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A Model for Regional Agricultural Analysis of Land and Water Use, Agricultural Structure, and the Environment: A Documentation

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Prepared by

Kenneth J. Nicol

Earl O. Heady

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AGRICULTURAL AND RURAL DEVELOPMENT

Center for Agricultural
and Rural Development
Iowa State University
Ames, Iowa

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Preface

THIS DOCUMENTATION outlines the many procedures followed and sources used in developing the structure and data inputs for the CARD-RANN (Center for Agricultural and Rural Development-Research Applied to National Needs) linear programming model of the U.S. agricultural sector. This model considers the relationship of agriculture to land and water use and the environment. The model was developed in stages over a period of more than 15 years with many members of the research team working under the guidance of Earl O. Heady, Center director. The model utilized a revised set of the budget data initially developed by Roger Eyvindson in a research project sponsored by the Iowa Agriculture and Home Economics Experiment Station [20]. The current structure of the model, including the water, crop management, and livestock sectors, was developed under the National Science Foundation-RANN program, contract number G1-32990. Procedures also were developed to handle the data more efficiently and to make the models more accessible and flexible for future users.

Other organizations which provided services, data, and other help include: the Soil Conservation Service and the Economic

Research Service of the U.S. Department of Agriculture, and the Bureau of Reclamation, U.S. Department of Interior. Persons who have provided direct help and input during the RANN-sponsored portion of the study were Howard Madsen, James Wade, Dan Dvoskin, Arden Colette, Gary Vocke, Brent Spaulding, Art Stoecker, Vince Sposito, and other staff members of the Center for Agricultural and Rural Development, Iowa State University. William Johnson, Soil Conservation Service; Roy M. Gray, Soil Conservation Service; and Larry Tombaugh; the National Science Foundation, provided particular aid in obtaining data and research services. The Soil Conservation Service supplied detailed data for the soil loss section of the model.

We express our appreciation to all these individuals and organizations.

The Authors

Chapter One

Mathematical Modeling of Agriculture

AGRICULTURE has played an important part in the economic position of many regions in the United States. Agriculture encompasses more than 1.2 billion acres of land including cropland, hayland, pasture land, and the millions of acres of privately or publicly owned forest land that is grazed. Within the agricultural sector, trade-offs in production occur on both an interregional and intraregional basis as production patterns are changed in response to the economic system. The ability to estimate the possible response to a policy change prior to its implementation can be a valuable asset. A linear mathematical programming model of the agricultural sector, incorporating the characteristics most relevant to the sector and its economic response factors, can provide the policymaker with such a tool. The usefulness and the reliability depend upon the ability to incorporate the major factors in the complex of interactions of the agricultural sector.

Objectives

This report provides a documentation and explanation of the CARD-RANN model of land and water use, environmental quality, agricultural policy, and food capacity for American agriculture. This model was constructed under a grant from the National Science Foundation through its Research Applied to National Needs program. This documentation and explanation is an attempt to provide detail on the manner in which this model is specified, the nature of data that serve as inputs for it, and the manner in which the model operates. This information is provided on behalf of persons and institutions interested in either using the results of the model or using the model itself to analyze problem sets. Hence, the report emphasizes the specification, structure, and output of the model and not a specific set of results analyzed by the model. Emphasized is a model which allows an analysis at national, regional, and interregional levels of land and water use and their environmental effects as expressed by alternative technologies relating to soil loss, nitrogen use, cropping patterns, livestock production systems, and alternative levels of demand and exports. The details of the model follow a brief statement on trends in American agriculture and the possibilities of linear programming models in analyzing those trends.

The Nature of the Agricultural Sector

The agricultural sector consists of a series of complex interactions relating to regional production possibilities, alternative comparative advantages, inter-industry competitive alternatives, and a marketing system that is both uncertain and complex. The importance of the sector results from its supplying the nation's food and natural fiber. In recent years government interest has turned to stabilizing the agricultural sector because of its capacity problems and problems concerning its effect on the environment.

Regional characteristics influence the predominant size of the production units, the methods of production that can be used, and the crops or livestock alternatives that are to be considered. Size characteristics are controlled by such a factor as the topography of the area. If the area is divided by many small streams or rough land, farming practices will reflect machinery use and production techniques consistent with farming these lands. If rough areas are common and livestock enterprises are tied to these units, then the cropping pattern may reflect changes in production to accommodate livestock rather than a more intensive cropping system. State or local governmental policies also affect the production patterns in the areas. Taxes, interest rates, and allowable capital availability are controlled at the state level and can affect the relative profitability of alternative production possibilities. Similarly, local property tax or building codes may affect the production possibilities.

Specialization resulting from regional comparative advantage occurs within the American agricultural sector as evidenced by the concentration of corn in the Midwest, cotton in a more limited area of the South and West, soybeans in the Midwest and more recently in the South Central states, and wheat in the Great Plains. Specialization by regions is a function of spatial price patterns as reflected in transportation costs and demand concentration, relative yields as affected by soils and climate, local resource supplies and prices, and the relative profitability of different crop and livestock enterprises for the individual farmer. Regions do not specialize completely because of the production advantages resulting from mixed farming patterns. Among the advantages of the multiactivity farming pattern are timeliness, risk aversion, cropping patterns consistent with resource management complementarily expressed in pest control and soil fertility, seasonal requirements and availability of resource services, and production-pattern adaptability to the farmer's preference.

The large number of producers in the agricultural sector make quantity control a difficult method of attaining economic stability. Federal acreage-control programs have been successful in controlling the quantity produced. However, these policies have been very costly to the Federal Treasury. The uncertainty surrounding both production and markets cause the agricultural sector to be relatively unstable. Evaluating the impact of market fluctuations and developing compensation policies has a large "trial and error" aspect because of the complexity and severity of the responses obtained from the agricultural sector. This instability has been emphasized in recent years when extreme oscillations in export demands, farm commodity prices, and domestic yields have occurred.

The public has become increasingly concerned with the relationship between farming technology and environmental quality. Legislation has been posed to control the use of chemical and pesticide inputs, the transport of sediment, and the treatment of livestock wastes. The controls have the potential for differential impacts on the income of farmers of different regions. Farmers in regions of limited rainfall and level land may even stand to gain in income, while farmers in other regions sacrifice as they are required to shift their technologies and cropping systems to lessen the environmental impacts of sediment, fertilizers, and insecticides. Of course, the extent to which American agriculture can meet future export demands and contribute to world food needs depends on the extent to which environmental controls are imposed on farming in different regions, the extent to which water and other resources can be transported among regions according to their productivity, and the extent to which the distribution of crop and livestock production is distributed among regions according to their comparative advantage.

Answers to these types of problems require analytical tools that generate detailed empirical results at both national and regional levels. National detail is required so that market impacts on prices can be measured, supplies can be equated with demand, and interdependence among regions can be established. Detail by region is needed so that the flexibilities of or restraints on production and resource use can be measured and impacts can be expressed at the local level. Also, regional detail is required if the full potential of agriculture under alternative export or market possibilities is to be established or possibilities of meeting national food demands at reasonable supply prices are to be evaluated. This detail is especially required for analyses related to equity in the impact of alterations in technologies and resource availabilities prescribed by environmental or other national policies. In meeting national food needs, land in one region is a substitute for water in another region, capital in the form of fertilizer used on level land is a substitute for crops on hilly land in another region, and alternative crops are substitutes as feed inputs for livestock within a given region or among regions. Thus, if either resource and production potentials under various environmental, resource, or production policies are to be fully evaluated, an analytical tool is needed that allows measures and generates results at the level of both individual regions and the nation. This type of detail can be provided by a linear programming model incorporating relevant production possibilities which are differentiated to reflect their regional technologies.

Use of Regional Linear Programming Models

The formulation of a minimizing linear program in matrix notation is:

$$\min \quad C' X$$

$$\text{subject to} \quad A_1 X \geq D \qquad (1.1)$$

$$A_2 X \leq R$$

where:

- C is a vector of costs;
- X is the vector of the activities in the model;
- D is the demands to be met;
- R is the resources available;
- A_1 is a matrix of the interaction coefficients between X and D; and
- A_2 is a matrix of the interaction coefficients between X and R.

