	13.1	56.5	61	18	43
234	25.9	5.0	13.7	.7	1.5	← Grouped	with HPA	0134 →

See footnotes at end of table.

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Table B.2 (continued)

HPA	Total acreage	Urban land 1964	Extra-urban land	Semi-agricultural land	Excluded crop acreage, average 1965-66	Net model acreage, circa 1965	Land requirement 1965-80 a/	Net model acreage, projected 1980
	1,000 acres							
251	90.0	6.6	.9	8.3	22.1	59	6	53
261	105.0	2.8	3.3	9.9	7.5	82	3	79
262	828.4	54.2	24.2	75.0	165.3	510	42	468
263	269.8	21.0	4.4	24.4	148.5	72	23	49
281	88.7	4.4	13.5	7.1	7.7	56	4	52
362	596.1	3.4	16.6	57.6	12.2	506	2	504
363	583.9	4.6	4.7	57.5	17.9	499	4	495
371	884.3	10.5	54.3	81.9	2.6	735	16	719
372	587.0	9.3	29.6	54.8	7.5	486	5	481
381	117.7	0	1.6	11.6	.7	104	0	104
391	130.0	0	41.2	8.9	0	80	0	80
521	95.3	11.2	42.7	4.1	1.0	36	7	29
522	36.7	5.6	14.6	1.7	0	15	4	11
531	39.9	30.0	0	1.0	.5	← Grouped with HPA 0132 →		
551	24.0	2.0	0	2.2	12.5	← " " " 0251 →		
561	166.8	4.9	9.6	15.2	14.8	122	4	118
562	102.5	1.9	0	10.1	19.9	71	3	68
563	27.7	1.4	0	2.6	0	24	1	23
572	218.2	4.1	11.4	20.3	41.6	141	10	131
1123	15.9	0	0	1.6	0	← Grouped with HPA 1151 →		
1151	255.1	1.9	0	25.3	2.5	240	1	239
1191	127.0	0	36.8	9.0	1.5	80	0	80
1221	45.6	25.0	.1	2.1	.3	18	8	10
1222	9.0	4.1	.1	.5	.6	← Grouped with HPA 1223 →		
1223	74.6	10.7	4.8	5.9	2.0	55	8	47
1231	23.9	3.8	5.1	1.5	.1	13	5	8
1232	17.1	0	0	1.7	0	22	6	16
1233	30.0	22.2	0	.8	0	← Grouped with HPA 1232 →		

See footnotes at end of table.

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Table B.2 (continued)

HPA	Total acreage	Urban land 1964	Extra-urban land	Semi-agricultural land	Excluded crop acreage, average 1965-66	Net model acreage, circa 1965	Land requirement 1965-80 [a]	Net model acreage, projected 1980
	1,000 acres							
1241	470.3	2.2	16.1	45.2	0	407	1	406
1251	462.2	39.9	2.6	42.0	5.3	372	21	351
1261	99.0	.5	4.0	9.4	0	85	0	85
1262	741.7	1.4	18.0	72.2	.3	650	1	649
1263	24.0	0	1.2	2.3	0	21	0	21
1281	69.3	0	1.7	6.8	1.6	59	0	59
1291	309.5	3.1	15.1	29.1	.1	262	0	262
1341	69.0	0	8.8	6.0	.6	54	1	53
1351	21.4	0	0	2.1	0	19	0	19
1361	121.0	0	4.2	11.7	0	105	0	105
1362	261.0	.6	24.2	23.6	0	213	1	212
1381	99.0	0	.9	9.8	0	88	0	88
1451	23.0	0	0	2.3	0	21	0	21
1461	10.0	0	.7	.9	0	8	0	8
1462	314.0	4.0	5.2	30.5	.2	274	2	272
1551	14.0	0	.4	1.4	0	12	0	12
1561	137.0	0	8.9	12.8	0	115	0	115
1562	678.0	8.5	11.9	65.8	.1	592	5	587
1572	104.0	0	22.0	8.2	.9	73	0	73
2111	35.0	2.9	2.8	2.9	1.7	25	1	24
2121	92.7	10.1	5.8	7.7	2.5	67	4	63
2122	196.2	10.5	25.7	16.0	2.7	144	5	139
2123	21.6	0	0	2.2	.8	19	0	19
2124	157.8	0	3.1	15.5	1.2	138	0	138
2131	38.3	0	0	3.8	.5	34	0	34
2132	34.2	22.0	0	1.2	1.6	← Grouped with HPA 2232 →		
2133	100.3	81.6	0	1.9	.1	← " " " 2232 →		
2134	332.5	49.2	.1	28.3	26.2	234	33	201

See footnotes at end of table.

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Table B.2 (continued)

HPA	Total acreage	Urban land 1964	Extra-urban land	Semi-agricultural land	Excluded crop acreage, average 1965-66	Net model acreage, circa 1965	Land requirement 1965-80 [a]	Net model acreage, projected 1980
	1,000 acres							
2141	134.8	.3	2.9	13.2	2.7	116	1	115
2142	345.2	2.1	6.5	33.7	16.6	286.	2	284
2151	15.0	0	0	1.5	0	13	0	13
2181	89.5	0	2.9	8.7	0	78	0	78
2223	51.0	0	0	5.1	.1	53	0	53
2232	62.7	21.3	0	4.1	6.2	167	142	25
2233	15.3	9.8	0	.6	0	⟵ Grouped with HPA 2232 ⟶		
2251	9.0	.5	0	.9	.2	⟵ " " " 2223 ⟶		
2262	12.6	0	.3	1.2	0	⟵ " " " 2263 ⟶		
2263	429.4	5.8	7.6	41.6	9.5	376	7	369
2311	31.0	3.4	1.5	2.6	0	24	1	23
2312	20.0	0	1.0	1.9	0	17	0	17
2321	24.0	.7	1.3	2.2	.3	20	1	19
2322	5.0	1.5	0	.3	0	⟵ Grouped with HPA 2122 ⟶		
2323	127.2	18.2	3.4	10.6	0	95	8	87
2331	45.1	14.0	6.3	2.5	0	22	11	11
2332	99.0	39.8	7.3	5.2	8.0	⟵ Grouped with HPA 2232 ⟶		
2333	3.2	1.4	0	.2	.2	⟵ " " " 2232 ⟶		
2334	10.8	.2	5.0	.6	0	⟵ " " " 2134 ⟶		
2341	21.0	.7	0	2.0	0	18	0	18
2342	120.0	1.2	3.3	11.6	1.0	103	1	102
2351	97.8	8.1	.8	8.9	.3	80	4	76
2361	21.5	0	1.0	2.0	0	18	0	18
2381	15.0	0	.1	1.5	0	13	0	13
2391	614.6	1.4	58.3	55.5	.8	499	1	498
2432	118.0	32.6	14.0	7.1	0	⟵ Grouped with HPA 2232 ⟶		
2441	187.2	2.8	6.1	17.8	0	160	2	158
2442	271.1	18.7	24.2	22.8	1.5	204	11	193

See footnotes at end of table.

--Continued on next page.

Table B.2 (continued)

HPA	Total acreage	Urban land 1964	Extra-urban land	Semi-agricultural land	Excluded crop acreage, average 1965-66	Net model acreage, circa 1965	Land requirement 1965-80 [a]	Net model acreage, projected 1980
	1,000 acres							
2451	548.7	55.1	11.4	48.2	.5	434	21	413
2461	43.9	4.8	.8	3.8	0	35	3	32
2462	49.1	2.4	1.8	4.5	0	40	1	39
2463	787.3	15.8	15.8	75.6	12.6	668	11	657
2471	92.2	0	0	9.2	0	83	0	83
Total	19,625.3	1,599.7	803.5	1,722.5	1,673.5	13,828 [b]	923	12,905

a/ Includes land for urbanization and excluded crops less previous semiagricultural requirements on land urbanized. Land requirements, 1965-80 = 0.9 (Urban land requirements, 1965-80) + 0.1073 (excluded crop acreage, average 1965-66).

b/ Total acreage minus other land uses may not exactly equal net model acreage due to rounding error.

TABLE B.3

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.4

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

APPENDIX C

GRAPHS OF HISTORICAL AND PROJECTED CROP YIELD

FIGURE C.1

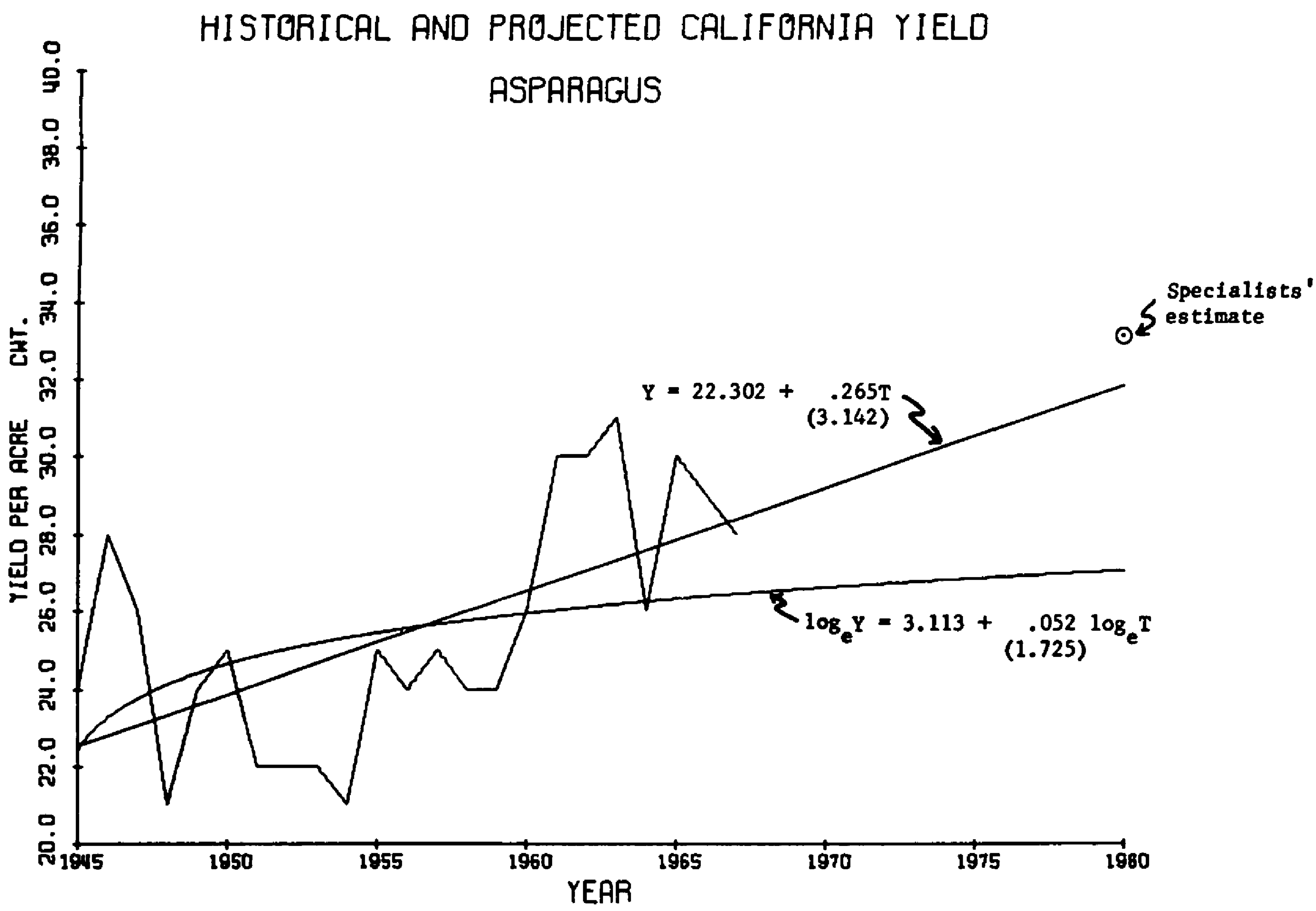

HISTORICAL AND PROJECTED CALIFORNIA YIELD
ASPARAGUS
YIELD PER ACRE CWT.
20.0
22.0
24.0
26.0
28.0
30.0
32.0
34.0
36.0
38.0
40.0
1945
1950
1955
1960
1965
1970
1975
1980
YEAR
Specialists' estimate
Y = 22.302 + .265T (3.142)
log_e Y = 3.113 + .052 log_e T (1.725)