This formulation is consistent with the regional structure of agriculture if the vector D represents the regional and national demands for the commodities to be met by the system and R represents a vector of regional and national resource availabilities for use in satisfying the demands. The activities in vector X represent production and transformation activities by region and the transportation alternatives which connect the regions in the model. These restraints and activities are defined in the next section. The A matrices include the activity interaction coefficients with the resources or demands. The interactions will be delineated and the quantification procedures outlined in the section following the model formulation.

The restraints or rows in the linear programming formulation represent markets in the agricultural economic system. The resources are obtained in a market, and the production (supplies) and demands interact in markets, including those for intermediate goods such as the feed grains and feeders. Other restraints are used to control relative use patterns or reflect institutional restraints where the use or production of one commodity requires a nonmarket but fixed interaction with another endogenous commodity or with an individual or group of factors not directly controlled by the model interactions. These generally are in the form of bounds on the activities restricting implementation to some level not regulated by the included resource or product market systems.

Policy alternatives can be evaluated in this framework by (1) incorporating new markets (restraints) necessitated by the new policy, (2) changing the relevant coefficients in the D vectors to reflect changes in demands or the R vector for changes in resource availabilities, (3) changing the values in the C vector to reflect changes in the relative activity costs resulting from the policy, (4) changing the coefficients in the A matrices to reflect a changed level of interaction between an activity and any of the relevant markets, or (5) by adding new activities to reflect the interactions of the new policy.

The regional aspects of the system are developed through markets and activities defined with the specific characteristics of the region within which the restraints (demands or resource availabilities) are determined to be most relevant given the data available and the modeling capabilities. The regional sections are connected through resource interactions with other regions or through transportation networks which can balance the regional demand and resource restraints. This brief outline of the characteristics of a linear programming system and the interregional agricultural production possibilities provides an overview of the structural possibilities available in formulating a system representing the agricultural sector.

Objectives of the System Developed

The system developed in the upcoming sections of this report is a tool for agricultural policy evaluations. It is formulated to tie together the many regional characteristics of American agriculture and to interpret their actions in response to the alternative policies. The system as formulated, including its backup data generators, has the capability of evaluating policies that affect:

(1) regional resource availabilities,
(2) soil loss limitation on alternative land classes,
(3) fertilizer input levels or the prices of the fertilizer components,
(4) the direct use of commodities through demand,
(5) the export market of the commodities included,
(6) farming techniques practiced, and
(7) supply controls or marketing quotas.

Regional resource availabilities could be altered by policies affecting land use, water availabilities or transfer, and the availability of other endogenously allocated inputs such as fertilizer or pasture. Soil conservation alternatives can be controlled at the per acre gross soil loss level with implications for water quality. The fertilizer input levels are affected by price changes or quantities available. Price change or per acre application restriction can be traced through indicating the relative reduction in yields or any possible shifts in crop rotations to conserve or supplement the fertilizer supply. Changes in demand as reflected in per capita consumption levels or commodity substitutions in the diet can be reflected by altering the regional demands. Similarly, the impact of policies affecting international trade can be analyzed by altering this portion of the total demands, including the regional export allocation. A broad category of policies which can be evaluated are those affecting the farming techniques utilized. Shifts from dryland to irrigated agriculture as a new irrigation development is initiated, shifts to new tillage practices such as minimum tillage, new varieties that expand the regional compatability of a crop, and technologies affecting the use of the commodities or the efficiency of their transformation are only a few of the farming techniques that can be evaluated using such a model. Supply control or resource use policies can be implemented by either minimum or maximum restraints on acreage or production by regions. Even with a great variety of alternative structures and evaluation possibilities, the linear programming procedure is not without limitation.

Limitations of the Linear Programming Model

Linear programming techniques represent a useful and versatile method of evaluating agricultural policies. But linear programming has limitations that restrict the scope of use and the interpretation of the results. Linear programming in the conventional form is, as its name implies, a tool utilizing linear approximations to define the relationships among inputs, outputs, and their associated costs. In other words, the production possibilities are all based on constant marginal products for the inputs and incorporate no reflection of any cost-decreasing or increasing scale economies. The objective function represents a constant cost over the relevant range of the variable simulating a perfectly elastic supply curve for the product and implying perfectly elastic demand curves for the resources.

These characteristics provide a normative system that can analyze impacts of alternative policies but the system provides little or no information on how the transformation from one alternative to the other can be accomplished with least impact during the transformation period. A model could be formulated to follow these transformations through time, but computer and cost problems must be considered. The linear programming technique is a handy and useful tool for impact analysis but is more complicated for transformation analysis.

Any linear programming model, as with systems simulation and other quantitative methods, is only as accurate as its data inputs. The delineation of the proper production, product transformation, or transportation activities can increase the reliability of the system. Failure to include the appropriate variables could restrict the possibilities open to the system as it adjusts. Or, without specification of the proper alternatives, the relevant base situation may not have been achieved and the response to the new policy biased accordingly. With the limitations of the quantitative method in mind and a proper perspective of the impacts, a large amount of information can be obtained about the direction and possible magnitudes of the impacts of a policy. As in any modeling effort, interpretations must be strictly in line with the capabilities of the formulation used in the analysis.

The following sections of the documentation outline the model interactions, explain the sources and methods of transformation of the data sets, outline the interpretations of the solution, and indicate the detail of the model output. The overall procedure in building, solving, and interpreting the model is outlined in Figure 1.1. The initial data base described in Chapter 3 is developed and formulated into the matrix for the programming model as described in Chapter 2. The model is solved using the programming package, and the solution generated is combined with the input data to provide the report-writing inputs (tables) as described in Chapter 4. This output can be used as summarized or can be aggregated to a greater level for incorporation into written reports as indicated in the section.