FIGURE C.2

HISTORICAL AND PROJECTED CALIFORNIA YIELD
BROCCOLI

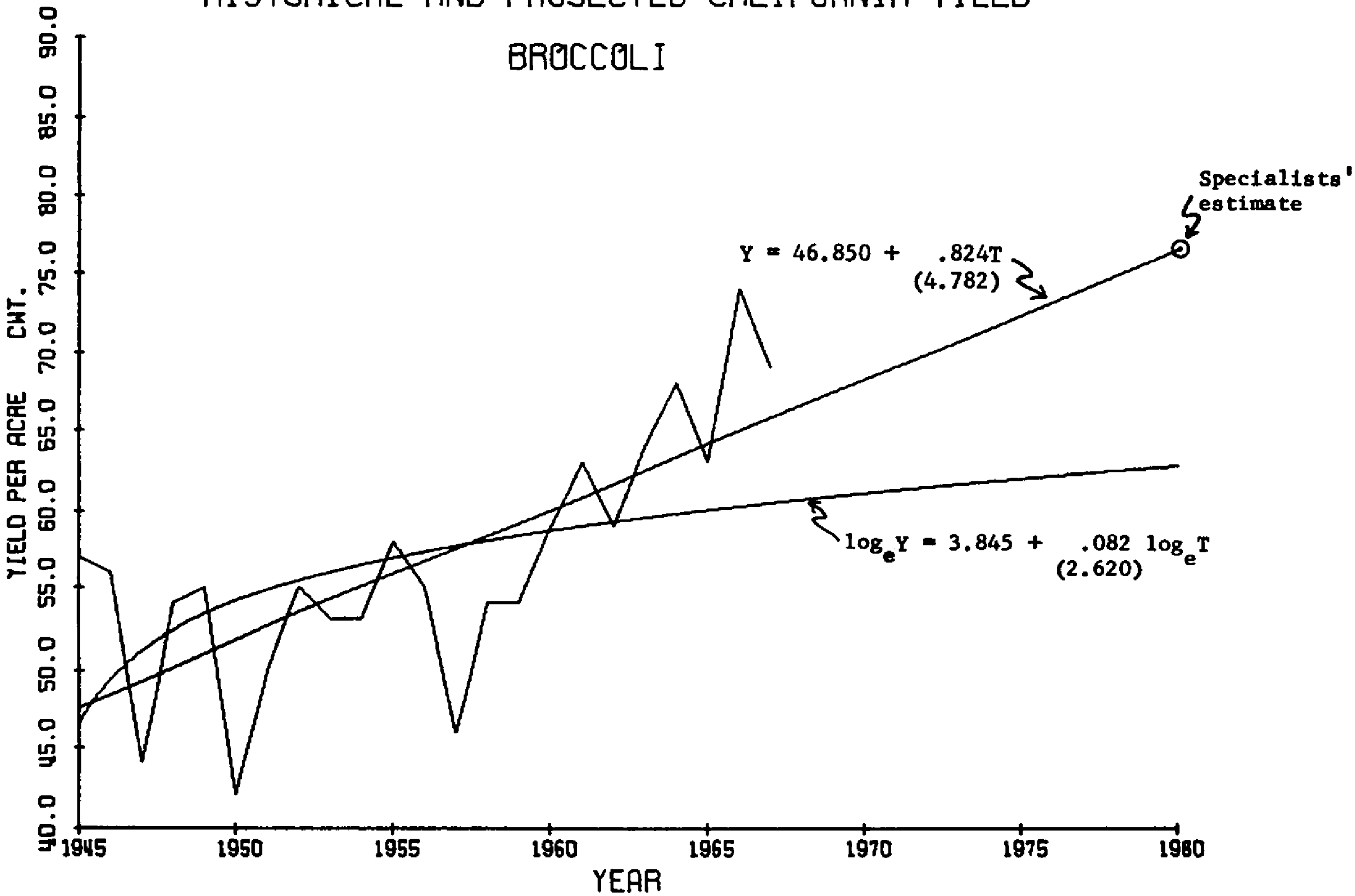


FIGURE C.3

HISTORICAL AND PROJECTED CALIFORNIA YIELD

LETTUCE - FALL

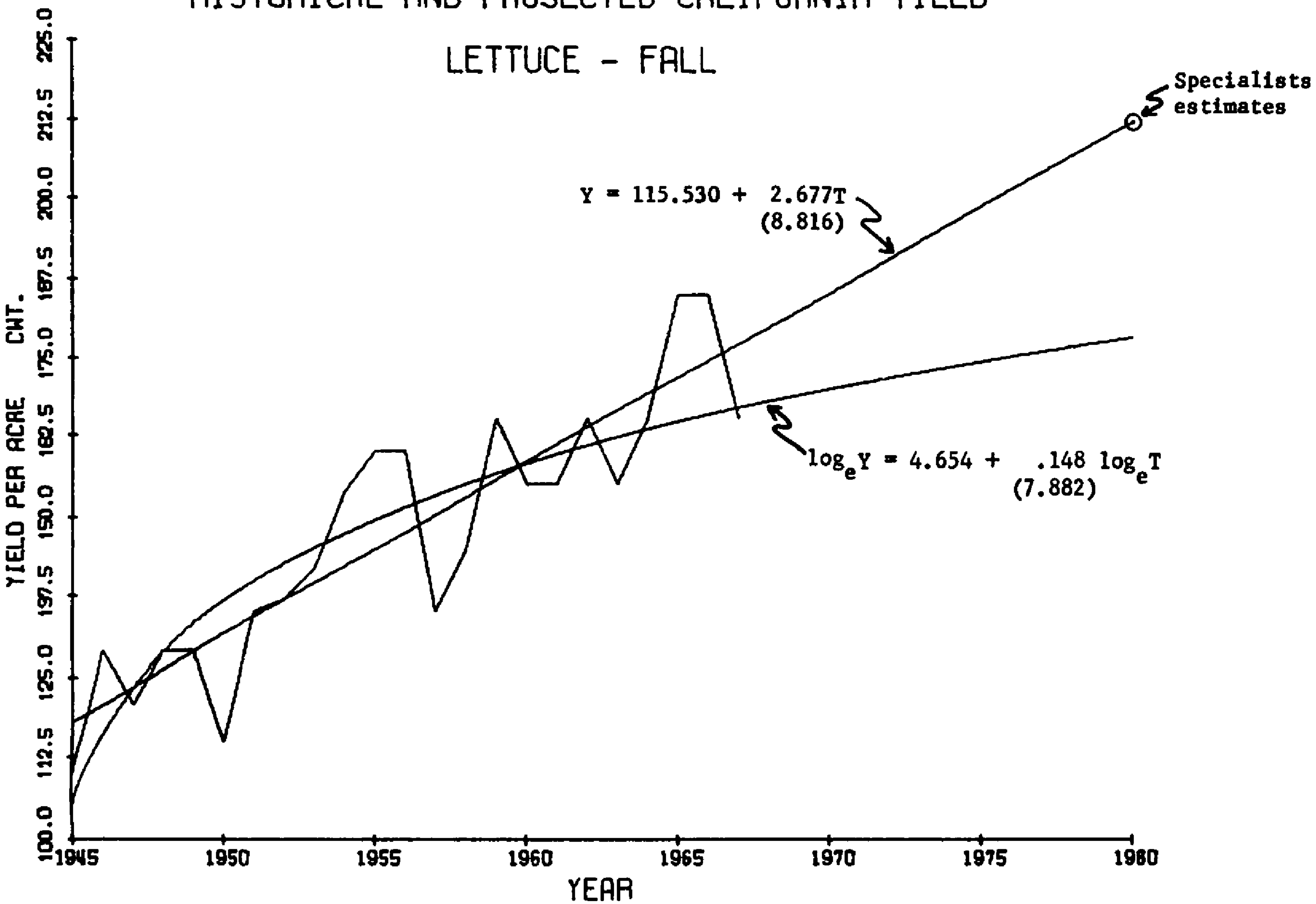


FIGURE C.4

HISTORICAL AND PROJECTED CALIFORNIA YIELD

CANTALOUPES - SUMMER

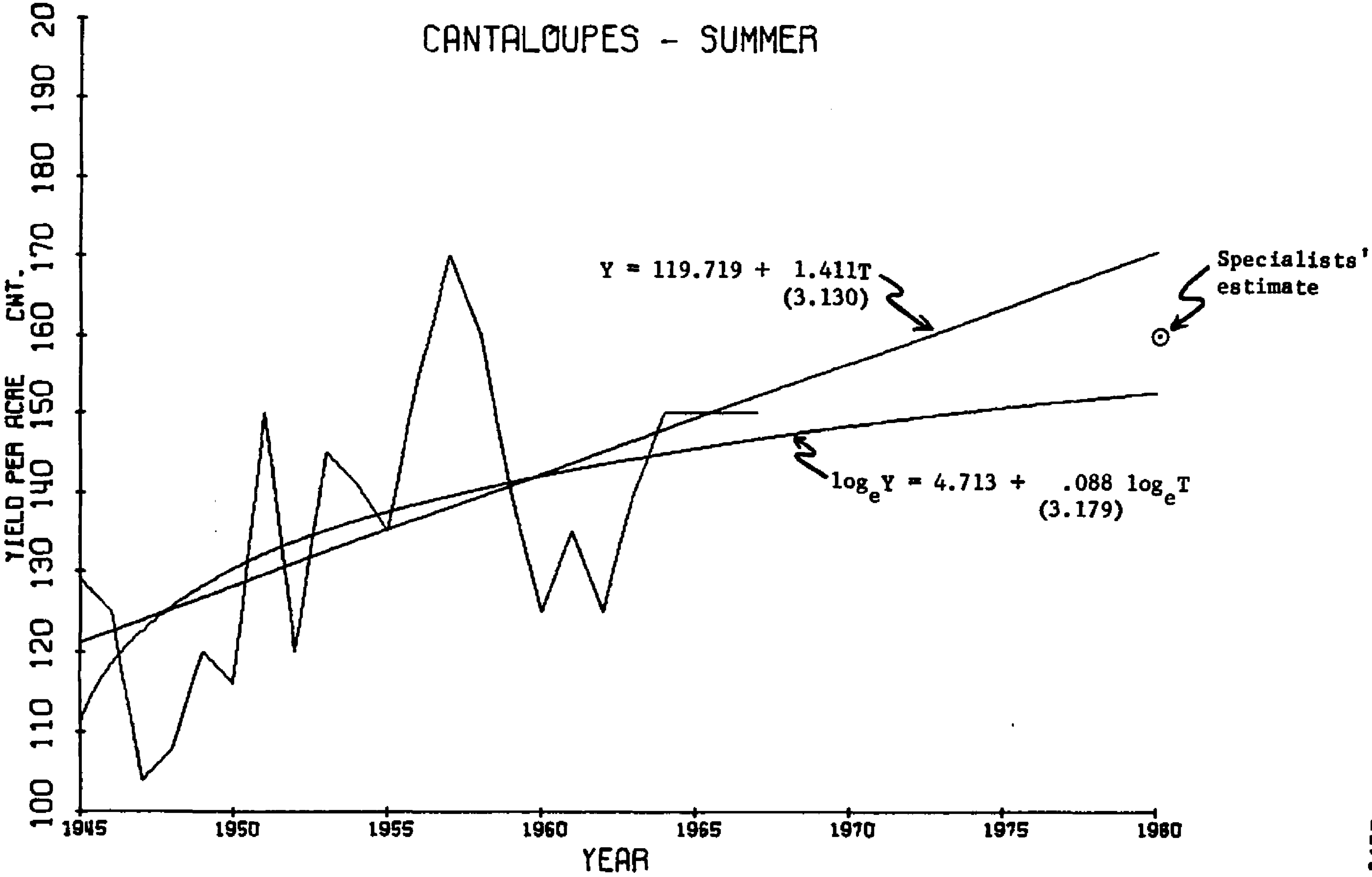


FIGURE C.5

HISTORICAL AND PROJECTED CALIFORNIA YIELD
POTATOES

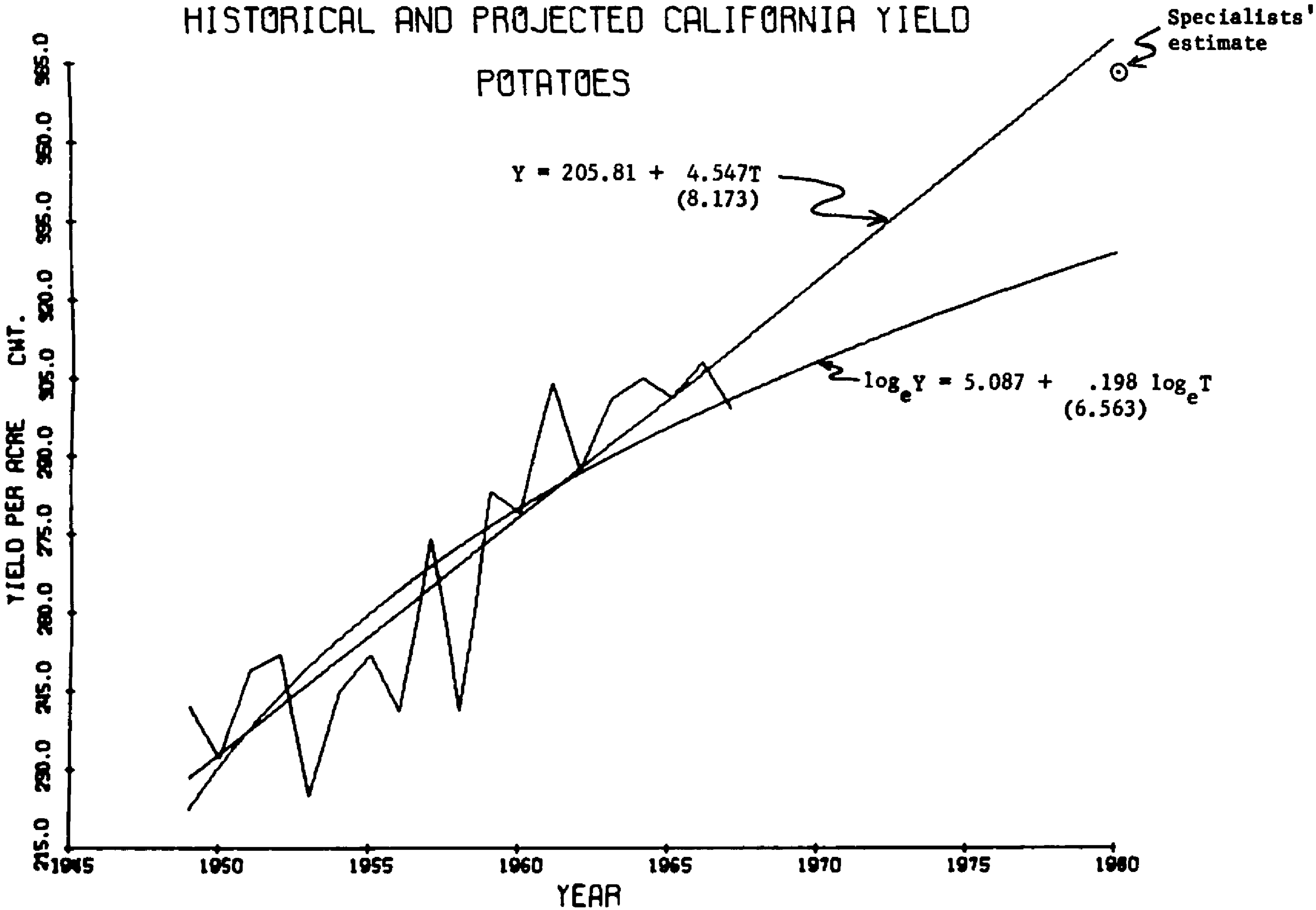


FIGURE C.6

HISTORICAL AND PROJECTED CALIFORNIA YIELD

TOMATOES FOR PROCESSING

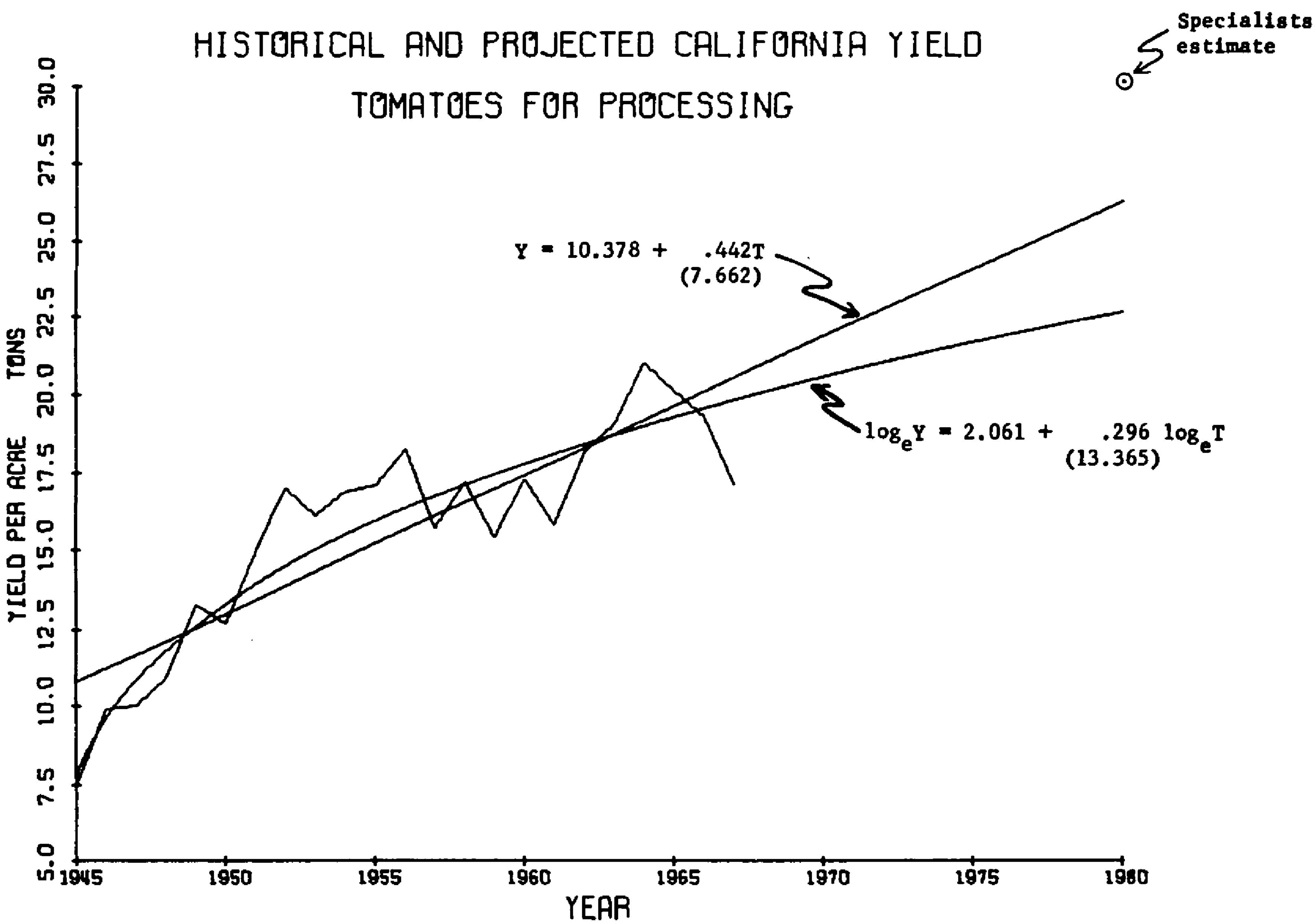


FIGURE C.7

HISTORICAL AND PROJECTED CALIFORNIA YIELD

CORN FOR GRAIN

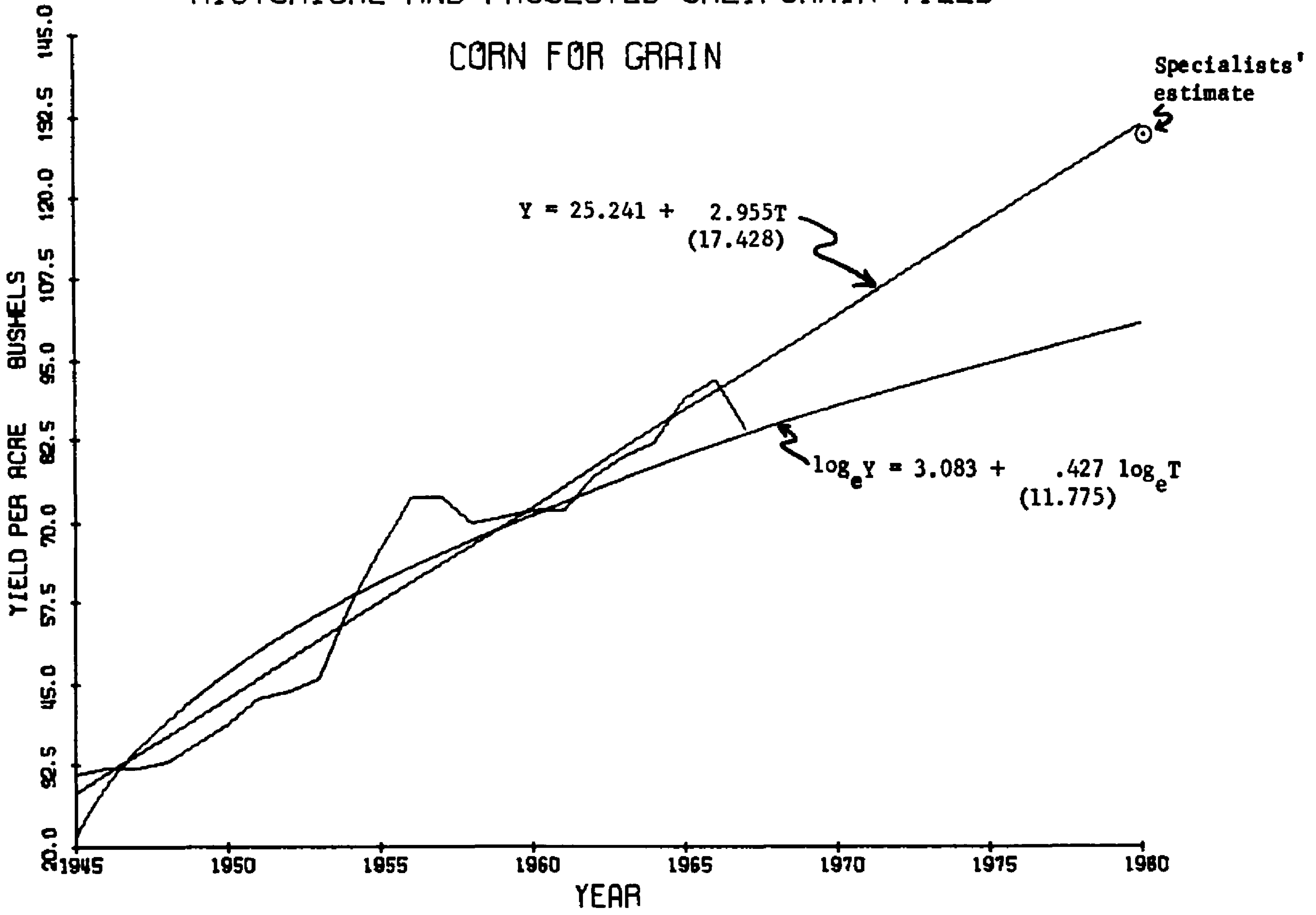


FIGURE C.8

HISTORICAL AND PROJECTED CALIFORNIA YIELD

BARLEY

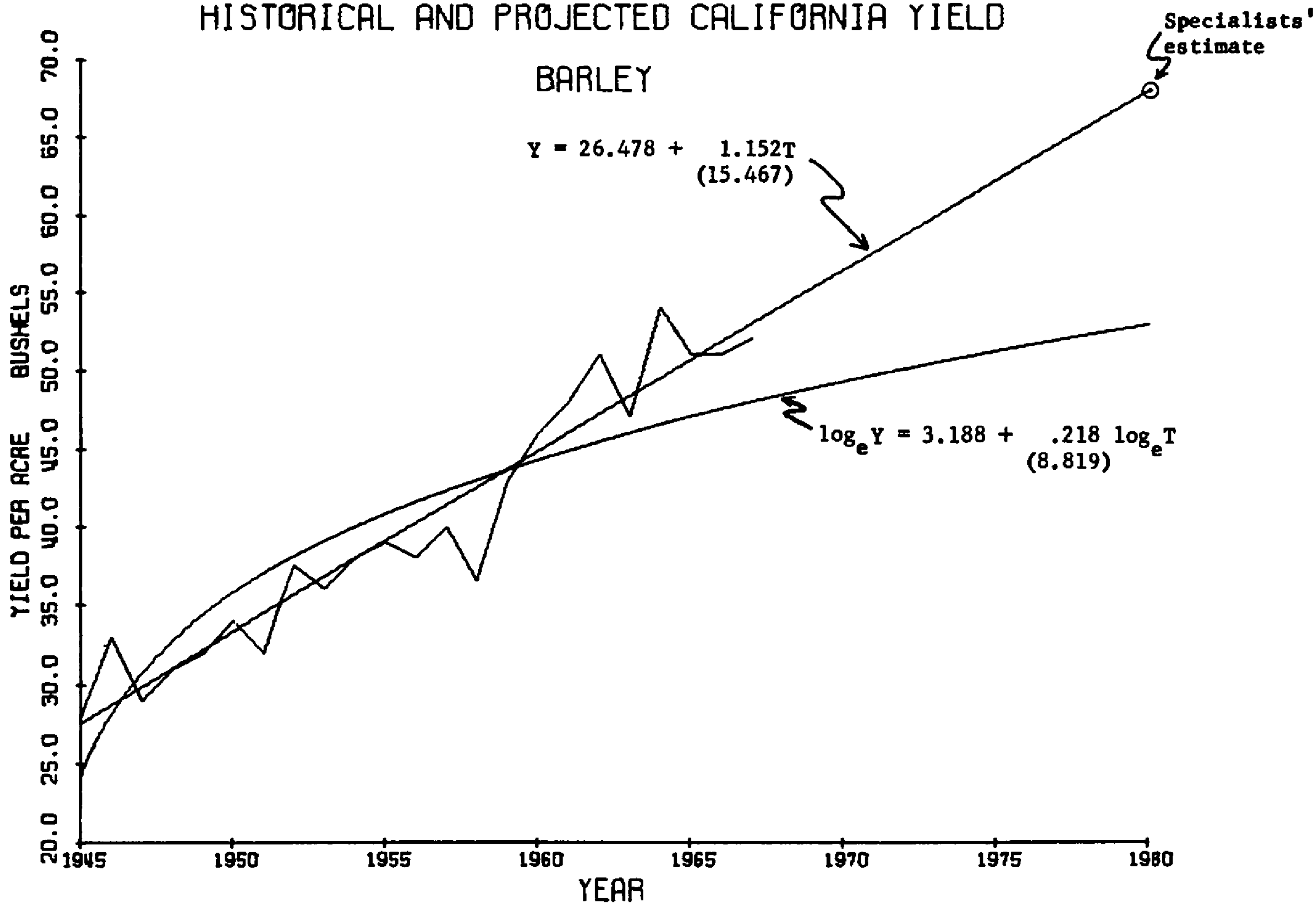


FIGURE C.9

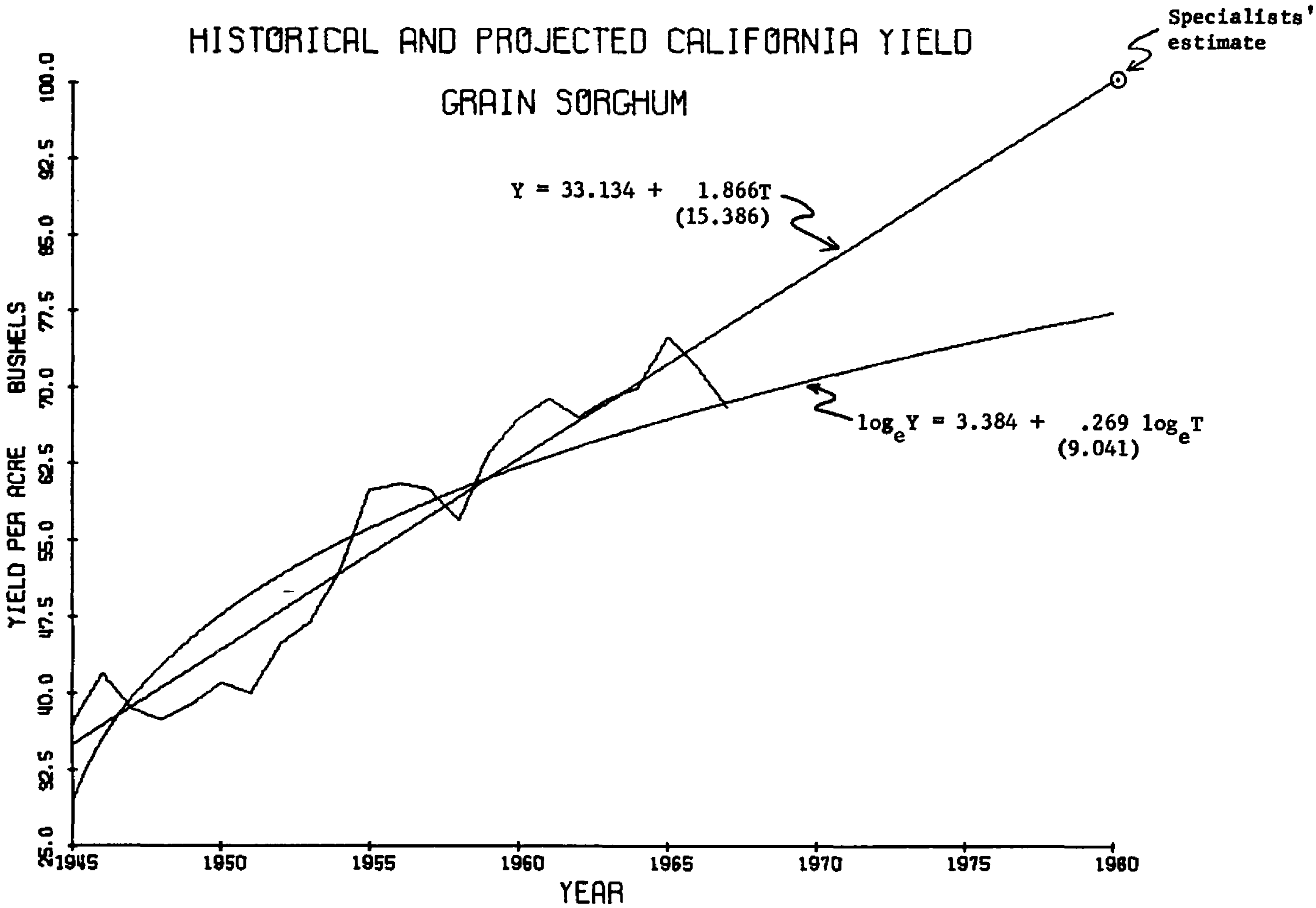

HISTORICAL AND PROJECTED CALIFORNIA YIELD
GRAIN SORGHUM
Specialists' estimate
Y = 33.134 + 1.866T (15.386)
log_e Y = 3.384 + .269 log_e T (9.041)
YIELD PER ACRE BUSHELS
100.0
92.5
85.0
77.5
70.0
62.5
55.0
47.5
40.0
32.5
25.0
1945
1950
1955
1960
1965
1970
1975
1980
YEAR

FIGURE C.10

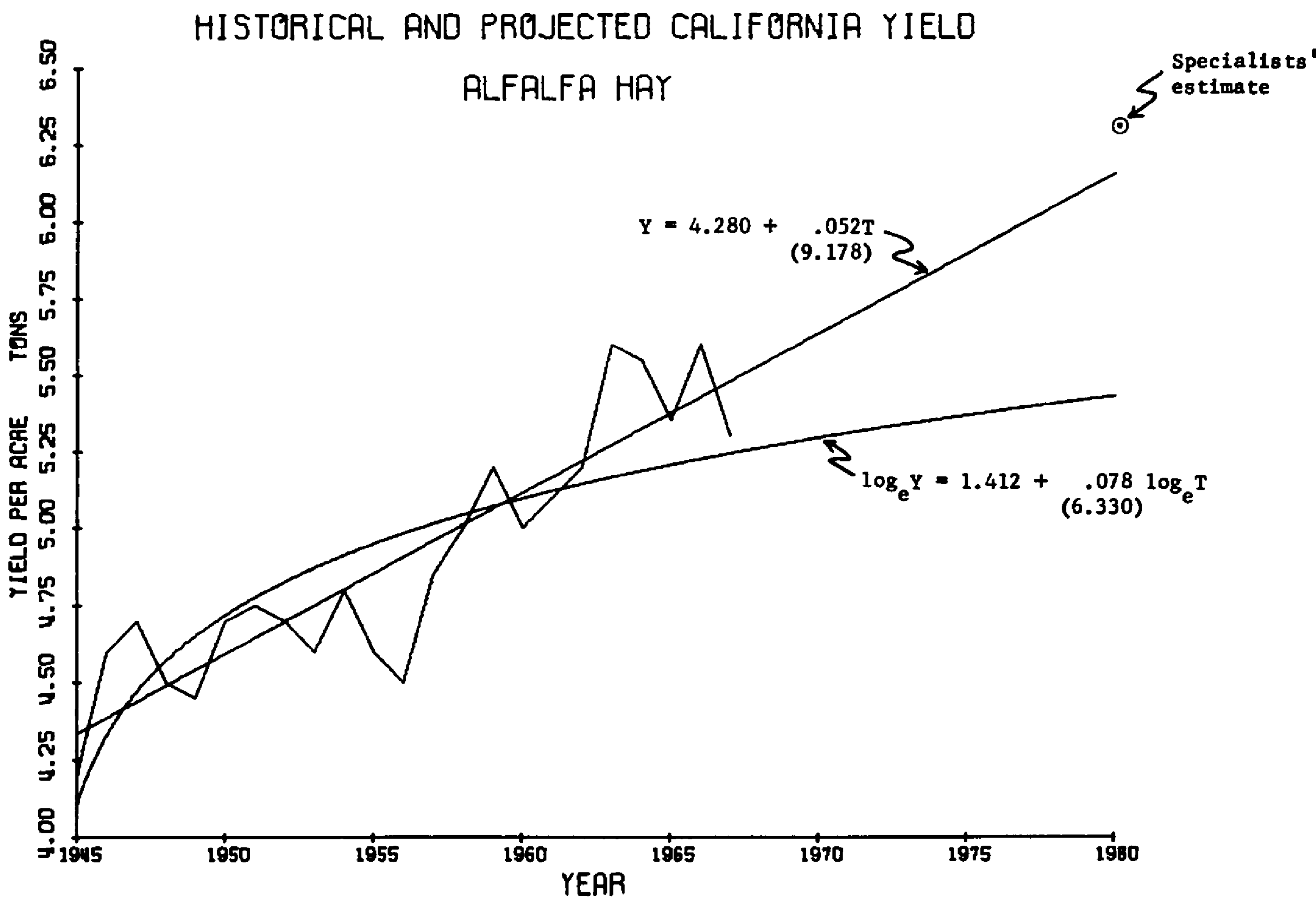

HISTORICAL AND PROJECTED CALIFORNIA YIELD
ALFALFA HAY
Specialists' estimate
Y = 4.280 + .052T
(9.178)
log_e Y = 1.412 + .078 log_e T
(6.330)
YIELD PER ACRE TONS
4.00
4.25
4.50
4.75
5.00
5.25
5.50
5.75
6.00
6.25
6.50
1945
1950
1955
1960
1965
1970
1975
1980
YEAR

FIGURE C.11

HISTORICAL AND PROJECTED CALIFORNIA YIELD

DRY BEANS

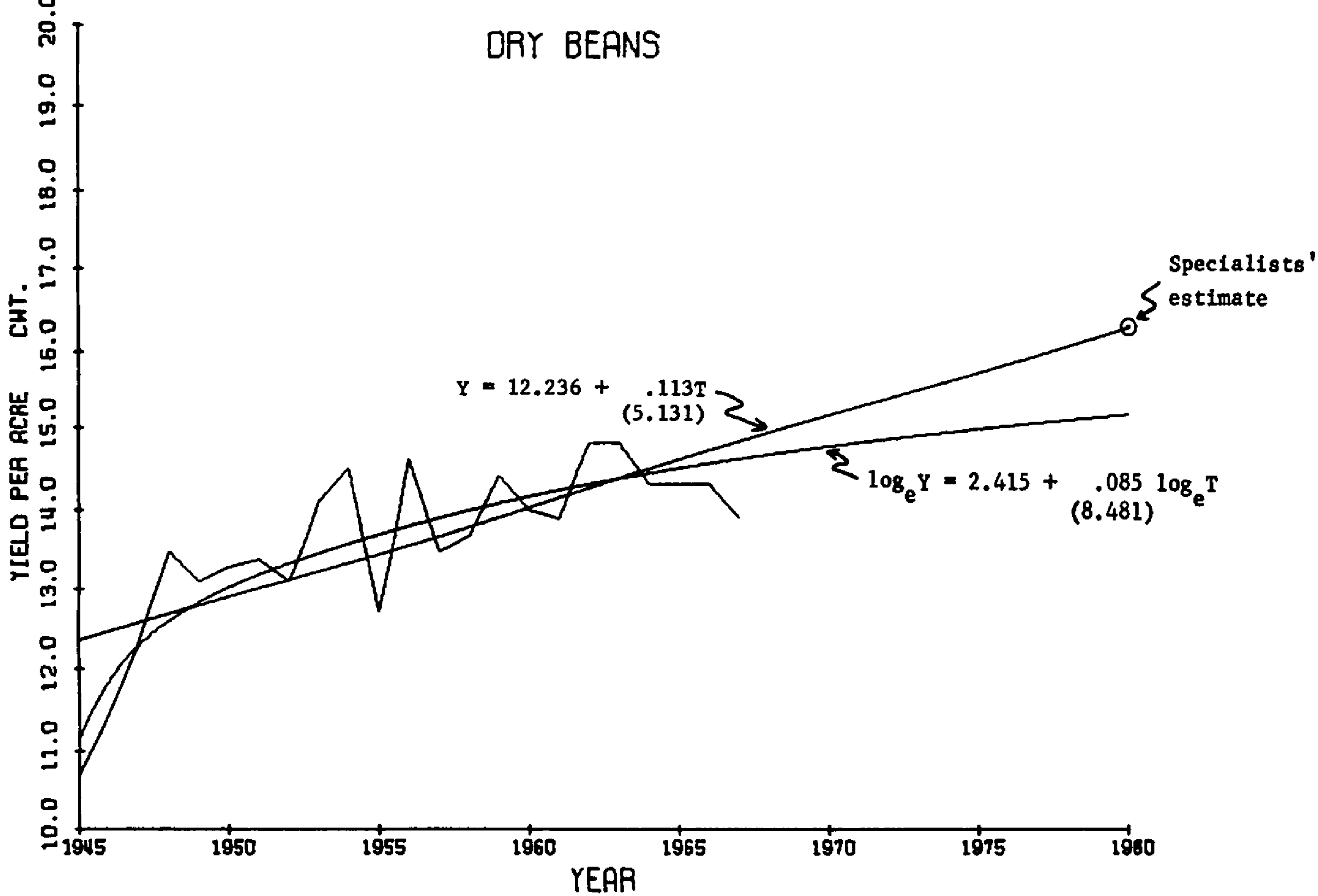


FIGURE C.12

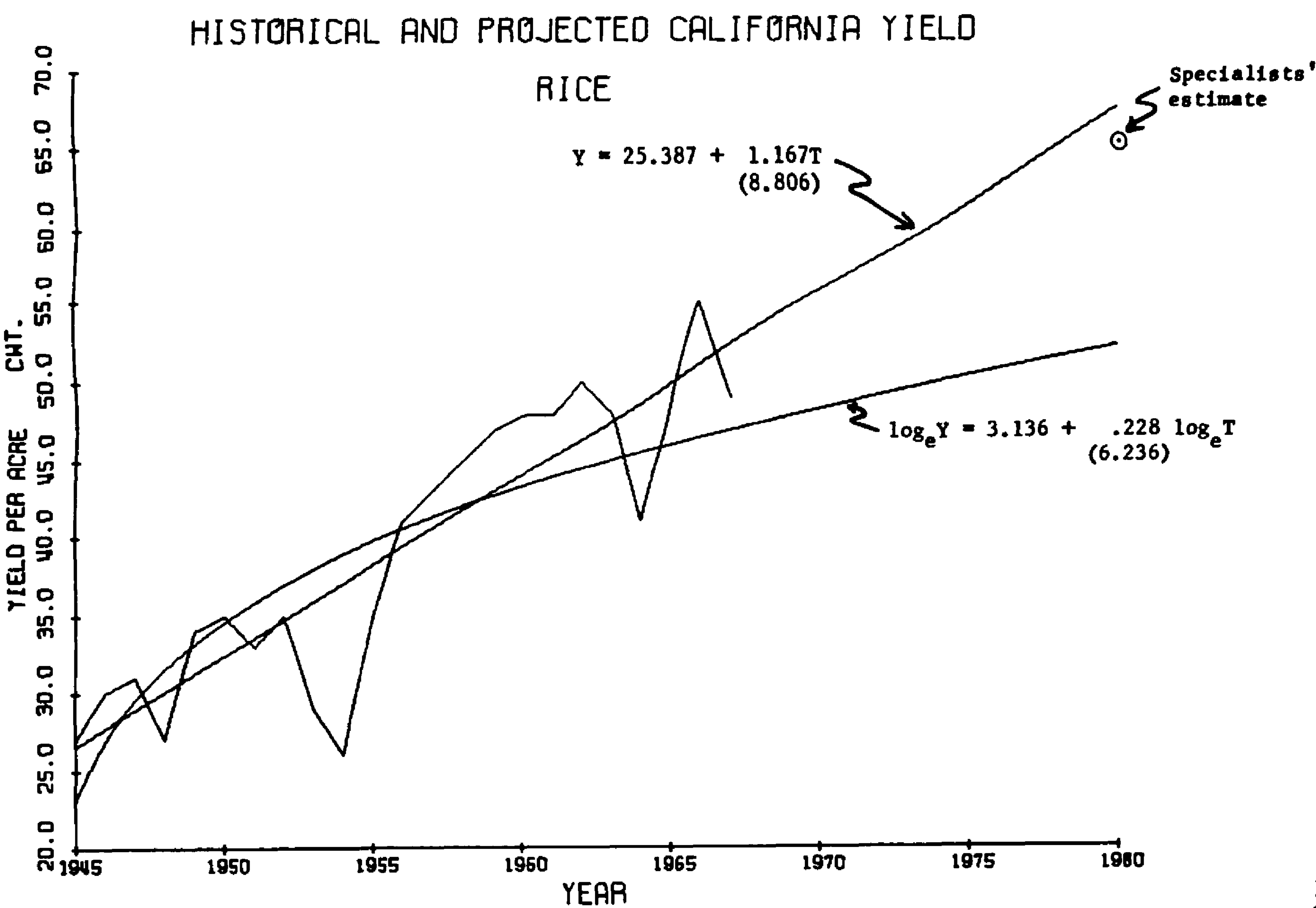

HISTORICAL AND PROJECTED CALIFORNIA YIELD
RICE
Specialists' estimate
Y = 25.387 + 1.167T
(8.806)
log_e Y = 3.136 + .228 log_e T
(6.236)
YIELD PER ACRE CWT.
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
1945
1950
1955
1960
1965
1970
1975
1980
YEAR