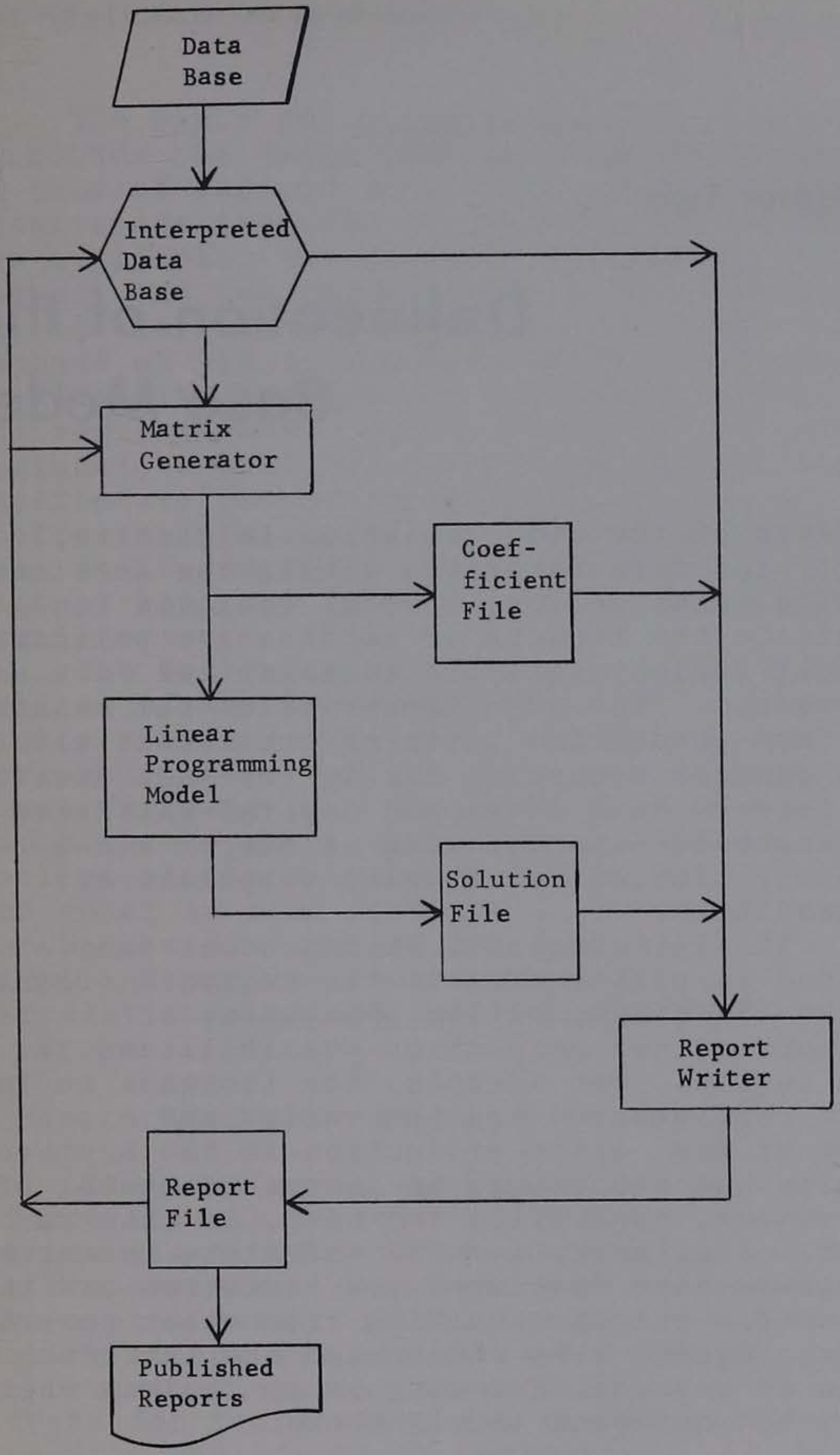

Figure 1.1. An overview of the agricultural policy analysis system.

Chapter Two

Delineation of the Base Model

BECAUSE of the wide variation in climate, soil, and farm structure within the American agricultural sector, a model designed to evaluate the impacts of alternative policies should reflect possible regional and firm adjustments. The adjustments allow for changes in farm production patterns consistent with the changes occurring during the past decades as farmers have developed capital-intensive enterprises--specializing in one or a few closely managed and usually complementary commodities.

The interregional shifts occur when a change in policy affects the regional comparative advantage, either penalizing or supporting the production possibilities in the region. For example, the increase in low cost refrigerated transportation and expansion of feed grain production in the Southern Plains has encouraged an increased number of livestock, especially fed beef, in this region. Similarly, federal and state research programs have developed new varieties and the favorable prices resulting from other government programs have encouraged the introduction of soybeans and sorghum in regions where they had not been widely grown.

The basis for an interregional model surrounds the definition of a set or number of sets of regions consistent with the characteristics required to describe the resources available, the possible production techniques, and the interaction to be examined. Within the relevant regions, restraints are imposed on the interaction between resource availability and use and commodity production and requirements. Within the bounds of other regional restraints, activities representing alternative production possibilities, resource transformations, and commodity transfers delineate the possible interactions consistent with the definitions of the agricultural sector.

The following sections give a structural outline of the CARD-RANN Base Model. Initially, the structure of the model is described in terms of its scope and interactions followed by a delineation of the regions developed in the model. A mathematical outline of the interactions developed within the model is also presented. The next chapter breaks out each of the sectors in the model and outlines the development of the interrelationships and the required data sets.

Structure of the Base Model

The base model incorporates three sets of operational regions in delineating the interactions of production, marketing, and resource sectors. Restraints are included at the appropriate regional level on the availability of dry and irrigated cropland by quality class, pasture, permanent hay, water, nitrogen for fertilizer, and the demands for the crop and livestock commodities. A restraint imposed exogenous to the model initially screens all crop production activities, eliminating those which develop environmental parameters (soil loss levels) above the allowable limit. Activities, besides those for crop production, define the possibilities for livestock production; fertilizer and water purchase; demand generation as related to population, industry, and international trade activities; the transfer of resources or commodities among regions; and requirements for the resources and agricultural goods for uses not specifically quantified in the model. A sector and restraint group delineation of the above-implied interactions is given in Figure 2.1. The model divides into three macro sectors including the resource availability; the production, transfer, and transformation; and the demand generating sectors.

The resource availability sector indicates the number of acres of land in each region that are available for cropland production, including cropland hay and pasture. The land base is adjusted for the requirements of the crops whose regional distribution is not specifically determined endogenously while solving the model. Also included in this section is nitrogen fertilizer availability which determines the source and price of the nitrogen fertilizer component. Additional resource determinations include the land available for nonrotation hay and pasture and forest land grazed by region. Water supply by water region also is determined in the resource availability sector.

The production and product transfer sector utilizes the resources to produce the crop and livestock commodities for both intermediate and final uses. Included in this

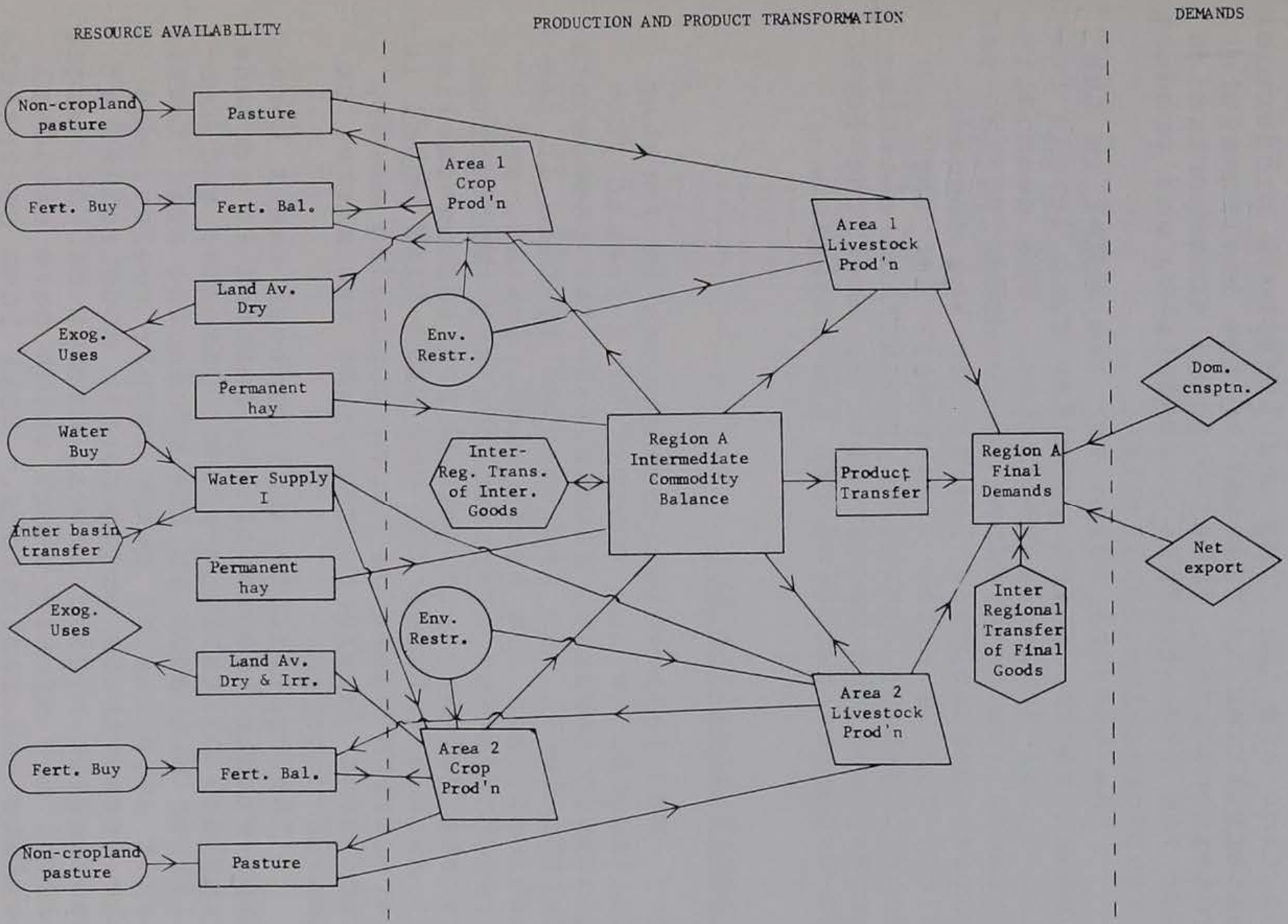

Figure 2.1. A schematic interaction outline of the NSF-CARD model.

section are the crop and livestock production alternatives as related to the environmental considerations, interregional transportation for the transferable commodities, and product transformation activities.