FIGURE C.13

HISTORICAL AND PROJECTED CALIFORNIA YIELD

SAFFLOWER

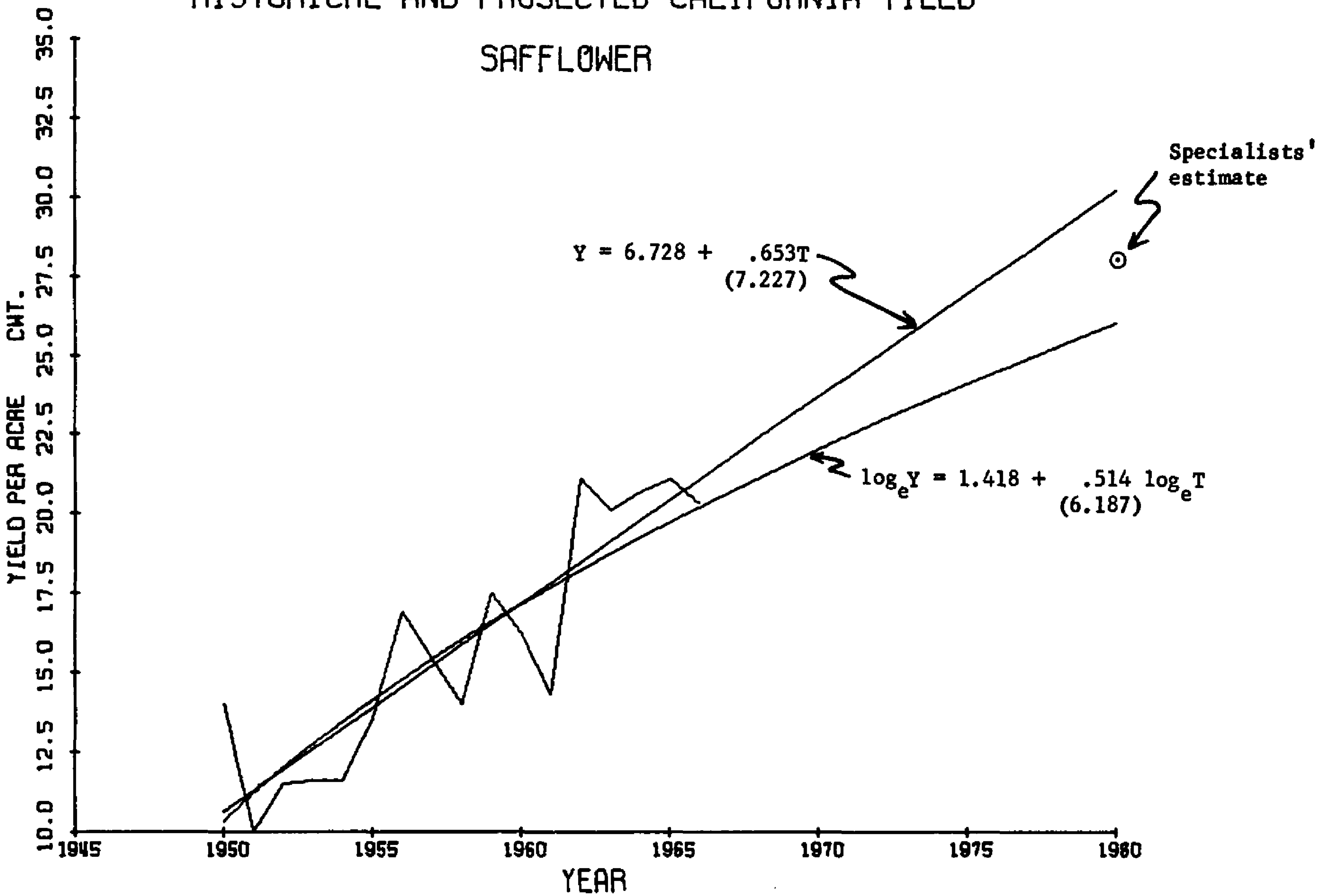


FIGURE C.14

HISTORICAL AND PROJECTED CALIFORNIA YIELD

SUGAR BEETS

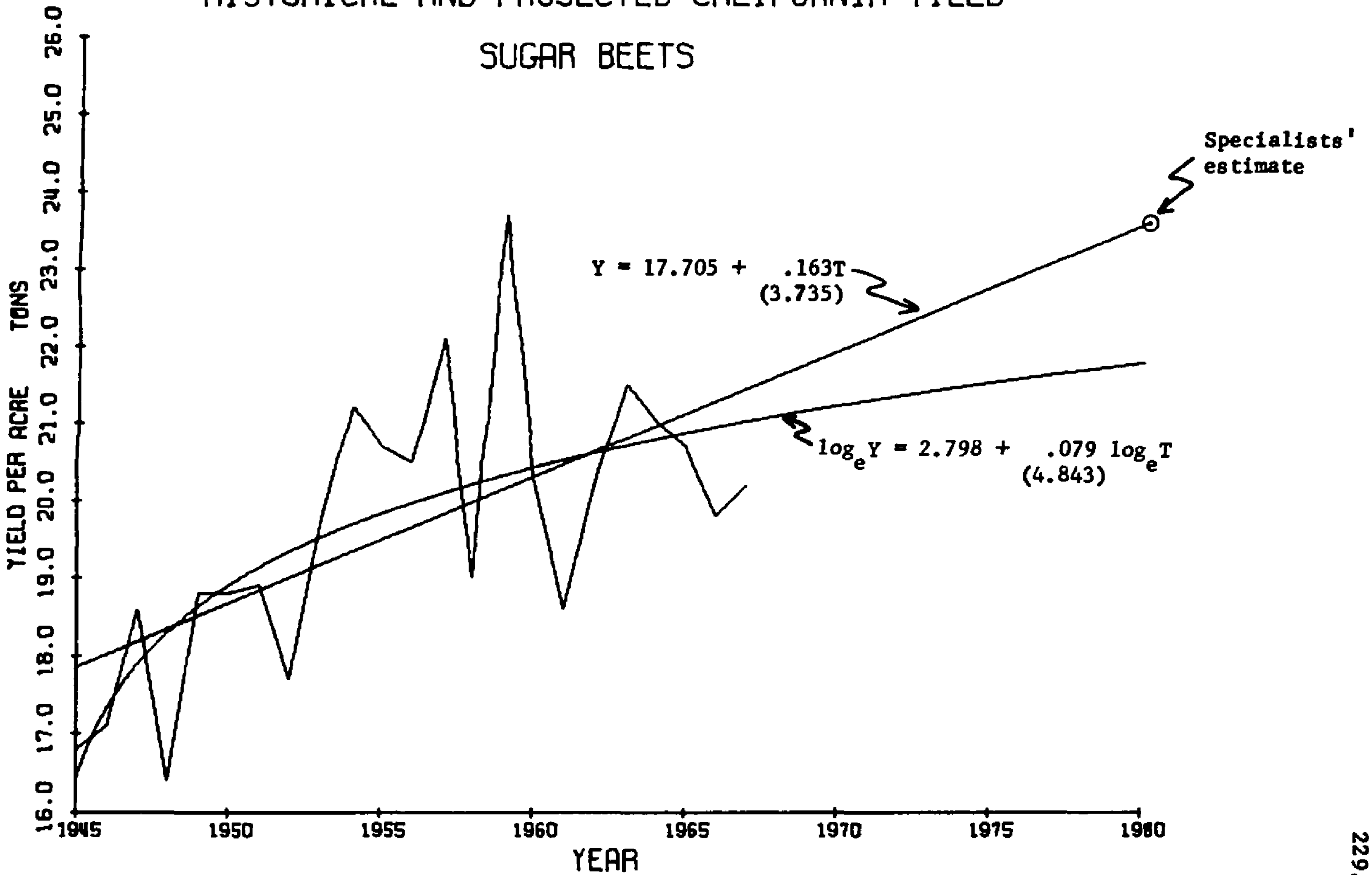
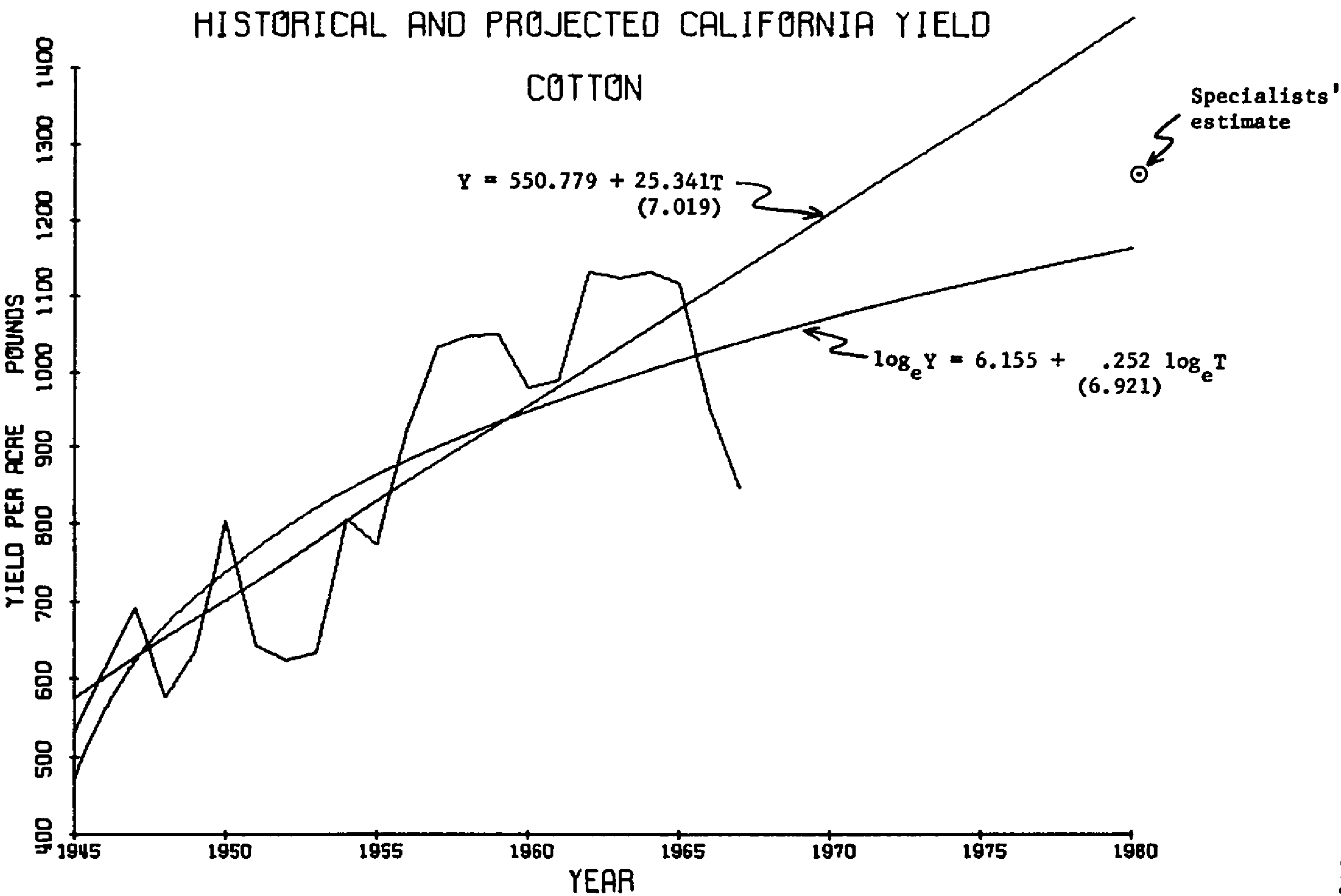


FIGURE C.15


HISTORICAL AND PROJECTED CALIFORNIA YIELD
COTTON
Specialists' estimate
Y = 550.779 + 25.341T
(7.019)
$\log_e Y = 6.155 + .252 \log_e T$
(6.921)
YIELD PER ACRE POUNDS
400
500
600
700
800
900
1000
1100
1200
1300
1400
1945
1950
1955
1960
1965
1970
1975
1980
YEAR

APPENDIX D

PRODUCTION COST COMPONENTS

TABLE D.1

Irrigation Water Requirements, Soil 01[a/]

Climate zone	Asparagus	Broccoli	Lettuce	Cantaloupes	Potatoes	Tomatoes	Corn	Barley
	acre feet							
11	NA	1.00	1.00	NA	1.75	NA	1.50	NA
12	NA	1.25	1.25	NA	2.00	NA	1.75	NA
21	1.25	1.25	1.25	NA	2.00	2.75	1.75	1.00
22	1.50	1.50	2.00	NA	2.25	3.00	2.00	1.50
23	1.50	1.50	2.00	NA	2.25	3.00	2.00	1.50
24	1.50	1.50	1.50	NA	2.25	3.00	2.00	1.00
31	2.50	1.75	1.75	NA	2.50	3.25	2.25	1.50
32	2.50	1.75	1.75	NA	2.50	3.25	2.25	1.50
34	2.50	2.00	2.00	2.00	2.75	3.50	2.50	1.50
41	1.50	1.50	1.50	1.50	2.25	3.00	2.00	1.25
42	1.50	1.50	1.50	1.50	2.25	3.00	2.00	1.25
51	1.50	1.50	1.50	NA	2.25	3.00	2.00	1.00
61	1.50	1.80	1.80	1.75	2.40	3.15	2.00	1.25
62	2.00	2.00	2.00	2.00	2.75	3.50	2.50	1.50
63	2.00	2.00	2.00	2.00	2.75	3.50	2.50	1.50
71	NA	NA	3.00	3.00	3.50	NA	4.50	2.40
72	3.00	3.00	3.00	3.00	3.50	5.00	4.50	2.50
81	1.50	1.50	NA	1.50	2.25	3.00	2.00	1.25
91	NA	1.25	NA	NA	2.00	NA	1.70	1.00

Climate zone	Grain sorghum	Alfalfa hay	Dry beans	Rice	Safflower	Sugar beets	Cotton
	acre feet						
11	1.50	2.25	1.50	NA	NA	NA	NA
12	1.75	2.50	1.75	NA	NA	NA	NA
21	1.75	2.50	1.75	NA	NA	2.00	NA
22	2.00	3.20	2.00	NA	NA	2.25	NA
23	2.00	3.00	2.00	NA	NA	2.25	NA
24	2.00	4.00	2.00	6.00	2.50	3.50	NA
31	2.25	4.50	2.20	NA	NA	2.75	NA
32	2.25	4.50	2.20	NA	NA	2.75	NA
34	2.50	5.00	2.50	NA	3.00	4.00	NA
41	2.00	4.00	1.80	6.00	2.50	3.50	NA
42	2.00	4.00	1.80	6.00	2.50	3.50	NA
51	2.00	4.00	2.00	6.00	2.50	3.50	NA
61	2.15	4.00	2.15	6.00	2.50	3.65	3.00
62	2.50	5.00	2.50	6.00	3.00	4.00	3.00
63	2.50	5.00	2.50	6.00	3.00	4.00	3.00
71	4.00	8.00	NA	NA	4.00	5.50	4.00
72	4.00	8.00	NA	10.00	4.00	5.50	4.00
81	2.00	3.30	1.80	NA	2.50	3.50	NA
91	1.70	3.20	NA	NA	NA	3.25	NA

a/ Soil 12 for rice.

NA Data not obtained.

TABLE D.2

Irrigation Water Requirements by Soil

Soil number	Relative irrigation requirements soil 01 = 100
01	100
02	100
03	100
05	120
11	100
12	80
13	80
14	100
15	100
21	85
22	68
23	85
24	85

TABLE D.3

Typical HPA Water Cost, 1965

HPA	Cost per acre-foot	HPA	Cost per acre-foot	HPA	Cost per acre-foot
	dollars		dollars		dollars
111	2.52	1151	0	2263	20.01
112	2.50	1191	4.02	2311	2.70
121	4.57	1221	2.61	2312	2.25
122	4.92	1223	4.48	2321	2.49
123	4.05	1231	10.00	2323	4.68
132	11.47	1232	10.00	2331	6.07
134	15.00	1241	2.31	2341	3.46
141	2.92	1251	3.28	2342	3.32
142	2.64	1261	2.38	2351	3.77
151	3.66	1262	9.93	2361	.41
161	1.49	1263	9.63	2381	2.25
162	2.53	1281	4.96	2391	NA
163	2.55	1291	1.95	2441	4.38
171	2.70	1341	1.90	2442	4.91
181	2.32	1351	2.34	2451	5.29
191	4.15	1361	1.91	2461	1.85
221	4.87	1362	12.91	2462	12.27
222	6.72	1381	NA	2463	5.18
223	5.66	1451	2.92	2471	NA
224	4.73	1461	2.07		
232	10.00	1462	6.73		
251	6.43	1551	.64		
261	2.44	1561	2.07		
262	9.95	1562	9.10		
263	6.07	1572	4.80		
281	6.45	2111	2.56		
362	14.70	2121	3.97		
363	19.36	2122	6.71		
371	4.89	2123	4.91		
372	4.09	2124	4.83		
381	11.36	2131	10.05		
391	2.92	2134	25.00		
521	4.05	2141	4.34		
522	5.20	2142	4.82		
561	1.82	2151	4.05		
562	2.48	2181	4.13		
563	2.41	2223	10.00		
572	4.32	2232	20.00		

NA Not applicable -- no irrigated activities specified in these HPAs.

TABLE D.4

Standard Unit Cost Estimates, 1965

Cost item	Unit	Cost/unit
		dollars
Skilled labor	hour	2.00
Unskilled labor	hour	1.75
Fertilizer:		
Nitrogen	pound	.07
P_2O_5	pound	.11
Sprinkler irrigation:[a]		
Investment	year	19.50
Cost of establishing pressure	acre-foot	3.00
		percent
Interest on investment	1/2 of total investment	6.0
Management and overhead	sum of all other costs	10.0

a/ On soils 21 - 24 only.

TABLE D.5

Standard Harvest Cost Estimates
Per Unit Crop Output, 1965

Representative commodity	Harvest costs
	dollars/ton
Vegetable crops:	
Asparagus	142.15
Broccoli	25.00
Lettuce	46.00
Cantaloupes	50.15
Potatoes	22.80
Tomatoes for processing	7.84
Field crops:	
Corn	3.75
Barley	2.00
Grain sorghum	2.40
Alfalfa hay	6.90
Dry beans	23.25
Rice	5.40
Safflower	2.50
Sugar beets	2.50
	dollars/bale
Cotton	40.41

TABLE D.6

Annual Investment Cost of Reclaiming Saline-Alkaline Soils

HPA	Barley, nonirrigated	Rice	Other crops[a/]
	dollars		
1341	0	4.00	20.00
1351	0	2.00	15.00
1361	0	2.00	14.00
1362	0	13.00	18.00
1381	0	b/	b/
1551	0	2.00	8.00
1561	0	2.00	8.00
1562	0	2.00	7.00
1572	0	5.00	15.00

a/ Cut in half for each crop in double cropping activity.

b/ Inadequate water supply for extensive permanent reclamation.

TABLE D.7

Barley and Grain Sorghum Double Crop Activity

Double crop climates	Proportion of years each crop can be:		
	Grown (a)	Grown with other crop (a_1)	Grown as a single crop (a_2)
22	.80	.60	.20
23	.80	.60	.20
24	.85	.70	.15
31	.80	.60	.20
32	.80	.60	.20
33	.80	.60	.20
34	1.00	1.00	0
41	.80	.60	.20
42	.80	.60	.20
51	.85	.70	.15
61	.85	.70	.15
62	.90	.80	.10
63	.90	.80	.10
72	1.00	1.00	0

TABLE D.8

County Agricultural Extension Service Sample Cost Sheets
Used for Development of Base Area Budgets

Crop	County	Year	HPA assumed applicable for
Vegetable crops:			
Asparagus	Solano	1966	0151
Broccoli	Santa Barbara	1968	0222
Lettuce	Santa Barbara	1968	0222
Cantaloupes	Kings	1968	0262
Potatoes	Tulare	1964	0262
Tomatoes for processing	San Joaquin	1965	0151
Field crops:			
Corn for grain	Tulare	1967	0262
Barley	Tulare	1967	0262
Grain sorghum	Tulare	1967	0262
Alfalfa hay	Tulare	1967	0262
Dry beans	Tulare	1967	0262
Rice	Sutter	1966	1241
Safflower	Tulare	1967	0262
Sugar beets	Tulare	1967	0262
Cotton	Tulare	1967	0262

APPENDIX E

MODEL 1961-65 YIELD AND PRODUCTION COST PARAMETERS

TABLE E.1

Estimated Base Period Annual Crop Yield and Total Nonland Cost per Acre for Single Crop Model Activities

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
121	AS	423.00	1.55
122	AS	530.00	2.22
123	AS	529.00	2.22
132	AS	451.00	1.55
134	AS	463.00	1.55
141	AS	423.00	1.55
142	AS	423.00	1.55
151	AS	465.00	1.81
161	AS	385.00	1.32
162	AS	355.00	1.10
163	AS	355.00	1.10
181	AS	386.00	1.32
221	AS	423.00	1.55
222	AS	533.00	2.22
223	AS	531.00	2.22
224	AS	460.00	1.77
232	AS	449.00	1.55
251	AS	463.00	1.77
261	AS	386.00	1.32
262	AS	372.00	1.10
263	AS	363.00	1.10
281	AS	393.00	1.32
362	AS	383.00	1.10
363	AS	393.00	1.10
372	AS	385.00	1.12
381	AS	401.00	1.32
521	AS	363.00	1.15
522	AS	445.00	1.65
561	AS	335.00	0.99
562	AS	314.00	0.82
563	AS	314.00	0.82
572	AS	405.00	1.22
1151	AS	379.00	1.34
1221	AS	441.00	1.55
1223	AS	549.00	2.22
1232	AS	464.00	1.55
1241	AS	442.00	1.55
1251	AS	484.00	1.81
1261	AS	406.00	1.32
1262	AS	388.00	1.10
1263	AS	387.00	1.10
1281	AS	409.00	1.32
1341	AS	463.00	1.55
1351	AS	499.00	1.81
1361	AS	421.00	1.32
1362	AS	413.00	1.10

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
1451	AS	364.00	1.18
1461	AS	333.00	0.99
1462	AS	321.00	0.82
1551	AS	369.00	1.18
1561	AS	343.00	0.99
1562	AS	334.00	0.82
1572	AS	357.00	0.82
2121	AS	378.00	1.15
2122	AS	463.00	1.65
2123	AS	460.00	1.65
2124	AS	408.00	1.32
2134	AS	439.00	1.15
2141	AS	381.00	1.15
2142	AS	382.00	1.15
2151	AS	407.00	1.32
2181	AS	355.00	0.99
2223	AS	477.00	1.60
2232	AS	437.00	1.15
2263	AS	375.00	0.82
111	BR	369.00	2.34
112	BR	369.00	2.24
134	BR	413.00	2.41
141	BR	369.00	2.06
142	BR	373.00	2.24
151	BR	380.00	2.41
161	BR	399.00	3.10
162	BR	395.00	2.75
163	BR	400.00	2.92
181	BR	359.00	1.72
191	BR	357.00	1.72
224	BR	377.00	2.26
251	BR	381.00	2.26
261	BR	396.00	2.91
262	BR	407.00	2.58
263	BR	403.00	2.74
281	BR	363.00	1.62
362	BR	413.00	2.41
363	BR	427.00	2.56
372	BR	401.00	2.21
381	BR	367.00	1.50
391	BR	350.00	1.50
561	BR	389.00	2.52
562	BR	387.00	2.24
563	BR	391.00	2.37
572	BR	409.00	2.12
1191	BR	356.00	1.68

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
1241	BR	351.00	1.63
1251	BR	361.00	1.90
1261	BR	378.00	2.44
1262	BR	386.00	2.17
1263	BR	389.00	2.30
1281	BR	348.00	1.36
1291	BR	341.00	1.36
1341	BR	373.00	1.63
1351	BR	375.00	1.90
1361	BR	393.00	2.44
1362	BR	411.00	2.17
1451	BR	367.00	1.96
1461	BR	385.00	2.52
1462	BR	390.00	2.24
1551	BR	371.00	1.96
1561	BR	393.00	2.52
1562	BR	403.00	2.24
1572	BR	407.00	1.76
2111	BR	373.00	1.90
2124	BR	385.00	1.96
2134	BR	432.00	1.96
2141	BR	377.00	1.68
2142	BR	381.00	1.81
2151	BR	385.00	1.96
2181	BR	369.00	1.40
2263	BR	425.00	2.49
2311	BR	369.00	1.75
2312	BR	373.00	1.81
2341	BR	372.00	1.55
2342	BR	375.00	1.68
2351	BR	379.00	1.81
2361	BR	393.00	2.32
2381	BR	363.00	1.29
2441	BR	371.00	1.48
2442	BR	376.00	1.61
2451	BR	379.00	1.73
2461	BR	393.00	2.23
2462	BR	409.00	1.98
2463	BR	399.00	2.10
141	LE	601.00	7.38
142	LE	601.00	7.38
151	LE	681.00	8.91
171	LE	576.00	6.42
224	LE	682.00	8.91
251	LE	685.00	8.91
371	LE	569.00	6.13

Footnotes at end of table. --Continued

Table E.1

HPA[a]	Crop activity code [b]	Estimated cost	Estimated yield [c]
		$/ac.	tons/ac.
1241	LE	591.00	7.13
1251	LE	667.00	8.61
1341	LE	613.00	7.13
1351	LE	683.00	8.61
1451	LE	633.00	7.87
1551	LE	637.00	7.87
2124	LE	661.00	8.12
2141	LE	587.00	6.68
2142	LE	588.00	6.68
2151	LE	659.00	8.12
2341	LE	546.00	5.89
2342	LE	546.00	5.89
2351	LE	609.00	7.13
2441	LE	525.00	5.44
2442	LE	525.00	5.44
2451	LE	586.00	6.63
111	LS	625.00	7.96
112	LS	585.00	7.12
122	LS	745.00	10.03
123	LS	781.00	10.78
221	LS	717.00	9.65
222	LS	771.00	10.46
223	LS	766.00	10.40
522	LS	755.00	9.96
1223	LS	765.00	10.42
2111	LS	637.00	7.82
2122	LS	739.00	9.47
2123	LS	753.00	9.80
2223	LS	755.00	9.70
2311	LS	588.00	6.86
2312	LS	541.00	5.87
372	CF	513.00	6.22
572	CF	338.00	3.05
1572	CF	465.00	5.02
134	CA	531.00	6.32
141	CA	510.00	6.51
142	CA	509.00	6.51
161	CA	489.00	6.14
162	CA	514.00	6.51
163	CA	514.00	6.51
171	CA	405.00	4.35
181	CA	457.00	5.58
261	CA	539.00	7.01
262	CA	581.00	7.44
263	CA	573.00	7.44
281	CA	511.00	6.42

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost	Estimated yield [c]
		$/ac.	tons/ac.
362	CA	647.00	8.44
363	CA	653.00	8.37
371	CA	479.00	5.58
381	CA	559.00	7.16
561	CA	389.00	4.38
562	CA	408.00	4.65
563	CA	407.00	4.65
1241	CA	455.00	5.58
1261	CA	439.00	5.26
1262	CA	472.00	5.58
1263	CA	471.00	5.58
1281	CA	412.00	4.74
1341	CA	476.00	5.58
1361	CA	454.00	5.26
1362	CA	497.00	5.58
1461	CA	423.00	4.91
1462	CA	451.00	5.21
1561	CA	431.00	4.91
1562	CA	464.00	5.21
2134	CA	517.00	5.42
2141	CA	481.00	5.58
2142	CA	482.00	5.58
2181	CA	435.00	4.74
2263	CA	506.00	5.58
2341	CA	358.00	3.37
2342	CA	357.00	3.37
2361	CA	345.00	3.18
2381	CA	331.00	2.90
112	PO	529.00	9.42
121	PO	539.00	9.64
122	PO	615.00	12.48
123	PO	561.00	10.40
132	PO	601.00	11.06
134	PO	627.00	11.44
141	PO	577.00	11.18
142	PO	505.00	8.32
151	PO	599.00	11.96
161	PO	595.00	11.96
162	PO	603.00	11.96
163	PO	550.00	9.88
171	PO	547.00	9.36
181	PO	569.00	10.92
191	PO	531.00	9.36
221	PO	588.00	11.58
222	PO	619.00	12.48
223	PO	561.00	10.24

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
224	PO	601.00	11.96
232	PO	607.00	11.44
251	PO	605.00	11.96
261	PO	597.00	11.96
262	PO	625.00	11.96
263	PO	561.00	9.88
281	PO	579.00	10.92
362	PO	639.00	11.96
363	PO	601.00	9.88
371	PO	556.00	9.36
372	PO	525.00	8.22
381	PO	591.00	10.92
391	PO	528.00	9.36
521	PO	525.00	9.05
522	PO	577.00	10.82
561	PO	559.00	10.40
562	PO	567.00	10.40
563	PO	521.00	8.60
572	PO	532.00	8.22
111	PO	522.00	9.29
1151	PO	633.00	13.00
1191	PO	549.00	10.12
1451	PO	531.00	9.33
1461	PO	531.00	9.33
1462	PO	549.00	9.33
1551	PO	534.00	9.33
1561	PO	539.00	9.33
1562	PO	564.00	9.33
1572	PO	498.00	6.40
2111	PO	507.00	7.84
2121	PO	519.00	8.11
2122	PO	569.00	9.73
2123	PO	525.00	8.11
2124	PO	555.00	9.33
2131	PO	531.00	7.71
2134	PO	605.00	8.92
2141	PO	539.00	8.72
2142	PO	449.00	5.10
2151	PO	554.00	9.33
2181	PO	534.00	8.53
121	TO	440.00	19.34
122	TO	449.00	20.02
123	TO	461.00	21.74
132	TO	443.00	16.15
134	TO	431.00	12.74
141	TO	455.00	21.36

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost	Estimated yield [c]
		$/ac.	tons/ac.
142	TO	453.00	21.36
151	TO	453.00	20.81
161	TO	431.00	19.11
162	TO	399.00	14.56
163	TO	399.00	14.56
181	TO	379.00	12.74
221	TO	431.00	18.20
222	TO	455.00	20.02
223	TO	465.00	21.47
224	TO	457.00	20.98
232	TO	465.00	19.39
251	TO	463.00	20.98
261	TO	435.00	19.11
262	TO	427.00	14.56
263	TO	413.00	14.56
281	TO	392.00	12.74
362	TO	446.00	14.56
363	TO	464.00	14.56
372	TO	389.00	10.92
381	TO	408.00	12.74
521	TO	369.00	10.61
522	TO	385.00	11.68
561	TO	369.00	11.14
562	TO	353.00	8.49
563	TO	352.00	8.49
572	TO	361.00	6.37
1151	TO	367.00	17.95
1221	TO	407.00	16.69
1223	TO	449.00	20.87
1231	TO	395.00	12.52
1232	TO	445.00	18.39
1241	TO	422.00	18.39
1251	TO	431.00	19.11
1261	TO	415.00	17.53
1262	TO	405.00	13.35
1263	TO	405.00	13.35
1281	TO	371.00	11.68
1341	TO	443.00	18.39
1351	TO	445.00	19.11
1361	TO	430.00	17.53
1362	TO	435.00	13.35
1451	TO	429.00	18.47
1461	TO	409.00	16.17
1462	TO	396.00	12.32
1551	TO	431.00	18.47
1561	TO	417.00	16.17

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
1562	TO	413.00	12.32
1572	TO	399.00	9.78
2121	TO	404.00	12.89
2122	TO	425.00	14.18
2123	TO	437.00	16.11
2124	TO	429.00	15.24
2131	TO	401.00	9.67
2134	TO	449.00	9.03
2141	TO	422.00	14.50
2142	TO	429.00	15.22
2151	TO	427.00	15.24
2181	TO	374.00	9.03
2223	TO	465.00	18.85
2232	TO	461.00	15.16
2263	TO	440.00	12.13
2321	TO	367.00	9.10
2323	TO	396.00	11.37
2331	TO	364.00	6.82
2341	TO	389.00	10.92
2342	TO	388.00	10.92
2351	TO	403.00	12.49
2361	TO	369.00	9.55
2381	TO	346.00	6.37
111	CN	97.00	1.65
112	CN	101.00	2.09
121	CN	106.00	2.24
122	CN	108.00	1.87
123	CN	107.00	1.87
132	CN	127.00	1.85
134	CN	143.00	1.94
141	CN	107.00	2.58
142	CN	104.00	2.09
151	CN	109.00	2.69
161	CN	103.00	2.42
162	CN	111.00	2.44
163	CN	109.00	2.02
171	CN	130.00	1.90
181	CN	103.00	1.91
191	CN	102.00	1.68
221	CN	105.00	2.09
222	CN	111.00	1.75
223	CN	109.00	1.80
224	CN	111.00	2.62
232	CN	123.00	1.72
251	CN	115.00	2.62
261	CN	105.00	2.35

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
262	CN	130.00	2.24
263	CN	118.00	1.87
281	CN	111.00	1.79
362	CN	143.00	2.14
363	CN	154.00	1.72
371	CN	140.00	1.65
372	CN	137.00	1.92
381	CN	121.00	1.65
391	CN	99.00	1.45
521	CN	106.00	1.50
522	CN	111.00	1.25
561	CN	105.00	1.73
562	CN	113.00	1.67
563	CN	111.00	1.33
572	CN	147.00	1.48
1151	CN	99.00	2.65
1191	CN	102.00	1.68
1221	CN	97.00	1.94
1223	CN	101.00	1.62
1231	CN	115.00	1.60
1232	CN	115.00	1.60
1241	CN	100.00	2.24
1251	CN	101.00	2.28
1261	CN	99.00	2.14
1262	CN	120.00	2.09
1263	CN	118.00	1.72
1281	CN	102.00	1.65
1291	CN	93.00	1.45
1341	CN	121.00	2.24
1351	CN	117.00	2.28
1361	CN	114.00	2.14
1362	CN	147.00	2.09
1451	CN	104.00	1.87
1461	CN	101.00	1.61
1462	CN	119.00	1.65
1551	CN	107.00	1.87
1561	CN	109.00	1.61
1562	CN	133.00	1.65
1572	CN	155.00	1.48
2111	CN	117.00	1.55
2121	CN	123.00	1.63
2122	CN	129.00	1.36
2123	CN	126.00	1.36
2124	CN	129.00	2.06
2131	CN	141.00	1.34
2134	CN	180.00	1.41

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
2141	CN	127.00	1.94
2142	CN	127.00	1.58
2151	CN	127.00	2.06
2181	CN	125.00	1.37
2223	CN	129.00	1.54
2232	CN	149.00	1.41
2263	CN	155.00	1.61
2311	CN	116.00	1.32
2312	CN	119.00	1.50
2321	CN	119.00	1.50
2323	CN	125.00	1.25
2331	CN	131.00	1.23
2341	CN	125.00	1.75
2342	CN	123.00	1.45
2351	CN	126.00	1.87
2361	CN	119.00	1.75
2381	CN	121.00	1.28
2441	CN	125.00	1.40
2442	CN	125.00	1.16
2451	CN	127.00	1.52
2461	CN	121.00	1.50
2462	CN	150.00	1.34
2463	CN	133.00	1.21
122	BF	21.43	0.44
123	BF	21.45	0.45
132	BF	21.54	0.49
141	BF	21.97	0.69
142	BF	21.67	0.55
151	BF	21.95	0.68
161	BF	21.60	0.52
181	BF	21.43	0.44
191	BF	21.37	0.41
222	BF	21.43	0.44
223	BF	21.43	0.44
224	BF	21.97	0.69
232	BF	21.45	0.45
251	BF	22.16	0.77
261	BF	21.60	0.52
281	BF	21.43	0.44
381	BF	21.43	0.44
391	BF	21.37	0.41
522	BF	21.21	0.34
561	BF	21.39	0.42
1223	BF	21.45	0.45
1231	BF	21.56	0.50
1232	BF	21.54	0.49

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
1241	BF	21.93	0.67
1251	BF	21.97	0.69
1261	BF	21.60	0.52
1281	BF	21.41	0.43
1291	BF	21.32	0.39
1341	BF	21.19	0.33
1351	BF	21.21	0.34
1361	BF	21.04	0.26
1381	BF	21.11	0.29
1451	BF	21.93	0.67
1461	BF	21.43	0.44
1551	BF	21.19	0.33
1561	BF	20.96	0.23
2122	BF	20.93	0.22
2123	BF	20.93	0.22
2124	BF	21.28	0.37
2131	BF	20.98	0.24
2134	BF	20.85	0.18
2141	BF	21.24	0.35
2142	BF	21.11	0.29
2151	BF	21.28	0.37
2181	BF	21.02	0.25
2223	BF	21.09	0.28
2232	BF	21.06	0.27
2323	BF	20.91	0.21
2331	BF	20.96	0.23
2341	BF	21.21	0.34
2342	BF	21.02	0.25
2351	BF	21.26	0.36
2361	BF	20.96	0.23
2371	BF	21.17	0.32
2381	BF	20.91	0.21
2391	BF	20.89	0.20
2441	BF	21.15	0.31
2442	BF	21.00	0.24
2451	BF	21.17	0.32
2461	BF	20.89	0.20
2463	BF	20.89	0.20
112	BN	47.00	0.94
121	BN	47.00	0.92
221	BN	47.00	0.75
521	BN	47.00	0.58
1221	BN	47.00	0.77
2121	BN	46.00	0.36
2312	BN	46.00	0.45
2321	BN	46.00	0.43