The driving force for the model is the demand sector which provides base levels for the final demand commodities. The commodity demands are determined by considering the per capita consumption levels for the commodities, the domestic requirement for the nonendogenous livestock production alternatives, and the requirement to meet the level of exports specified for the analysis.

Abbreviated tableau

The interrelationships can be further delineated in the context of a linear programming tableau, Figure 2.2 The restraints in the model are represented by rows in the tableau, and the production, demand, and transformation alternatives are represented by the columns. Figure 2.2 gives an outline of such a tableau for the CARD-RANN model interactions based on three producing areas, two water supply regions, and two market or demand regions.

The restraints that control the allocation within the model are defined to include cropland by quality class, pasture, and fertilizer nitrogen at the producing area level; water supplies by water supply region; and the commodities endogenously constrained at the market region level, except cotton, sugar beets, and spring wheat which have national markets and restraints. Soil loss restraints on a per acre basis are implied by controlling the crop production activities, thereby

1, 2, 3-producing areas
A, B-market regions
I, II-water supply regions
i for the 18 land classes

	popln & ind. 1	popln & ind. 2	popln & ind. 3	intnl trade A	intnl trade B	exog. lvstk A	exog. lvstk B	exog. crops A	exog. crops B	crop prodn 1 i	crop prodn 2 i	crop prodn 3 i	livestock 1	livestock 2	livestock 3	buy fert. 1	buy fert. 2	buy fert. 3	buy water I	buy water II	water export I	water transfer I-II	comm. transp. A-B	comm. transp. B-A	non-rotn past 1	non-rotn past 2	non-rotn past 3	non-rotn hay 1	non-rotn hay 2	non-rotn hay 3	beef quality transfer A	beef quality transfer B	
Cropland 1 i										+																							≤ i
Cropland 2 i											+																						≤ i
Cropland 3 i												+																					≤ i
Pasture 1						-				+			-												+								≥ 0
Pasture 2						-					+			-												+							≥ 0
Pasture 3							-					+			-												+						≥ 0
Water I	-					-		-		-			-						+		-	-			-			-					≥ 0
Water II		-									-			-						+		+				-			-				≥ 0
Fertilizer 1						+		-		-			+			+																	≥ 0
Fertilizer 2						+		-			-			+			+																≥ 0
Fertilizer 3							+		-			-			+			+															≥ 0
Commodities A	-	-		-		-				+	+		±	±									-	+				+	+		∓		≥ 0
Commodities B			-		-		-					+			±								+	-						+		∓	≥ 0
Cost										+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+			
Bound	L	L	L	L	L	L	L	L	L										U	U	L	U			U	U	U	U	U	U			

Figure 2.2. Interactions within the agricultural sectors on a regional basis using a LP tableau approach.

allowing only those meeting the restraint to be included. Additional restraints are included to regulate the level of the population, international trade, exogenous crop and livestock production, water availability, water transfers and exports, and nonrotation hay and pasture production. The form of the restraints is indicated in Figure 2.2 as being either upper, U, or lower, L, restraints, and all activities have the additional restraint implied in the standard linear programming formulation which requires all activities to be greater than zero. (The default can be changed to allow negative levels, but for our modeling the greater-than-zero restraint holds for all activities.) Each of the interpretations and coefficient determination procedures associated with the restraints is discussed in Chapter 3.

The activities in the model (the columns in Figure 2.2) represent the demand generating, commodity production and transfer, and resource purchase alternatives. In the tableau, the interaction of the activities with each of the resources is indicated by a positive or negative sign appropriate with the formulation.

The first four activity categories and their associated lower bounds represent the demand sector of the model which must be satisfied by the appropriate incorporation of the other activities. Population and industry activities, defined by producing area, interact with the market regions to create a demand for the commodities and, with the water supply regions, to create a water use requirement representing municipal and industrial needs. The per capita use coefficients and the population bound insert an accumulation of demands into the appropriate market or water regions.

The international trade activities are expressed as net export levels and are formulated with bound limits on the activities which represent net export of the commodities: corn, sorghum, oats, barley, oilmeals, wheat, and cotton. International trade for each of the commodities not allocated endogenously to the central model is determined, and their level of domestic requirement is adjusted to reflect this option. The export activities are defined by consuming region, and the relative magnitude of each bound determines the regional distribution of the net export as based on the shipments from the major ports in the region.

The exogenous livestock classes are represented by a set of activities that simulate a fixed level of production of broilers, turkeys, eggs, sheep and lambs, and an "other livestock" category. These alternatives utilize pasture, water, and the commodities that are relevant for the type of livestock and the typical regional production method. These livestock activities also produce nitrogen into the regional fertilizer balance at a level approximating the production of nitrogen equivalents from their wastes. The lower bound forces in the required level of production by market region and is representative of the region's proportionate share of each of the exogenous livestock groups.

The exogenous crop sector accounts for the water and fertilizer requirements of those crops that have small production levels or whose production patterns are concentrated in one or two areas. Included in this category are such crops as broomcorn, buckwheat, cowpeas, dry beans, dry peas, flax, hops, orchards and vineyards, peanuts, potatoes, proso-millet, rice, rye, safflower, sugar cane, sunflowers, sweet potatoes, tobacco, and vegetables. The activities representing the aggregate production patterns of these crops indicate the utilization of water and fertilizer by these crops. This crop sector does not interact with the land base because the land base is defined as land available for crop production after these exogenous commodities have been allocated their acreage.

The next two sectors named in Figure 2.2 indicate the heart of the model's production sector. These two sectors produce the endogenous crop and livestock commodities to satisfy the demand levels determined in the demand generating sector. The crop production sector produces the endogenous commodities--barley, corn, corn silage, cotton, legume hay, nonlegume hay, oats, sorghum, sorghum silage, soybeans, sugar beets, wheat (both spring and winter), and summerfallow. The cropping activities are defined to represent rotations ranging from one to eight years in length, incorporating the above-named crops in appropriate combinations to give the desired rotational effect. Alternative conservation and tillage practices are combined with the regions' rotations to provide a spectrum of crop management systems each reflecting a different soil loss level. The crop production activities interact with the relevant land group utilizing an acre of this land and the other resources, water and fertilizer, as is appropriate for the defined crop management system. These activities produce commodities based on the cropping system and also produce aftermath pasture in a quantity variable with the crops included in the rotation and the historic utilization of this pasture alternative.

The livestock alternatives include dairy cow, beef cow, beef feeding, and pork enterprises. The livestock activities utilize water, pasture, and the feed commodities that are appropriate for their defined rations and location. They produce intermediate commodity feeders; the final demand commodities, dairy products, fed and nonfed beef (a secondary product of the beef cow and dairy operations) and pork; and the by-product residual nitrogen available for fertilizer.

The remaining activities incorporate the resource availability and commodity or resource transfer sectors. The fertilizer and water-buy sectors represent the purchase of the particular resource at the relevant regional price. The upper bound for water is consistent with the available water supply. The water export sector represents contractual water laws requiring the transfer of water from within the water supply regions to other areas external to the water supply region. The water transfer activities represent both natural flow and developed interbasin transfer networks to move water between the relevant water supply regions. Similarly, the commodity transport sector represents the movement of the intermediate or final goods from market region to market region as is consistent with the transport networks and the feasibility of transferring the commodities. The nonrotation hay and pasture activities represent the production of roughage from lands not presently defined as being under cultivation. They provide roughage in nonlegume hay equivalents into the nonlegume hay or pasture balance markets and utilize water for those lands which have historically produced these commodities under irrigation.

The final sector represents the transfer of fed beef from its market into the nonfed or cull beef category. This activity allows for the balancing of the two meat markets without having a surplus of the primary products (milk or feeders), as the producing activities attempt to increase production of the cull or nonfed beef while preventing the lower quality beef from satisfying more than its historic proportion of the regional market.

Regional Delineations in the Model

In completely defining the workings of the model, five separate sets of regions are incorporated. The first represents regions within which the data base is defined; the second, the areas within which the production activities are defined; the third, the regions detailing water availability and transfer possibilities; the fourth, the areas within which the markets are defined; and the fifth, the regions into which the results are aggregated for reporting.

The data regions

These regions represent many sets of political and geographic areas within which data is tabulated by the collecting agencies. They include the counties and states of the continental United States within which census and commodity production data are tabulated. An additional set of regions included in this group is the county approximations of the major land resource areas as used for data collection by the Soil Conservation Service, U.S. Department of Agriculture (Figure 2.3). These regions divide the land in the continental United States into 164 areas based on soil type and management characteristics. It is from these regions that the data used in calculating the soil loss by alternative cropping activity is developed.

Sets of weights based on relevant data relationships are used to transfer data from the regions in which they are obtained into the common resource or producing areas where the data are used in the model or in combination with other data to generate coefficients to be used in the model.

The producing areas

Figure 2.4 illustrates the 223 producing areas defined in the model. These areas are based on county approximations of the Water Resource Council's subareas [112] modified to be consistent with the water supply regions and the market regions. Each producing area is an aggregation of contiguous counties contained in a watershed draining to a common waterway. The producing areas represent the regions in which crop and livestock production activities and the land by quality class, pasture, and nitrogen balance restraints are defined.

The water supply regions

Fifty-one water supply regions define the areas in the 17 western states where water supplies are determined in the model

Figure 2.3. The SCS data collection areas

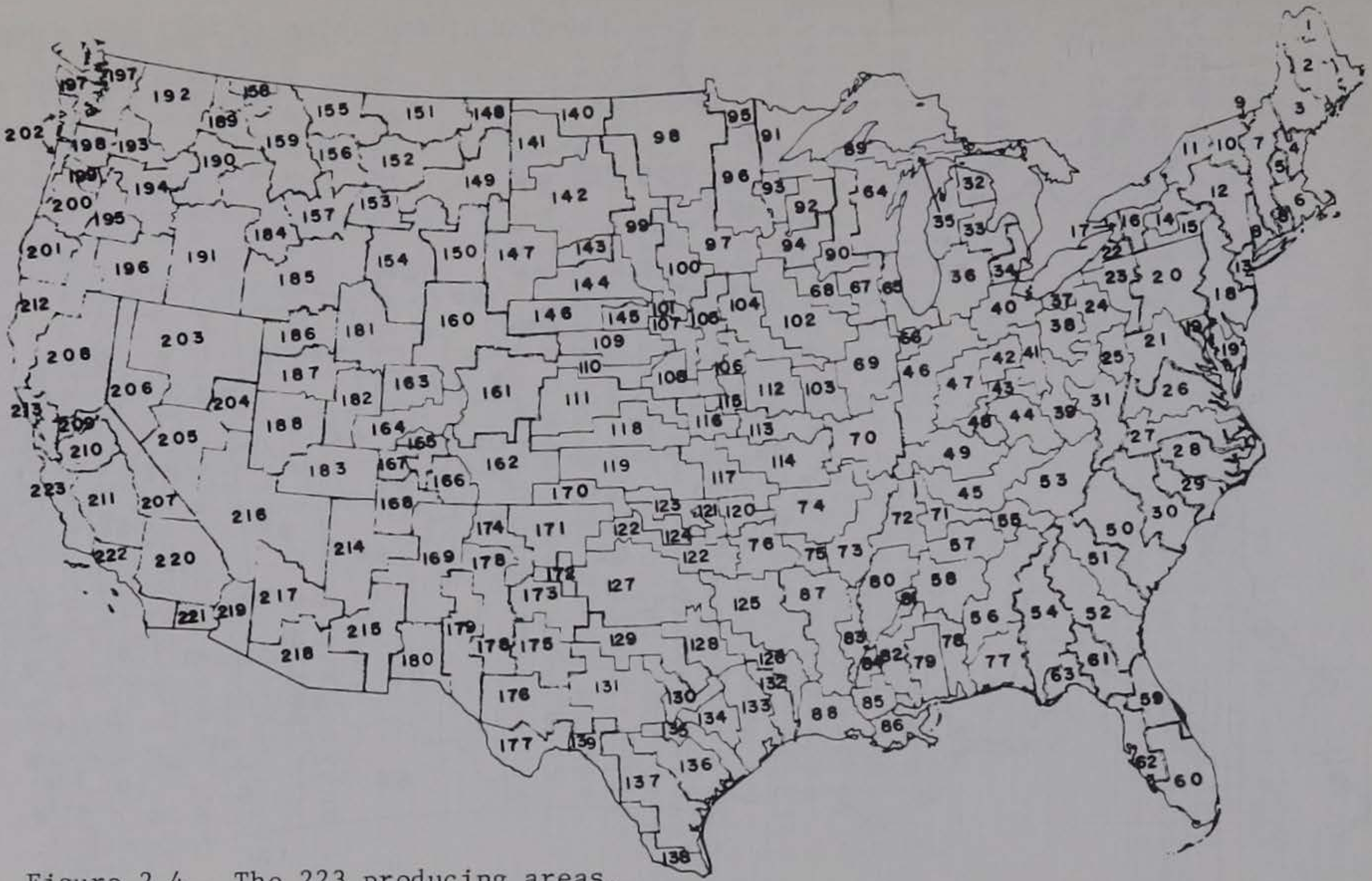

Figure 2.4. The 223 producing areas.