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
141	BI	63.00	1.78
142	BI	63.00	1.76
151	BI	63.00	1.76
161	BI	61.00	1.76
162	BI	63.00	1.68
163	BI	63.00	1.64
171	BI	69.00	1.76
181	BI	63.00	1.76
191	BI	63.00	1.76
251	BI	66.00	1.76
261	BI	63.00	1.76
262	BI	76.00	1.66
263	BI	69.00	1.67
281	BI	68.00	1.76
362	BI	84.00	1.75
363	BI	91.00	1.78
371	BI	75.00	1.76
381	BI	75.00	1.76
391	BI	62.00	1.76
1151	BI	58.00	1.76
1191	BI	63.00	1.84
1241	BI	61.00	1.76
1251	BI	61.00	1.76
1261	BI	61.00	1.76
1262	BI	73.00	1.83
1263	BI	72.00	1.76
1281	BI	64.00	1.76
1291	BI	59.00	1.60
1341	BI	83.00	1.76
1351	BI	77.00	1.76
1361	BI	76.00	1.76
1362	BI	96.00	1.83
111	GS	73.00	1.36
112	GS	73.00	1.29
121	GS	79.00	1.84
171	GS	96.00	1.94
181	GS	74.00	1.75
191	GS	73.00	1.36
221	GS	79.00	1.84
281	GS	83.00	1.75
371	GS	105.00	1.78
381	GS	93.00	1.60
391	GS	71.00	1.24
521	GS	75.00	1.38
1191	GS	73.00	1.36
1221	GS	73.00	1.69

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a/]	Crop activity code [b/]	Estimated cost $/ac.	Estimated yield [c/] tons/ac.
1281	GS	76.00	1.60
1291	GS	67.00	1.24
2111	GS	93.00	0.87
2121	GS	99.00	1.69
2181	GS	99.00	1.53
2311	GS	93.00	0.78
2312	GS	94.00	0.78
2321	GS	96.00	1.53
2381	GS	95.00	1.45
111	AL	106.00	3.73
112	AL	113.00	4.44
121	AL	116.00	3.86
122	AL	134.00	5.38
123	AL	123.00	5.31
132	AL	169.00	4.96
134	AL	204.00	5.38
141	AL	125.00	5.76
142	AL	125.00	5.53
151	AL	133.00	6.01
161	AL	126.00	5.73
162	AL	141.00	6.06
163	AL	139.00	5.84
171	AL	143.00	4.55
181	AL	115.00	4.97
191	AL	97.00	3.73
221	AL	123.00	4.69
222	AL	141.00	5.38
223	AL	130.00	5.53
224	AL	138.00	5.98
232	AL	161.00	5.08
251	AL	145.00	5.98
261	AL	135.00	6.33
262	AL	183.00	6.23
263	AL	159.00	6.02
281	AL	131.00	4.97
362	AL	209.00	6.22
363	AL	233.00	6.04
371	AL	167.00	5.14
372	AL	178.00	6.02
381	AL	152.00	5.43
391	AL	93.00	3.73
521	AL	122.00	3.39
522	AL	141.00	4.43
561	AL	132.00	4.89
562	AL	145.00	4.97
563	AL	145.00	4.97

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
572	AL	195.00	5.28
1151	AL	129.00	5.68
1191	AL	96.00	3.59
1221	AL	104.00	3.40
1223	AL	113.00	4.43
1231	AL	144.00	3.62
1232	AL	145.00	4.47
1241	AL	111.00	4.64
1251	AL	119.00	4.94
1261	AL	119.00	4.89
1262	AL	163.00	5.51
1263	AL	158.00	4.97
1281	AL	113.00	4.08
1291	AL	81.00	3.07
1341	AL	132.00	4.64
1351	AL	132.00	4.94
1361	AL	133.00	4.89
1362	AL	197.00	5.51
1451	AL	125.00	5.20
1461	AL	125.00	5.31
1462	AL	160.00	5.56
1551	AL	123.00	5.20
1561	AL	135.00	5.31
1562	AL	181.00	5.56
1572	AL	195.00	5.23
2111	AL	130.00	3.47
2121	AL	140.00	3.85
2122	AL	163.00	5.01
2123	AL	150.00	5.01
2124	AL	161.00	5.29
2131	AL	185.00	4.11
2134	AL	269.00	5.01
2141	AL	155.00	5.20
2142	AL	159.00	5.09
2151	AL	159.00	5.29
2181	AL	145.00	4.32
2223	AL	157.00	4.91
2232	AL	203.00	4.61
2263	AL	225.00	5.43
2311	AL	126.00	2.91
2312	AL	133.00	3.73
2321	AL	131.00	3.22
2323	AL	143.00	4.20
2331	AL	163.00	3.42
2341	AL	146.00	4.52
2342	AL	149.00	4.52

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
2351	AL	153.00	4.65
2361	AL	144.00	4.65
2381	AL	135.00	3.86
2441	AL	147.00	4.18
2442	AL	153.00	4.18
2451	AL	155.00	4.27
2461	AL	147.00	4.30
2462	AL	205.00	4.36
2463	AL	173.00	4.51
111	BE	97.00	0.53
112	BE	97.00	0.51
121	BE	112.00	0.91
122	BE	117.00	0.99
123	BE	113.00	0.91
132	BE	129.00	0.82
134	BE	142.00	0.76
141	BE	105.00	0.75
142	BE	103.00	0.69
151	BE	109.00	0.77
161	BE	100.00	0.61
162	BE	109.00	0.77
163	BE	107.00	0.72
181	BE	98.00	0.53
221	BE	109.00	0.80
222	BE	121.00	0.99
223	BE	116.00	0.91
224	BE	109.00	0.72
232	BE	125.00	0.79
251	BE	115.00	0.82
261	BE	105.00	0.69
262	BE	127.00	0.72
263	BE	117.00	0.72
281	BE	107.00	0.53
362	BE	141.00	0.76
363	BE	154.00	0.76
381	BE	116.00	0.53
521	BE	111.00	0.82
522	BE	118.00	0.89
561	BE	101.00	0.54
562	BE	109.00	0.69
563	BE	108.00	0.69
1221	BE	101.00	0.69
1223	BE	105.00	0.69
1231	BE	115.00	0.63
1232	BE	116.00	0.66
1241	BE	97.00	0.55

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a/]	Crop activity code [b/]	Estimated cost $/ac.	Estimated yield [c/] tons/ac.
1251	BE	99.00	0.56
1261	BE	96.00	0.45
1262	BE	117.00	0.57
1263	BE	116.00	0.57
1281	BE	97.00	0.40
1341	BE	119.00	0.55
1351	BE	115.00	0.56
1361	BE	111.00	0.45
1362	BE	143.00	0.57
1451	BE	101.00	0.58
1461	BE	97.00	0.43
1462	BE	114.00	0.54
1551	BE	105.00	0.58
1561	BE	105.00	0.43
1562	BE	128.00	0.54
2111	BE	112.00	0.37
2121	BE	123.00	0.64
2122	BE	131.00	0.69
2123	BE	127.00	0.64
2124	BE	124.00	0.54
2131	BE	138.00	0.59
2134	BE	175.00	0.53
2141	BE	121.00	0.53
2142	BE	122.00	0.53
2151	BE	125.00	0.61
2181	BE	117.00	0.37
2223	BE	131.00	0.62
2232	BE	148.00	0.59
2263	BE	153.00	0.53
2311	BE	110.00	0.28
2312	BE	111.00	0.28
2321	BE	117.00	0.48
2323	BE	123.00	0.48
2331	BE	126.00	0.45
2341	BE	117.00	0.41
2342	BE	117.00	0.41
2351	BE	119.00	0.41
2361	BE	111.00	0.32
2381	BE	111.00	0.28
2441	BE	117.00	0.38
2442	BE	119.00	0.38
2451	BE	121.00	0.41
2461	BE	113.00	0.30
2462	BE	142.00	0.38
2463	BE	127.00	0.45
1231	RI	239.00	1.75

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost	Estimated yield [c]
		$/ac.	tons/ac.
1232	RI	239.00	1.75
1241	RI	193.00	2.56
1251	RI	196.00	1.90
1261	RI	191.00	2.04
1262	RI	241.00	2.06
1263	RI	239.00	2.09
1341	RI	195.00	2.56
1351	RI	192.00	1.90
1361	RI	190.00	2.04
1362	RI	275.00	2.06
1451	RI	205.00	1.60
1461	RI	197.00	1.93
1462	RI	249.00	1.93
1551	RI	182.00	1.60
1561	RI	199.00	1.93
1562	RI	277.00	1.93
1572	RI	236.00	2.45
2124	RI	281.00	1.75
2131	RI	339.00	1.75
2134	RI	509.00	2.67
2141	RI	281.00	2.67
2142	RI	286.00	2.52
2151	RI	273.00	1.75
2232	RI	348.00	1.91
2331	RI	254.00	1.50
2341	RI	241.00	2.29
2342	RI	241.00	2.29
2351	RI	239.00	1.50
2361	RI	219.00	1.81
2441	RI	247.00	2.21
2442	RI	251.00	2.29
2451	RI	249.00	1.65
2461	RI	228.00	1.81
2462	RI	297.00	1.81
2463	RI	250.00	1.81
134	SI	93.00	1.04
141	SI	51.00	1.08
142	SI	50.00	1.08
151	SI	53.00	1.04
161	SI	47.00	1.04
162	SI	52.00	1.22
163	SI	52.00	1.22
171	SI	55.00	0.70
181	SI	49.00	0.87
224	SI	55.00	1.04
251	SI	61.00	1.04

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
261	SI	49.00	1.04
262	SI	77.00	1.22
263	SI	63.00	1.22
281	SI	60.00	0.87
362	SI	92.00	1.20
363	SI	107.00	1.22
371	SI	65.00	0.70
372	SI	63.00	1.22
381	SI	73.00	0.87
561	SI	47.00	0.45
562	SI	52.00	0.52
563	SI	52.00	0.52
572	SI	66.00	0.52
1151	SI	39.00	1.13
1241	SI	47.00	0.77
1251	SI	49.00	0.82
1261	SI	47.00	0.70
1262	SI	67.00	0.66
1263	SI	67.00	0.66
1281	SI	51.00	0.30
1341	SI	67.00	0.77
1351	SI	63.00	0.82
1361	SI	61.00	0.70
1362	SI	95.00	0.66
1451	SI	49.00	0.59
1461	SI	47.00	0.59
1462	SI	65.00	0.74
1551	SI	52.00	0.59
1561	SI	56.00	0.59
1562	SI	80.00	0.74
1572	SI	81.00	0.90
2134	SI	143.00	0.70
2141	SI	80.00	0.77
2142	SI	81.00	0.77
2151	SI	79.00	0.70
2181	SI	79.00	0.57
2263	SI	114.00	0.66
2341	SI	77.00	0.59
2342	SI	77.00	0.59
2351	SI	78.00	0.56
2361	SI	71.00	0.56
2381	SI	75.00	0.47
121	SB	267.00	22.09
122	SB	277.00	24.43
123	SB	273.00	23.60
132	SB	303.00	24.35

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
134	SB	319.00	24.46
141	SB	239.00	20.27
142	SB	237.00	19.77
151	SB	263.00	21.28
161	SB	245.00	21.14
162	SB	255.00	21.14
163	SB	255.00	21.06
171	SB	295.00	17.61
181	SB	235.00	19.57
191	SB	229.00	15.66
221	SB	271.00	23.21
222	SB	285.00	25.73
223	SB	279.00	24.44
224	SB	269.00	21.66
232	SB	299.00	24.93
251	SB	275.00	21.66
261	SB	253.00	22.59
262	SB	287.00	20.48
263	SB	272.00	21.51
281	SB	251.00	19.57
362	SB	309.00	21.29
363	SB	333.00	22.11
371	SB	307.00	17.61
372	SB	315.00	22.22
381	SB	270.00	19.57
391	SB	225.00	15.66
521	SB	260.00	19.24
522	SB	274.00	21.20
561	SB	242.00	17.61
562	SB	253.00	17.61
563	SB	255.00	18.43
572	SB	319.00	18.75
1151	SB	256.00	20.26
1191	SB	225.00	14.58
1221	SB	259.00	22.11
1223	SB	269.00	23.43
1231	SB	283.00	22.51
1232	SB	288.00	24.24
1241	SB	226.00	18.41
1251	SB	252.00	20.12
1261	SB	241.00	20.71
1262	SB	273.00	20.40
1263	SB	274.00	21.19
1281	SB	235.00	18.75
1291	SB	213.00	14.98
1341	SB	247.00	18.41

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a]	Crop activity code [b]	Estimated cost $/ac.	Estimated yield [c] tons/ac.
1351	SB	265.00	20.12
1361	SB	255.00	20.71
1362	SB	303.00	20.40
1451	SB	257.00	19.77
1461	SB	245.00	20.16
1462	SB	271.00	20.22
1551	SB	257.00	19.77
1561	SB	253.00	20.16
1562	SB	289.00	20.22
1572	SB	331.00	20.47
2121	SB	283.00	20.74
2122	SB	297.00	22.80
2123	SB	291.00	21.97
2124	SB	289.00	19.91
2131	SB	308.00	21.08
2134	SB	367.00	21.97
2141	SB	260.00	17.57
2142	SB	263.00	17.97
2151	SB	284.00	19.91
2181	SB	259.00	17.57
2223	SB	288.00	19.51
2232	SB	315.00	19.82
2263	SB	315.00	17.91
2321	SB	271.00	17.32
2323	SB	281.00	18.34
2331	SB	289.00	17.61
2341	SB	249.00	14.68
2342	SB	251.00	15.41
2351	SB	274.00	16.67
2361	SB	251.00	15.85
2381	SB	245.00	14.68
2441	SB	249.00	13.59
2442	SB	253.00	14.26
2451	SB	275.00	15.15
2461	SB	253.00	14.68
2462	SB	299.00	14.68
2463	SB	274.00	15.35
			bales/ac.
161	CT	208.00	1.73
162	CT	221.00	1.94
163	CT	221.00	1.94
171	CT	213.00	1.17
261	CT	211.00	1.73
262	CT	245.00	1.94
263	CT	233.00	1.94

Footnotes at end of table. --Continued

Table E.1 (continued)

HPA[a/]	Crop activity code [b/]	Estimated cost	Estimated yield [c/]
		$/ac.	bales/ac.
362	CT	269.00	2.09
363	CT	285.00	2.09
371	CT	227.00	1.27
372	CT	282.00	2.60
561	CT	211.00	1.58
562	CT	221.00	1.73
563	CT	220.00	1.73
572	CT	293.00	2.60
1261	CT	209.00	1.94
1262	CT	235.00	2.09
1263	CT	235.00	2.09
1361	CT	223.00	1.94
1362	CT	263.00	2.09
1461	CT	203.00	1.58
1462	CT	225.00	1.73
1561	CT	212.00	1.58
1562	CT	241.00	1.73
1572	CT	256.00	1.73
2263	CT	264.00	1.84
2361	CT	213.00	1.43
2461	CT	213.00	1.33
2462	CT	249.00	1.48
2463	CT	229.00	1.48

a/ The first two digits of the HPA code identify soil; the last two digits identify climate. On a three digit HPA, a zero is assumed before the first digit recorded.

b/ Crop activity legend:
- AS - asparagus
- BR - broccoli
- LE - lettuce, fall or spring
- LS - lettuce, summer
- CF - cantaloupes, fall or spring
- CA - cantaloupes, summer
- PO - potatoes, U.S.D.A. No. 1's
- TO - tomatoes for processing
- CN - corn
- BF - barley (fallow); yield estimates are 1/2 expected yield in year grown; cost estimates are 1/2 combined cost of one year fallow and one year barley
- BN - barley (nonirrigated)
- BI - barley (irrigated)

--Continued

Table E.1 (continued)

b/ (continued)

GS - grain sorghum
AL - alfalfa
BE - dry beans
RI - rice
SI - safflower, irrigated
SB - sugar beets
CT - cotton, solid plant; yield estimates are for gross lint weight.

c/ The refinement of yield estimation to two decimal places is not intended to reflect the degree of accuracy assumed. Original estimation was rough and sometimes made in whole numbers only. But to assure that the estimates in 1980 are relatively the same as originally derived for average 1961-65, it is necessary to carry the estimates to more decimal places. It is relative yield differences and not absolute differences that determine the linear programming optimal solution.

TABLE E.2

Estimated Base Period Annual Crop Yield and Total Nonland Cost per Acre, Broccoli-Lettuce Double Crop Activities

HPA[a]	Broccoli lettuce activity code	Estimated cost	Estimated yield[b]	
			Broccoli	Lettuce
		$/ac.	tons/ac.	
121	BL	1043.00	3.45	8.94
122	BL	1117.00	3.63	10.03
123	BL	1145.00	3.37	10.78
132	BL	1083.00	2.61	9.39
221	BL	1065.00	2.91	9.65
222	BL	1131.00	3.05	10.46
223	BL	1127.00	3.16	10.40
232	BL	1075.00	2.27	9.50
521	BL	1021.00	2.52	8.76
522	BL	1109.00	2.74	9.96
1221	BL	1005.00	2.44	8.87
1223	BL	1105.00	2.66	10.42
1231	BL	1065.00	2.30	9.47
1232	BL	1052.00	2.18	9.29
2121	BL	997.00	2.52	8.35
2122	BL	1083.00	2.74	9.47
2123	BL	1094.00	2.74	9.80
2131	BL	1057.00	2.37	8.91
2223	BL	1105.00	2.74	9.70
2232	BL	1076.00	2.19	9.05
2321	BL	939.00	2.41	7.32
2323	BL	1027.00	2.53	8.60
2331	BL	983.00	2.19	7.82

a/ The first two digits of the HPA code identify soil, the last two digits identify climate. On a three digit HPA, a zero is assumed before the first digit recorded.

b/ The refinement of yield estimation to two decimal places is not intended to reflect the degree of accuracy assumed. Original estimation was rough and sometimes made in whole numbers only. But to assure that the estimates in 1980 are relatively the same as originally derived for average 1961-65, it is necessary to carry the estimates to more decimal places. It is relative yield differences and not absolute differences that determine the linear programming optimal solution.