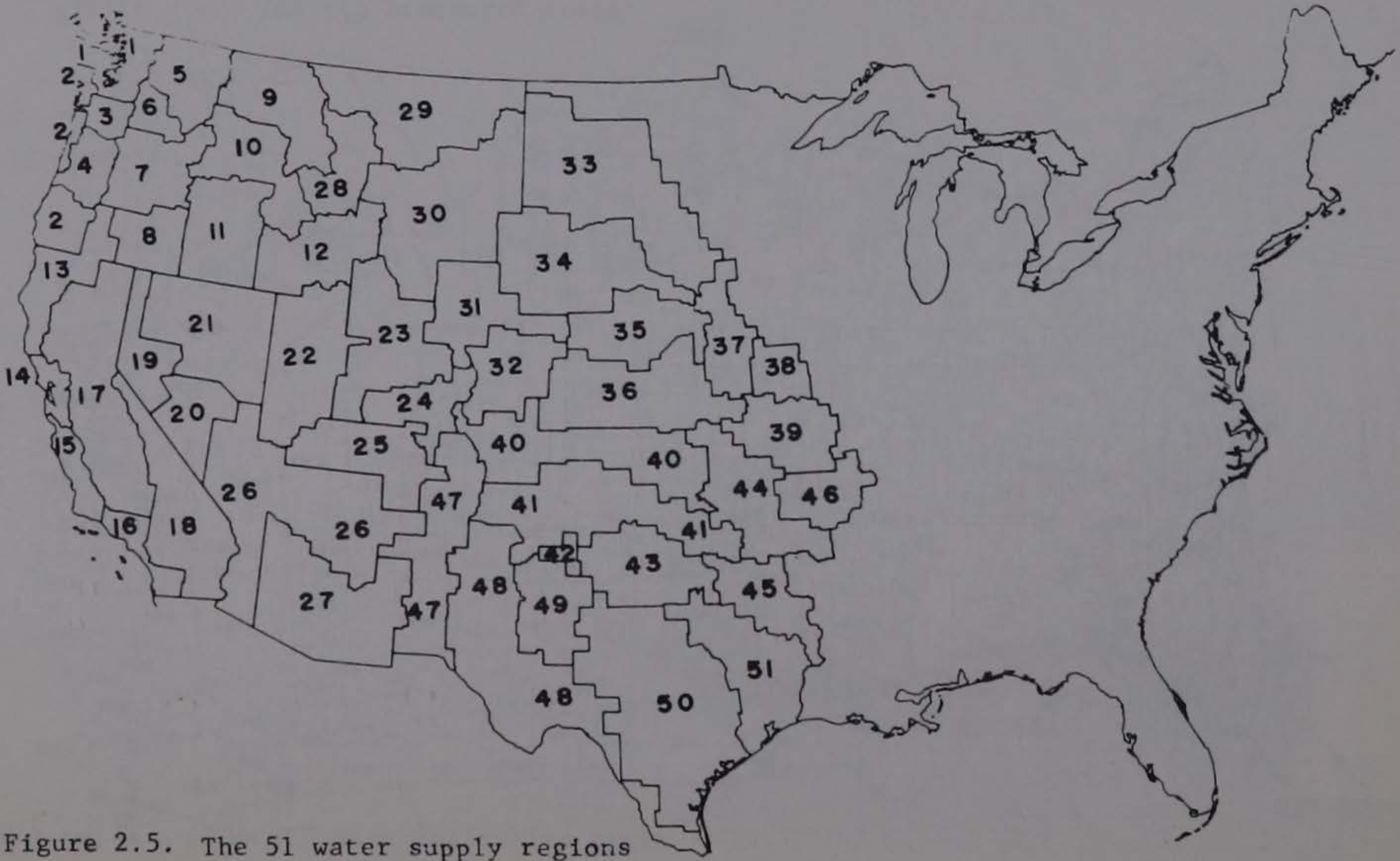

Figure 2.5. The 51 water supply regions

(Figure 2.5). These regions are an aggregation of contiguous producing areas within which a water supply can be said to exist. The subdivisions of the 18 major river basins of the Water Resources Council form the basis of these regions [112].

The market regions

Contiguous producing areas are aggregated into major marketing areas of the United States to give the 30 market regions for the model (Figure 2.6). It is within these regions that the market balance restraints are defined for the major commodities analyzed. The regions also have as their market center a city that serves as a hub in the existing national transportation network. The commodity transfer section of the model uses these centers as points between which commodities are moved as the model adjusts its production pattern to account for each region's comparative advantage.

The reporting regions

These regions represent aggregations of the market regions such that regional similarities in agricultural production possibilities are maintained. The resulting seven regions form a manageable number between which regional comparisons can be defined while neither completely over aggregating the production impacts nor creating a reporting system completely overpowered by numbers. An approximation of these regions is given in Figure 2.7.

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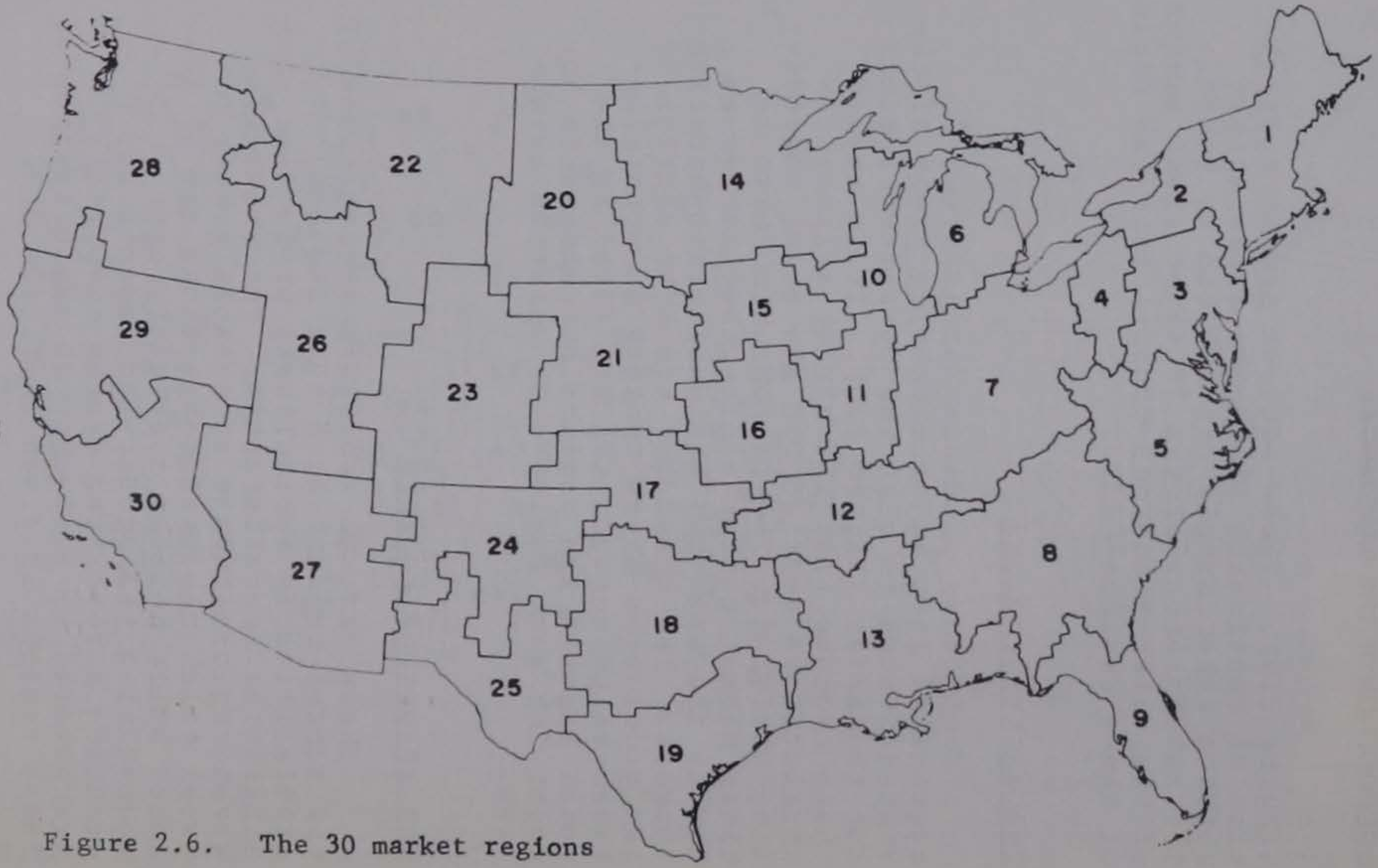