TABLE E.3

Estimated Base Period Annual Crop Yield
and Total Nonland Cost per Acre,
Lettuce Double Crop Activities
in One Seasonal Group a/

HPA b/	Crop activity code c/	Estimated cost	Estimated yield d/
		$/ac.	tons/ac.
121	LL	1317.00	17.88
122	LL	1448.00	20.06
123	LL	1521.00	21.56
132	LL	1401.00	18.77
134	LL	1321.00	16.67
161	LL	1286.00	17.23
162	LL	1265.00	16.63
163	LL	1265.00	16.63
221	LL	1391.00	19.30
222	LL	1500.00	20.93
223	LL	1489.00	20.81
232	LL	1408.00	19.01
261	LL	1290.00	17.23
262	LL	1297.00	16.63
263	LL	1280.00	16.63
362	LL	1280.00	15.88
363	LL	1301.00	15.88
521	LL	1319.00	17.52
522	LL	1469.00	19.92
1221	LL	1312.00	17.74
1223	LL	1489.00	20.85
1231	LL	1404.00	18.95
1232	LL	1385.00	18.57
1261	LL	1264.00	16.63
1262	LL	1269.00	16.14
1263	LL	1268.00	16.14
1361	LL	1278.00	16.63
1362	LL	1299.00	16.14
1461	LL	1201.00	15.25
1462	LL	1200.00	14.75
1561	LL	1209.00	15.25
1562	LL	1218.00	14.75
2121	LL	1271.00	16.69
2122	LL	1415.00	18.95
2123	LL	1441.00	19.60
2131	LL	1361.00	17.82
2134	LL	1291.00	15.15
2223	LL	1455.00	19.40
2232	LL	1400.00	18.10
2263	LL	1273.00	15.36
2321	LL	1163.00	14.63
2323	LL	1319.00	17.21
2331	LL	1238.00	15.64
2361	LL	1125.00	13.76
2461	LL	1080.00	12.77
372	LW	1447.00	19.30

Footnotes at end of table. --Continued

Table E.3 (continued)

HPA b/	Crop activity code c/	Estimated cost	Estimated yield d/
		\$/ac.	tons/ac.
572	LW	1463.00	19.01
1572	LW	1399.00	18.02

a/ Cost and yield parameters are for two crops of winter or one crop each of fall and spring lettuce.

b/ The first two digits of the HPA code identify soil, the last two digits identify climate. On a three digit HPA, a zero is assumed before the first digit recorded.

c/ Crop activity legend:
LL - lettuce, fall and spring
LW - lettuce, winter.

d/ The refinement of yield estimation to two decimal places is not intended to reflect the degree of accuracy assumed. Original estimation was rough and sometimes made in whole numbers only. But to assure that the estimates in 1980 are relatively the same as originally derived for average 1961-65, it is necessary to carry the estimates to more decimal places. It is relative yield differences and not absolute differences that determine the linear programming optimal solution.

TABLE E.4

Estimated Base Period Annual Crop Yield and Total Nonland Cost per Acre, Fall or Spring and Summer Lettuce Double Crop Activities

HPA[a/]	Lettuce activity code	Estimated cost	Estimated lettuce yield[b/]	
			fall or spring	summer
		$/ac.	tons/ac.	
121	LO	1317.00	8.94	8.94
122	LO	1448.00	10.03	10.03
123	LO	1521.00	10.78	10.78
132	LO	1401.00	9.39	9.39
221	LO	1391.00	9.65	9.65
222	LO	1500.00	10.46	10.46
223	LO	1489.00	10.40	10.40
232	LO	1408.00	9.50	9.50
521	LO	1319.00	8.76	8.76
522	LO	1469.00	9.96	9.96
1221	LO	1312.00	8.87	8.87
1223	LO	1489.00	10.42	10.42
1231	LO	1404.00	9.47	9.47
1232	LO	1385.00	9.29	9.29
2121	LO	1271.00	8.35	8.35
2122	LO	1415.00	9.47	9.47
2123	LO	1441.00	9.80	9.80
2131	LO	1361.00	8.91	8.91
2223	LO	1455.00	9.70	9.70
2232	LO	1400.00	9.05	9.05
2321	LO	1163.00	7.32	7.32
2323	LO	1319.00	8.60	8.60
2331	LO	1238.00	7.82	7.82

a/ The first two digits of the HPA code identify soil, the last two digits identify climate. On a three digit HPA, a zero is assumed before the first digit recorded.

b/ The refinement of yield estimation of two decimal places is not intended to reflect the degree of accuracy assumed. Original estimation was rough and sometimes made in whole numbers only. But to assure that the estimates in 1980 are relatively the same as originally derived for average 1961-65, it is necessary to carry the estimates to more decimal places. It is relative yield differences and not absolute differences that determine the linear programming optimal solution.

TABLE E.5

Estimated Base Period Annual Crop Yield and Total Nonland Cost per Acre, Barley-Grain Sorghum Double Crop Activities a/

HPA b/	Barley-sorghum activity code	Estimated cost	Estimated yield c/	
			Barley, irrigated	Grain sorghum
		$/ac.	tons/ac.	
122	BG	101.00	1.41	1.40
123	BG	98.00	1.41	1.40
132	BG	124.00	1.41	1.55
134	BG	175.00	1.76	1.94
141	BG	95.00	1.43	1.88
142	BG	93.00	1.41	1.65
151	BG	104.00	1.50	1.97
161	BG	101.00	1.50	1.80
162	BG	112.00	1.51	1.94
163	BG	111.00	1.47	1.72
222	BG	106.00	1.41	1.40
223	BG	103.00	1.41	1.40
224	BG	107.00	1.50	2.00
232	BG	119.00	1.41	1.55
251	BG	112.00	1.50	2.00
261	BG	104.00	1.50	2.01
262	BG	141.00	1.49	1.97
263	BG	126.00	1.50	1.79
362	BG	161.00	1.58	1.89
363	BG	179.00	1.61	1.73
372	BG	144.00	1.84	1.96
522	BG	101.00	1.20	1.05
561	BG	98.00	1.27	1.43
562	BG	109.00	1.35	1.57
563	BG	109.00	1.35	1.38
572	BG	147.00	1.31	1.68
1151	BG	83.00	1.50	2.01
1223	BG	95.00	1.41	1.28
1231	BG	111.00	1.41	1.42
1232	BG	111.00	1.41	1.42
1241	BG	93.00	1.41	1.65
1251	BG	100.00	1.50	1.83
1261	BG	101.00	1.50	1.78
1262	BG	133.00	1.65	1.88
1263	BG	131.00	1.59	1.68
1341	BG	114.00	1.41	1.65
1351	BG	115.00	1.50	1.83
1361	BG	115.00	1.50	1.78
1362	BG	161.00	1.65	1.88
1451	BG	101.00	1.22	1.51
1461	BG	101.00	1.27	1.29
1462	BG	127.00	1.35	1.54
1551	BG	103.00	1.22	1.51
1561	BG	109.00	1.27	1.29
1562	BG	145.00	1.35	1.54
1572	BG	163.00	1.45	1.48

Footnotes at end of table. --Continued

Table E.5 (continued)

HPA b/	Barley-sorghum activity code	Estimated cost	Estimated yield c/	
			Barley, irrigated	Grain sorghum
		$/ac.	tons/ac.	
2122	BG	129.00	1.20	1.28
2123	BG	124.00	1.20	1.28
2124	BG	130.00	1.27	1.78
2131	BG	141.00	1.20	1.42
2134	BG	229.00	1.50	1.70
2141	BG	121.00	1.20	1.60
2142	BG	123.00	1.20	1.46
2151	BG	128.00	1.27	1.78
2223	BG	129.00	1.20	1.33
2232	BG	155.00	1.20	1.42
2263	BG	179.00	1.35	1.64
2323	BG	123.00	1.20	1.16
2331	BG	129.00	1.20	1.30
2341	BG	119.00	1.20	1.55
2342	BG	119.00	1.20	1.39
2351	BG	127.00	1.27	1.64
2361	BG	122.00	1.27	1.65
2441	BG	121.00	0.99	1.30
2442	BG	121.00	0.99	1.26
2451	BG	129.00	1.05	1.45
2461	BG	125.00	1.05	1.36

a/ See Table D.1 for adjustment factors and Chapter 6 for procedure used to modify grain sorghum cost and yield estimates per harvested acre to obtain model parameters.

b/ The first two digits of the HPA code identify soil, the last two digits identify climate. On a three digit HPA, a zero is assumed before the first digit recorded.

c/ The refinement of yield estimation of two decimal places is not intended to reflect the degree of accuracy assumed. Original estimation was rough and sometimes made in whole numbers only. But to assure that the estimates in 1980 are relatively the same as originally derived for average 61-65, it is necessary to carry the estimates to more decimal places. It is relative yield differences and not absolute differences that determine the linear programming optimal solution.

APPENDIX F

OUTPUT RESTRAINTS

TABLE F.1

Linear Programming Minimum Output Restraints

Crop	Representative commodity	Model 1961-65[a/]	Model 1980A	Model 1980B	Model 1980C	Model 1980D
		tons	1,000 tons			
Vegetable crops						
Asparagus	Same	94,990	100	100	100	100
Cole crops:	Broccoli	151,010	179	221	221	221
Broccoli						
Brussels sprouts						
Cauliflower						
Lettuce:						
Spring & fall	Same	385,760	544	544	544	544
Summer	Same	367,500	518	518	518	518
Winter	Same	388,050	547	547	547	547
Melons, spring & fall:	Cantaloupes, spring & fall	98,610	100	100	100	100
Cantaloupes, spring & fall						
Honeydew melons, spring						
Watermelons, spring						
Melons, summer:	Cantaloupes, summer	397,080	398	398	398	398
Cantaloupes, summer						
Honeydew melons, summer						
Watermelons, summer						
Potatoes:	Same	1,138,790	1,336	1,336	1,336	1,336
Russet burbank	Same	149,250	175	175	175	175
Tomatoes, fresh & processing	Tomatoes, processing	3,332,950	4,917	5,127	5,127	5,127
Field crops						
Feed grains:	Corn for grain	NA	NA	NA	3,958	3,958
Corn	Corn for grain	405,350	620	576	0	0
Small grains:	Barley	2,258,200	3,418	2,931	429[b/]	429[b/]
Barley						
Oats						
Wheat						

See footnotes on next page.

--Continued on next page.

Table F.1 (continued)

Crop	Representative commodity	Model 1961-65a/	Model 1980A	Model 1980B	Model 1980C	Model 1980D
		tons	1,000 tons			
Sorghums	Sorghums for grain	522,070	769	683	0	0
Alfalfa hay & seed	Alfalfa hay	6,837,340	8,002	7,699	7,699	7,699
Dry beans	Same	156,540	203	176	176	176
Baby lima, kidney, blackeye, & pink	Same	84,950	110	95	95	95
Rice	Same	764,500	934	934	934	934
Safflower	Same	257,200	678	880	880	1,033
Sugar beets	Same	5,866,400	7,591	7,892	7,892	7,892
		bales	1,000 bales			
Cotton	Same	1,753,000	1,948	2,771	2,771	1,948

a/ Source: California Crop and Livestock Reporting Service [10, 14].

b/ Projected output of wheat in barley units.

NA Not applicable.

APPENDIX G

STUDY CROP ACREAGE, ACTUAL AND ESTIMATED MODEL REQUIREMENTS

TABLE G.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[a/]	0	59	6	0	4	4	43	0	0	116
Melons[a/]	0	0	2	3	5	47	16	0	0	73
Potatoes[a/]	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[a/]	3	104	110	301	199	744	116	203	91	1,871
Sorghums[a/]	0	1	7	50	55	74	77	1	0	265
Alfalfa	2	19	31	114	151	624	259	24	52	1,276
Dry beans[a/]	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

a/ Alternative crop varieties, seasons, and activities are not differentiated.

TABLE G.2

Harvested Study Crop Acreage in Base Period, 1961-65, Estimated Model Requirements

Crop group	Region									State[a/]
	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[b/]	0	74.6	0	0	0	0	40.2	0	0	114.8
Melons[b/]	0	0	0	0	0	47.1	15.8	0	0	62.9
Potatoes[b/]	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[b/]	0	17.0	0	162.3	300.5	479.0	109.8	90.0	260.0	1,418.6
Sorghums[b/]	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[b/]	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	96.4	0	18.0	0	258.4
Cotton	0	0	0	0	0	606.0	206.0	0	0	812.0
Total[a/]	35.0	478.5	72.0	888.0	1,109.4	1,666.4	582.7	165.0	372.0	5,369.0

a/ Computed from unrounded data.

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

TABLE G.3

Harvested Study Crop Acreage in Base Period, 1961-65, Estimated Model Less Actual Requirements

Crop group	Region									State[a]
	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	-3.0	-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[a]	29.0	145.5	-146.0	-34.0	304.4	-1,012.6	-66.3	-84.0	214.0	-650.0

a/ Computed from unrounded data.

TABLE G.4

Harvested Study Crop Acreage in Base Period, 1961-65, Estimated Model as Percent of 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	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	94.82
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	94.63	44.33	285.71	75.82
Sorghums	100.00	0	0	0	422.65	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 G.5

Harvested Study Crop Acreage, Estimated Model 1980C Requirements

Crop group	Region									State[a/]
	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[b/]	0	80.1	0	0	0	0	43.8	0	0	123.9
Melons[b/]	0	0	0	0	0	40.9	14.0	0	0	54.9
Potatoes[b/]	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[b/]	0	16.4	0	199.7	266.9	296.1	0	0	14.7	793.8
Sorghums[b/]	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[b/]	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
Suger 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[a/]	24.0	398.2	53.0	992.8	1,074.8	2,338.8	499.9	119.3	327.0	5,827.8

a/ Computed from unrounded data.

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

TABLE G.6

Harvested Study Crop Acreage, Estimated Model 1980C Less Base Period Actual Requirements

Crop group	Region									State[a]
	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	-6.0	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[a]	18.0	65.2	-165.0	70.8	269.8	-340.2	-149.1	-129.7	169.0	-191.2

a/ Computed from unrounded data.

TABLE G.7

Harvested Study Crop Acreage, Estimated Model 1980C as Percent of 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	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 G.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 G.9

Harvested Study Crop Acreage, Estimated Model 1980C as Percent of 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	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 G.10

Harvested Study Crop Acreage, Estimated Model 1980D Requirements

Crop group	Region									State[a]
	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[b]	0	79.9	0	0	0	0	43.8	0	0	123.7
Melons[b]	0	0	0	0	0	40.9	14.0	0	0	54.9
Potatoes[b]	0	28.0	0	0	36.0	14.5	0	0	14.3	92.8
Tomatoes	0	0	0	93.8	66.4	0	0	0	0	160.2
Field crops:										
Corn	0	0	0	0	0	0	0	0	0	0
Small grains[b]	0	16.4	0	171.8	268.2	325.2	0	0	14.7	796.4
Sorghums[b]	0	3.4	0	171.8	266.9	325.2	0	0	0	767.3
Alfalfa	24.0	16.0	0	266.0	340.0	282.7	0	73.0	298.0	1,299.7
Dry beans[b]	0	60.8	21.0	0	49.0	63.0	0	0	0	193.7
Rice	0	0	0	268.4	0	0	0	0	0	268.4
Safflower	0	0	0	0	43.6	320.0	240.0	0	0	603.6
Sugar beets	0	108.5	29.0	0	3.3	126.7	0	45.0	0	312.5
Cotton	0	0	0	0	0	744.8	74.5	0	0	819.3
Total[a]	24.0	395.5	50.0	971.9	1,073.5	2,254.6	372.3	118.0	327.0	5,586.8

a/ Computed from unrounded data.

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

TABLE G.11

Study Crop Land Use by Soil Category, Estimated Model 1980C Requirements

Crop activity	Soil										State[a/b/]
	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 & 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 & spring (double crop)	0	0	0	0	0	0	0	0	0	0	0
Lettuce, fall or spring & 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

See footnotes at end of table.

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Table G.11 (continued)

Crop activity	Soil										State[a/b/]
	Alluvial				Basin					Terrace	
	01	02	03	05	11	12	13	14	15	21	
	1,000 acres										
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 & 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[b/]	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[c/]	396	122	1,610	114	0	455	232	182	661	1,085	7,757[d/]
Net model acreage available, projected 1980 [b/]	1,377	956	2,384	380	319	1,913	479	301	788	1,108	12,905[d/]

a/ In the optimal solution, no production is projected on soils 22 - 24.
b/ Computed from unrounded data.
c/ Includes acreage to be used for pasture and nonalfalfa hay.
d/ Includes acreage of soils 22 - 24. Figure is from Appendix Table B.2.

TABLE G.12

Study Crop Acreage and Imputed Value of Restricting Variable by HPA, Model 1980C Estimates

HPA a/	Crop activity b/	Acreage	Restricting variable c/	Imputed rent to restricting variable
		1,000 acres		dollars per unit
	Vegetable crops:			
0123	Asparagus	5.8	D	-302.22
0223	"	35.0	L	41.43
0161	Broc. (sc)	11.6	D	-146.47
0121	Broc. Let.	10.0	L	34.60
0122	" "	14.0	L	61.25
0123	" "	17.7	D	-76.90
0123	Let. (s, sc)	4.7	L	44.43
0522	" "	2.7	D	-86.26
1223	" "	31.0	L	30.75
0372	" (w, dc)	21.9	D	-85.38
0362	Cant. (s)	40.9	D	-90.84
0372	" (f)	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 d/
0142	Tomatoes	57.2	D	-21.26
1151	"	110.0	L	45.08
	Field crops:			
0112	Alfalfa hay	24.0	R	11.67
0141	" "	237.0	R	6.44
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	" "	38.0	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	10.49
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

See footnotes at end of table --Continued on next page.

Table G.12 (continued)

HPA a/	Crop activity b/	Acreage	Restricting variable c/	Imputed rent to restricting variable
		1,000 acres		dollars per unit
0224	Bar. (fa)	26.0	L	3.28
0391	" (i, sc)	13.0	I	1.54
1191	" "	1.7	L	3.14
0141	" sorghum	59.0	L	36.28
0224	" "	4.0	I	26.64
0251	" "	10.0	L	23.92
0561	" "	59.0	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 e/
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	" "	22.0	R	9.98
0232	" "	14.0	R	5.78
0251	" "	17.0	R	11.54
0262	" "	3.2	D	-13.15 f/
0263	" "	8.0	L	13.00
0521	" "	10.0	R	29.24
0522	" "	4.0	R	34.79
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	24.69
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

See footnotes at end of table. --Continued on next page.

Table G.12 (continued)

HPA a/	Crop activity b/	Acreage	Restricting variable c/	Imputed rent to restricting variable
		1,000 acres		dollars per unit
1231	Sugar beets	3.0	R	13.41
1232	" "	5.0	R	35.23
1261	" "	28.0	R	9.23
1263	" "	7.0	R	4.54
1281	" "	19.0	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	61.00
1361	"	35.0	R	38.99
1362	"	70.0	R	26.00
1462	"	90.0	R	13.30

a/ The first two digits identify the soil; the latter two, the climate.

b/ Crop activity legend:

Bar.	= Barley,	(f)	= fall or spring,
Broc.	= Broccoli	(fa)	= fallow,
Cant.	= Cantaloupes,	(i)	= irrigated,
Let.	= Lettuce	(s)	= summer,
Sorg.	= Grain sorghum,	(sc)	= single crop,
(dc)	= double crop	(w)	= winter.

c/ Restricting variable legend:

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.