Figure 2.6. The 30 market regions

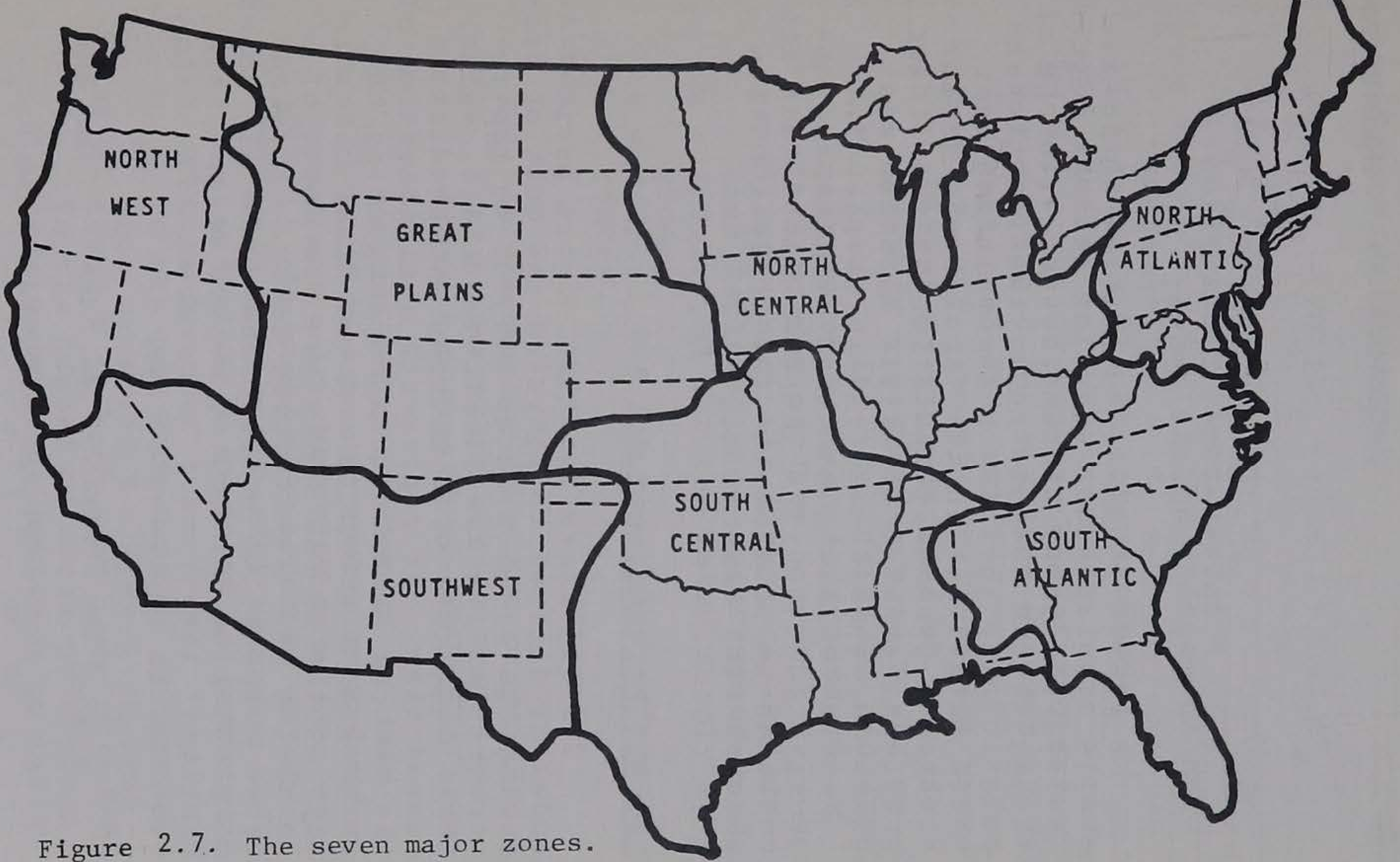

Figure 2.7. The seven major zones.

A Mathematical Explanation of the Model

A linear programming problem forms a simple simulataneous equation network representing the group of restraints, with one of the equations designated as the functional relationship that is to be optimized over those activities in the final basis (solution). A general formulation of the linear programming model in matrix notation was given in equation set 1.1 in chapter 1.

The following sections outline the objective function and the restraints that are combined to provide the interrelationships encompassing this model.

The objective function

The objective function of the basic model is defined to minimize the cost of producing the given demands subject to the restraints on the availability of land, water, fertilizer, pasture, and the intermediate commodities. It represents a minimization of the cost of producing and transporting the intermediate products and the final commodities of the model, including the costs of obtaining and transferring water. It simulates competitive equilibrium since all costs of production (including return on the farm families' labor) must be covered. The function can be represented by:

$$\text{min.}\sum_{i}\Big(\Big(\sum_{k}\sum_{m} X_{ikm}\,XC_{ikm} + \sum_{n} Y_{ikn}\,YC_{ikn} + \sum_{m} Z_{ikm}\,ZC_{ikm}\Big)$$

$$+ \sum_{p} L_{ip}\,LC_{ip} + DPP_{i}\,PAC_{i} + IPP_{i}\,PAC_{i} + DWH_{i}\,PAC_{i}$$

$$+ IWH_i PAC_i + FLG_i PAC_i + FP_i UC_i) + \sum_w (WB_w WC_w$$

$$+ WD_w WC_w + WT_w WC_w) + \sum_t \sum_c T_{tc} TC_{tc} \tag{2.1}$$

c = 1,2, ...,17 for the endogenous commodities,[1]

i = 1,2,...,223 for the producing areas,

j = 1,2,...,30 for the market regions,

k = 1,2,...,9 for the land classes in each producing area,

m = 1,2,..., for the dryland crop management systems defined on a land class in a producing area,

n = 1,2,..., for the irrigated crop management systems on a land class in a producing area,

p = 1,2,..., for the livestock activities defined in the purchasing area,

w = 1,2,...,51 for the water supply regions,

t = 1,2,...,458 for the transportation routes.

where:

X_{ikm}	is the number of acres of dryland crop management system m on land class k employed in producing area i;
XC_{ikm}	is the per acre cost of dryland crop management system m on land class k in producing area i;
Y_{ikn}	is the number of acres of irrigated crop management system n on land class k employed in producing area i;
YC_{ikn}	is the per acre cost of irrigated crop management system n on land class k in producing area i;
Z_{ikm}	is the number of acres of dryland crop management system m on irrig-

ated land class k employed in producing area i;

ZC_{ikm} is the cost per acre of dryland crop management system m on irrigated land class k in producing area i;

L_{ip} is the number of units of livestock activity p employed in producing area i;

LC_{ip} is the unit cost of livestock activity p in producing area i;

DPP_i is the number of acres of dryland permanent pasture employed in producing area i;

IPP_i is the number of acres of irrigated permanent pasture employed in producing area i;

DWH_i is the number of acres of dryland wild hay employed in producing area i;

IWH_i is the number of acres of irrigated wild hay employed in producing area i;

FLG_i is the number of acres of forest land grazed employed in producing area i;

PAC_i is the per acre cost of the respective permanent roughage source in producing area i;

FP_i is the number of pounds of nitrogen fertilizer purchased in producing area i;

UC_i is the unit cost of fertilizer in producing area i;

WB_w is the number of acre feet of water purchased for use in water supply region w;

WD_w is the number of acre feet of water generated from desalting in water supply region w;

WT_w is the number of acre feet of water transferred from water supply region w;

WC_w is the cost per acre foot of the associated water activity in water supply region w;

T_{tc} is the net movement of commodity c over transport route t expressed in the units of the commodity; and

TC_{tc} is the per unit cost of transporting commodity c over transport route t.

Restraints at the activity level in the model

Restraints on the level of an activity or group of activities are included in the linear programming model at the activity, producing area, water supply region, market region, and national level. Each crop management system activity and certain other activities, such as population-industry, water-buy, water-transfer, commodity-export, nonrotation pasture production, and nonrotation hay production, are regulated at the individual component level.

The population-industry activities represent the interaction of the consumer and manufacturing sectors of the economy with the agricultural sector. One activity is defined for each of the producing areas and is of the form:

$$PN_i \geq IPN_i \qquad (2.2)$$

$i = 1,2,\ldots,223$ for the producing areas

where:

PN_i is the level of population in producing area i; and
LPN_i is the lower level of population allowed in producing area i.

The lower limit on the regional population activity is set at a level consistent with the Bureau of Economic Analysis's population projections for the area [101].

A set of activities, closely related to the population-industry activities, generates a demand for water in each of the 51 water supply regions to reflect the increased demand for water navigation, wetlands, and other onsite water consuming activities. The onsite demand for water reflects a use over and above the level in 1969, because the 1969 level of use is not part of the calculated available supply. These restraints are of the form:

$$WO_w \geq RWO_w \qquad (2.3)$$

$w = 1,2,\ldots,51$ for the water supply regions.

where:

WO_w is the level of water used for wetland, navigation, and other onsite uses in water supply region w; and
RWO_w is the required minimum level of water needed for wetland, navigation and other onsite uses in water supply region w.

The foreign trade sector of the model adjusts the commodity demands to reflect the international aspects of agricultural equilibrium. For the base model, trade of all commodities is held at a level equal to the 1969 to 1971 annual average net trade.

The export demands for the commodities corn, sorghum, barley, oats, wheat, and oilmeals are allocated to the market regions where they are restrained as:

$$E_{jc} \geq EX_{jc} \qquad (2.4)$$

$j = 1, 2, \ldots, 30$ for the market regions,
$c = 1, 2, \ldots, 17$ for the commodities (see footnote 1, p. 178).

where:

E_{jc} is the level of export of commodity c from market region j; and
EX_{jc} is the regional minimum level of export of commodity c from market region j.

The activities controlling the export of water to areas outside the water resource areas are bound with restraints of the form:

$$WE_{w} \geq LWE_{w} \qquad (2.5)$$

$w = 1, 2, \ldots, 51$ for the water supply regions,

where:

WE_{w} is the level of export of water from water supply region w; and
LWE_{w} is the lower limit arranged by compact for export of water from water supply region w.