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

e/ Marginal cost per ton corn equivalent of feed grains.

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

APPENDIX H

MATHEMATICAL FORMULATION OF A LINEAR PROGRAMMING GENERAL SPATIAL EQUILIBRIUM MODEL

The Walras-Cassel general equilibrium model and its expansion to a general spatial equilibrium model are developed in this appendix. Consideration of intermediate production is bypassed. Demand is specified as functionally dependent on price. Transportation costs per unit of homogeneous good are constant in the spatial model.

Walras-Cassel General Equilibrium Model

The following notation will be used in presenting the Walras-Cassel general equilibrium model as summarized by Dorfman, Samuelson, and Solow [42, pp. 351-353, 369]:

m = number of resources,

n = number of commodities,

S_i = i^{th} resource,

R_i = amount of i^{th} resource supplied,

X_j = amount of j^{th} commodity produced,

A_{ij} = amount of i^{th} resource required to produce one unit of commodity j,

V_i = price of resource i,

P_j = price of commodity j,

F_j, G_j = functional relationships.

The production functions may be written:

$$X_1 = \frac{1}{A_{11}} S_1 + \frac{1}{A_{21}} S_2 + \dots + \frac{1}{A_{m1}} S_m,$$

$$X_2 = \frac{1}{A_{12}} S_1 + \frac{1}{A_{22}} S_2 + \dots + \frac{1}{A_{m2}} S_m,$$

$$\vdots$$

$$X_n = \frac{1}{A_{1n}} S_1 + \frac{1}{A_{2n}} S_2 + \dots + \frac{1}{A_{mn}} S_m.$$

Then the supply and demand relations for each resource are written:

$$A_{11} X_1 + A_{12} X_2 + \ldots + A_{1n} X_n \leq R_1,$$
$$A_{21} X_1 + A_{22} X_2 + \ldots + A_{2n} X_n \leq R_2,$$
$$\vdots$$
$$A_{m1} X_1 + A_{m2} X_2 + \ldots + A_{mn} X_n \leq R_m.$$

The inequalities of this system replace the usual equalities of the Walras-Cassel formulation, since the market will determine which goods are free and which scarce [57, p. 9].

The market demand functions may be written:

$$X_1 = F_1 (P_1, P_2, \ldots, P_n; V_1, V_2, \ldots, V_m),$$
$$X_2 = F_2 (P_1, P_2, \ldots, P_n; V_1, V_2, \ldots, V_m),$$
$$\vdots$$
$$X_n = F_n (P_1, P_2, \ldots, P_n; V_1, V_2, \ldots, V_m).$$

Inclusion of factor prices allows for changes in demand induced by shifts in the level and distribution of income. Functions are homogeneous of zero degree [57, pp. 9-10].

Under the assumption of perfect competition, unit cost equals price, and the relationship of resource to product price can be written:

$$A_{11} V_1 + A_{21} V_2 + \ldots + A_{m1} V_m \geq P_1,$$
$$A_{12} V_1 + A_{22} V_2 + \ldots + A_{m2} V_m \geq P_2,$$
$$\vdots$$
$$A_{1n} V_1 + A_{2n} V_2 + \ldots + A_{mn} V_m \geq P_n.$$

If the cost for any commodity exceeds the price, the corresponding output must be zero [57, p. 10].

The supply of resource flows can be written:

$$R_1 = G_1\ (P_1 \ldots P_n;\ V_1 \ldots V_m),$$
$$R_2 = G_2\ (P_1 \ldots P_n;\ V_1 \ldots V_m),$$
$$\vdots$$
$$R_m = G_m\ (P_1 \ldots P_n;\ V_1 \ldots V_m).$$

Supply functions are homogeneous of zero degree [57, p. 10].

Had the inequalities of this system been written as equalities, as originally done by Walras, they would meet the nonrigorous conditions for the existence of a solution. The number of equations (2m + 2n) equals the number of unknowns (2m + 2n). If the supply of resources are taken as constant, a solution still exists according to the nonrigorous conditions since m equations and m unknowns are dropped from the system. Dorfman, Samuelson, and Solow [42, pp. 366-375] suggest more rigorous requirements which must be met to assure the existence and uniqueness of a solution.

The above sets of equations comprise the Walras-Cassel general equilibrium system when space is not included as a variable.

General Spatial Equilibrium Model[1/]

The Walras-Cassel general equilibrium conditions need to be expanded to include multiple regions. Additional notation will be required:

w = number of production regions,

y = number of demand regions,

A^k_{ij} = amount of resource i required to produce one unit of commodity j in production region k (k=1,2, ..., w),

R^k_i = amount of i^{th} resource supplied in production region k,

1/ The following framework assumes only one production process in each producing region. However, the framework could be expanded to allow the system to choose between alternative production processes. This would be a simple expansion of the activities, but will be omitted here to prevent needless complexity in the notation. (See King [57, pp. 18-19, 31-33] for alternative processes in a spaceless model.) The framework is developed for the case where production and demand regions may not coincide.

X_j^{kl} = amount of j^{th} commodity produced in production region k and shipped to demand region l (l=1,2, ..., y),

V_i^k = price of resource i in production region k,

P_j^l = price of commodity j in demand region l,

T_j^{kl} = cost of transporting one unit of commodity j from production region k to demand region l,

C_j^k = cost of production (exclusive of fixed resources) for one unit of j^{th} commodity in the k^{th} production region,

N_j^{kl} = net return per unit of output of j^{th} commodity produced in region k and shipped to demand region l,

W_j^k = price of commodity j in producing region k ($W_j^k = P_j^l - T_j^{kl}$),

D_j^l = demand for j^{th} commodity in demand region l.

Demand for resources:

$$\text{Production Region 1}\left\{\begin{array}{l} \overbrace{A_{11}^{1}X_1^{11} + \dots + A_{11}^{1}X_1^{1y}}^{\text{Commodity 1}} + \dots + \overbrace{A_{1n}^{1}X_n^{11} + \dots + A_{1n}^{1}X_n^{1y}}^{\text{Commodity n}} \le R_1^1, \\ \vdots \\ A_{m1}^{1}X_1^{11} + \dots + A_{m1}^{1}X_1^{1y} + \dots + A_{mn}^{1}X_n^{11} + \dots + A_{mn}^{1}X_n^{1y} \le R_m^1, \end{array}\right.$$

$$\vdots$$

$$\text{Production Region w}\left\{\begin{array}{l} A_{11}^{w}X_1^{w1} + \dots + A_{11}^{w}X_1^{wy} + \dots + A_{1n}^{w}X_n^{w1} + \dots + A_{1n}^{w}X_n^{wy} \le R_1^w, \\ \vdots \\ A_{m1}^{w}X_1^{w1} + \dots + A_{m1}^{w}X_1^{wy} + \dots + A_{mn}^{w}X_n^{w1} + \dots + A_{mn}^{w}X_n^{wy} \le R_m^w, \end{array}\right.$$

$$\sum_k X_j^{kl} = X_j^l$$

Market demand functions:

$$\text{Commodity } 1\begin{cases} \sum\limits_k X_1^{k1} = X_1^1 = F_1^1\,(P_1^1,\ \ldots,\ P_n^1;\ V_1^1,\ \ldots,\ V_m^1,\ \ldots,\ V_1^w,\ \ldots,\ V_m^w), \\ \vdots \\ \sum\limits_k X_1^{ky} = X_1^y = F_1^y\,(P_1^y,\ \ldots,\ P_n^y;\ V_1^1,\ \ldots,\ V_m^1,\ \ldots,\ V_1^w,\ \ldots,\ V_m^w), \end{cases}$$

$$\vdots$$

$$\text{Commodity } n\begin{cases} \sum\limits_k X_n^{k1} = X_n^1 = F_n^1\,(P_1^1,\ \ldots,\ P_n^1;\ V_1^1,\ \ldots,\ V_m^1,\ \ldots,\ V_1^w,\ \ldots,\ V_m^w), \\ \vdots \\ \sum\limits_k X_n^{ky} = X_n^y = F_n^y\,(P_1^y,\ \ldots,\ P_n^y;\ V_1^1,\ \ldots,\ V_m^1,\ \ldots,\ V_1^w,\ \ldots,\ V_m^w). \end{cases}$$

Unit cost relationships:

$$\begin{array}{ll}
 & \begin{array}{ccccc} \underline{\text{resource } 1} & & \underline{\text{resource } m} & & \end{array} \\
\text{Commodity } 1 & \begin{cases}
\left.\begin{array}{lclcl} A_{11}^1\,V_1^1 & + \ldots + & A_{m1}^1\,V_m^1 & \geq & P_1^1 - T_1^{11}, \\ \vdots & & & & \\ A_{11}^w\,V_1^w & + \ldots + & A_{m1}^w\,V_m^w & \geq & P_1^1 - T_1^{w1}, \end{array}\right\} \text{Shipped to Region 1} \\
\vdots \\
\left.\begin{array}{lclcl} A_{11}^1\,V_1^1 & + \ldots + & A_{m1}^1\,V_m^1 & \geq & P_1^y - T_1^{1y}, \\ \vdots & & & & \\ A_{11}^w\,V_1^w & + \ldots + & A_{m1}^w\,V_m^w & \geq & P_1^y - T_1^{wy}, \end{array}\right\} \text{Shipped to Region y}
\end{cases} \\
 & \vdots \\
\text{Commodity } n & \begin{cases}
\left.\begin{array}{lclcl} A_{1n}^1\,V_1^1 & + \ldots + & A_{mn}^1\,V_m^1 & \geq & P_n^1 - T_n^{11}, \\ \vdots & & & & \\ A_{1n}^w\,V_1^w & + \ldots + & A_{mn}^w\,V_m^w & \geq & P_n^1 - T_n^{w1}, \end{array}\right\} \text{Shipped to Region 1} \\
\vdots \\
\left.\begin{array}{lclcl} A_{1n}^1\,V_1^1 & + \ldots + & A_{mn}^1\,V_m^1 & \geq & P_n^y - T_n^{1y}, \\ \vdots & & & & \\ A_{1n}^w\,V_1^w & + \ldots + & A_{mn}^w\,V_m^w & \geq & P_n^y - T_n^{wy}. \end{array}\right\} \text{Shipped to Region y}
\end{cases}
\end{array}$$

The unit transportation matrix is a matrix of constants. Therefore, the marginal cost of transportation equals average cost of transportation.

In equilibrium, the price of a commodity in one demand region less the unit cost of transportation from any production region shipping to it is equal to or greater than the price in any other demand region less the cost of transportation from the same production region. The derived price to producers from any region shipped to is the same regardless of which demand region the product is shipped to. And the price in any producing region plus the transportation cost to any demand region shipped to is equal to or less than the price in any other producing region plus the transportation cost to the same region. The price to buyers in any demand region from any production region shipping to it is the same regardless of which production region the product is shipped from. In mathematical language:

$$P_j^l - T_j^{kl} \geq P_j^o - T_j^{ko}$$ for any demand region l to which production region k ships; demand region l not equal to demand region o.

$$W_j^k + T_j^{kl} \leq W_j^o + T_j^{ol}$$ for any production region k shipping to demand region l; region k not equal to region o.

This system is worked easily into a linear programming framework. By specifying an objective function to be maximized, a solution can be found. Let us specify the objective function as: maximize the net value of output (market value less transfer and production costs):[1/]

$$\sum_j \sum_k \sum_l N_j^{kl} X_j^{kl} = \sum_j \sum_k \sum_l \left(P_j^l X_j^{kl} - T_j^{kl} X_j^{kl} - C_j^k X_j^{kl} \right).$$

The linear programming simplex format for the case of two production regions, two demand regions, two fixed resources, two commodities, and a single production process in each region is given in Table H.1. The dual

1/ When demand is specified as fixed quantities at assumed equilibrium prices, identical solutions are obtained from minimizing costs as from maximizing profits [45, p. 12].

format is offered in Table H.2. The demand function can enter the programming format in either of two ways: (1) Quadratic programming can be used and the demand function enter the format directly [89, pp. 510-523]. An equilibrium solution of regional prices and production can be obtained directly from this method. (2) An alternative to quadratic programming is to use an interative procedure. A set of prices is estimated, and quantities demanded under this set are determined. These quantities are entered as restrictions into the linear programming model. From a comparison of the resource rents obtained by the program with actual costs assumed, the set of prices may be re-estimated, quantities demanded determined, and the new quantities entered into the program for a second run of the model. This process can be repeated until supply in each region approximates demand. This procedure has been shown by Takayama and Judge [90, pp. 349-365] to be consistent with a quadratic programming formulation and has been found satisfactory for empirical work with partial equilibrium single commodity models.

TABLE H.1
[57, p. 24]

Maximization of Net Value of Output --
Matrix of Two Fixed Resources, Two Regions, Two Final Products, and One Production Process for Each Product in Each Region

Rents	Production and shipment activity								Restriction
	Commodity 1				Commodity 2				
	X_1^{11}	X_1^{12}	X_1^{21}	X_1^{22}	X_2^{11}	X_2^{12}	X_2^{21}	X_2^{22}	
	N_1^{11}	N_1^{12}	N_1^{21}	N_1^{22}	N_2^{11}	N_2^{12}	N_2^{21}	N_2^{22}	
V_1^1	A_{11}^1	A_{11}^1			A_{12}^1	A_{12}^1			R_1^1
V_2^1	A_{21}^1	A_{21}^1			A_{22}^1	A_{22}^1			R_2^1
V_1^2			A_{11}^2	A_{11}^2			A_{12}^2	A_{12}^2	R_1^2
V_2^2			A_{21}^2	A_{21}^2			A_{22}^2	A_{22}^2	$\leq$ R_2^2
U_1	-1		-1						$-D_1^1$
U_2		-1		-1					$-D_1^2$
U_3					-1		-1		$-D_2^1$
U_4						-1		-1	$-D_2^2$

$$X_j^{kl} \geq 0$$

Maximize net value of output =

$$\sum_j^2 \sum_k^2 \sum_l^2 N_j^{kl} X_j^{kl} = \sum_j^2 \sum_k^2 \sum_l^2 \left(P_j^l X_j^{kl} - T_j^{kl} X_j^{kl} - C_j^k X_j^{kl} \right),$$

--Continued on next page.

Table H.1 (continued)

subject to

(1) Demand and supply of resource by region:

$$A^1_{11}X^{11}_1 + A^1_{11}X^{12}_1 + A^1_{12}X^{11}_2 + A^1_{12}X^{12}_2 \leq R^1_1,$$

$$A^1_{21}X^{11}_1 + A^1_{21}X^{12}_1 + A^1_{22}X^{11}_2 + A^1_{22}X^{12}_2 \leq R^1_2,$$

$$A^2_{11}X^{21}_1 + A^2_{11}X^{22}_1 + A^2_{12}X^{21}_2 + A^2_{12}X^{22}_2 \leq R^2_1,$$

$$A^2_{21}X^{21}_1 + A^2_{21}X^{22}_1 + A^2_{22}X^{21}_2 + A^2_{22}X^{22}_2 \leq R^2_2;$$

Availability of a resource in a region must equal or exceed production requirements for commodities.

(2) Demand and supply of final commodity:

$$X^{11}_1 + X^{21}_1 \geq D^1_1,$$

$$X^{12}_1 + X^{22}_1 \geq D^2_1,$$

$$X^{11}_2 + X^{21}_2 \geq D^1_2,$$

$$X^{12}_2 + X^{22}_2 \geq D^2_2;$$

Supply of final commodity produced and shipped to market 1 or 2 in equilibrium must equal the quantity demanded at the specified market price.

TABLE H.2

Minimization of Returns to Resources
(Dual Problem to that in Table H.1)

Rents								Restriction	
V_1^1	V_2^1	V_1^2	V_2^2	U_1	U_2	U_3	U_4		
R_1^1	R_2^1	R_1^2	R_2^2	D_1^1	D_1^2	D_2^1	D_2^2		
A_{11}^1	A_{21}^1			-1					N_1^{11}
A_{11}^1	A_{21}^1				-1				N_1^{12}
		A_{11}^2	A_{21}^2	-1					N_1^{21}
		A_{11}^2	A_{21}^2		-1			$\geq$	N_1^{22}
A_{12}^1	A_{22}^1					-1			N_2^{11}
A_{12}^1	A_{22}^1						-1		N_2^{12}
		A_{12}^2	A_{22}^2			-1			N_2^{21}
		A_{12}^2	A_{22}^2				-1		N_2^{22}

$$V_j^k,\ U_i \geq 0$$

Minimize returns to resources =

$$V_1^1R_1^1 + V_2^1R_2^1 + V_1^2R_1^2 + V_2^2R_2^2 + U_1D_1^1 + U_2D_1^2 + U_3D_2^1 + U_4D_2^2$$

--Continued on next page.

Table H.2 (continued)

subject to net returns at producer location equaling unit rent to resources:

$$A_{11}^{1}V_1^1 + A_{21}^{1}V_2^1 - U_1 \geq N_1^{11} = P_1^1 - T_1^{11} - C_1^1,$$

$$A_{11}^{1}V_1^1 + A_{21}^{1}V_2^1 - U_2 \geq N_1^{12} = P_1^2 - T_1^{12} - C_1^1,$$

$$A_{11}^{2}V_1^2 + A_{21}^{2}V_2^2 - U_1 \geq N_1^{21} = P_1^1 - T_1^{21} - C_1^2,$$

$$A_{11}^{2}V_1^2 + A_{21}^{2}V_2^2 - U_2 \geq N_1^{22} = P_1^2 - T_1^{22} - C_1^2,$$

$$A_{12}^{1}V_1^1 + A_{22}^{1}V_2^1 - U_3 \geq N_2^{11} = P_2^1 - T_2^{11} - C_2^1,$$

$$A_{12}^{1}V_1^1 + A_{22}^{1}V_2^1 - U_4 \geq N_2^{12} = P_2^2 - T_2^{12} - C_2^1,$$

$$A_{12}^{2}V_1^2 + A_{22}^{2}V_2^2 - U_3 \geq N_2^{21} = P_2^1 - T_2^{21} - C_2^2,$$

$$A_{12}^{2}V_1^2 + A_{22}^{2}V_2^2 - U_4 \geq N_2^{22} = P_2^2 - T_2^{22} - C_2^2.$$

When the assumed market prices are equal to the equilibrium market prices, the net returns per unit of output at the producer location is equal to the rent to the fixed resources entering as activities. V_i^k is the rent per unit of fixed resource i in production region k. Rent per unit of output is obtained when V_i^k is multiplied by the input-output coefficient. $U_1 - U_4$ are artificial rents which will equal zero when assumed prices equal equilibrium prices.

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