The exogenous crop sector, representing the production of crops not included in the model, adjusts for water and fertilizer requirements through restraining activities of the following form:

$$EC_{ih} \geq PEC_{ih} \qquad (2.6)$$

$i = 1,2,\ldots,223$ for the producing areas,
$h = 1,2,\ldots,19$ for the exogenous crop groups in the model,

where:

EC_{ih} is the level of the activity for exogenous crop group h in producing area i; and
PEC_{ih} is the required minimum level of the exogenous crop group h in producing area i.

Similarly, the exogenous livestock sector, representing production of the livestock commodities not endogenously allocated, is restrained to account for feed, pasture, and water requirements and the production of nitrogen equivalent wastes as:

$$EL_{ie} \geq PEL_{ie} \qquad (2.7)$$

$i = 1,2,\ldots,223$ for the producing areas,
$e = 1,2,\ldots,5$ for the exogenous livestock groups considered.

where:

EL_{ie} is the level of exogenous livestock activity e in purchasing area i; and

PEL_{ie} is the prespecified minimum level of exogenous livestock activity e in producing area i.

Restraints are defined on the water purchase activities in each water supply region to control the level of water use at a level consistent with the regions' water resources. This restraint is of the form:

$$WP_w \leq WS_w \qquad (2.8)$$

w = 1,2,...,51 for the water supply regions,

where:

WP_w is the number of acre feet of water purchased in water supply region w; and

WS_w is the number of acre feet of water in the predetermined supply in water supply region w.

Restraints for the irrigated and dryland native and noncropland roughages are of the forms:

Dryland hay for producing area i:

$$DWH_i \leq ADWH_i \qquad (2.9)$$

Irrigated hay for producing area i in the irrigated area:

$$IWH_i \leq AIWH_i \qquad (2.10)$$

Dryland permanent pasture for producing area i:

$$DPP_i \leq ADPP_i \qquad (2.11)$$

Irrigated permanent pasture for producing area i in the irrigated area:

$$IPP_i \leq AIPP_i, \text{ and} \quad (2.12)$$

Forest land grazed for each producing area i:

$$FLG_i \leq AFLG_i \quad (2.13)$$

i = 1,2,...,223 for the producing areas,

where:

DWH_i is the number of acres of dryland wild hay cut in producing area i;
IWH_i is the number of acres of irrigated wild hay cut in producing area i;
DPP_i is the number of acres of dryland permanent pasture grazed in producing area i;
IPP_i is the number of acres of irrigated permanent pasture grazed in producing area i;
FLG_i is the number of acres of forest land grazed in producing area i; and
A is the number of acres of the type of roughage source indicated as corresponding to the above five types in producing area i.

Within the crop production sector two activity restraints exist. The first regulates the per acre soil loss and is of the form:

$$SL_{ikm+n} \leq ASL_{ik} \quad (2.14)$$

$i = 1,2,\ldots,223$ for the producing areas,
$k = 1,2,\ldots,9$ for the land classes,
$m = 1,2,\ldots,$ for the dryland crop management systems on the land class in the producing area,
$n = 1,2,\ldots,$ for the irrigated crop management systems on the land class in the producing area,

where:

SL_{ikm+n} is the level of soil loss associated with the crop management system in m+n on land class k in producing area i; and
ASL_{ik} is the allowed level of soil loss on land class k in producing area i.

The second restraint is not directly incorporated but is implied in the definition of the rotations. This restraint maintains cropping sequences which are agronomically feasible. As an example, it is not a recommended policy to raise continuous soybeans in the Corn Belt. Thus, no crop management system representing soybeans grown alone continuously is defined. The remaining restraints in the model are multiple activity restraints and are defined at the relevant region level.

Restraints defined at the producing area level

The major restraint at the producing area level is the availability of cropland. Within each producing area there exists the possibility of nine land groups in each of the dryland and irrigated agricultural sectors. The nine land groups represent aggregations of the major land class and subclass categories of the Soil Conservation Service, U.S. Department of Agriculture. The dryland restraint by producing area and land class is of the form:

$$\sum_m X_{ikm} a_m \leq LD_{ik} \qquad (2.15)$$

i = 1,2,...,223 for the producing areas,
k = 1,2,...,9 for the land groups, and
m = 1,2,..., for the dryland crop management systems defined,

where:

X_{ikm} is the number of units of crop management system m employed on land class k in producing area i;
a_m is the number of acres of land associated with one unit of crop management system m (scaled to be one acre for this formulation); and
LD_{ik} is the number of acres of dryland available in land class k in producing area i;

and the irrigated cropland restraint by producing area by land class is of the form:

$$\sum_n Y_{ikn} a_n + \sum_m Z_{ikm} a_m \leq LR_{ik} \qquad (2.16)$$

i = 1,2,...,223 for the producing areas,
k = 1,2,...,9 for the land groups,
m = 1,2,..., for the dryland crop man-

agement systems, and
n = 1,2,..., for the irrigated crop management systems,

where:

Y_{ikm} is the number of units of irrigated crop management system n employed on land class k in producing area i;
a_n is the number of acres of land associated with one unit of irrigated crop management system n;
Z_{ikm} is the number of units of dryland crop management system m employed on irrigated land class k in producing area i;
a_m is the number of acres of land associated with one unit of dryland crop management system m; and
LR_{ik} is the number of acres of irrigated land available in land class k in producing area i.

The nitrogen fertilizer balance is also defined at the producing area level and has the form:

$$\begin{aligned} FP_i &+ \sum_p L_{ip} b_p + \sum_e EL_{ie} b_e - \sum_h EC_{ih} f_{ih} - \sum_k \Big(\sum_m X_{ikm} fx_{im} \\ &+ \sum_n Y_{ikn} fy_{in} + \sum_m Z_{ikm} fx_{im}\Big) - DPP_i ff_i - IPP_i ff_i \qquad (2.17) \\ &- DWH_i ff_i - IWH_i ff_i - FLG_i ff_i = 0 \end{aligned}$$

e = 1,2,...,5 for the exogenous livestock groups considered,
i = 1,2,...,223 for the producing areas,
k = 1,2,...,9 for the land groups,
m = 1,2,..., for the dryland crop management systems defined,
n = 1,2,..., for the irrigated crop management systems defined, and

$p = 1, 2, \ldots,$ for the livestock activities defined,

where:

FP_i is the number of pounds of fertilizer purchased in producing area i;

L_{ip} is the number of units of livestock type p in producing area i;

b_p is the number of pounds of fertilizer per unit of livestock type p;

EL_{ie} is the number of units of exogenous livestock group e in producing area i;

b_e is the number of pounds of fertilizer per unit of livestock type e;

EC_{ih} is the number of acres of exogenous crop group h in producing area i;

f_{ih} is the number of pounds of fertilizer nitrogen required per acre of exogenous crop group h in producing area i;

X_{ikm} is the level of crop management system m employed on land class k in producing area i;

fx_{im} is the pounds of nitrogen required per unit of crop management system m in producing area i;

Y_{ikn} is the level of crop management system n employed on land class k in producing area i;

fy_{in} is the pounds of nitrogen required per acre of crop management system n in producing area i;

Z_{ikm} is the level of crop management system m employed on irrigated land class k in producing area i;

DPP_i is the acres of dryland permanent pasture grazed in producing area i;

IPP_i is the acres of irrigated permanent pastures grazed in producing area i;
DWH_i is the acres of dryland permanent hayland cut in producing area i;
IWH_i is the acres of irrigated permanent hayland cut in producing area i;
FLG_i is the acres of forestland grazed in producing area i; and
ff_i is the pounds of nitrogen required per acre for the corresponding noncropland roughage source.

The final restraint defined at the producing area level controls the use of the pasture-associated roughages and is of the form:

$$\sum_k \left(\sum_m X_{ikm} rx_{ikm} + \sum_n Y_{ikn} ry_{ikn} + \sum_m Z_{ikm} rx_{ikm}\right) + DPP_i r_i + IPP_i r_i + FLG_i r_i - \sum_p L_{ip} qf_{ip} - EL_{ei} q_{ei} \geqq 0 \quad (2.18)$$

i = 1,2,...,223 for the producing areas,
k = 1,2,...,9 for the land groups,
m = 1,2,..., for the dryland crop management systems,
n = 1,2,..., for the irrigated crop management systems, and
p = 1,2,..., for the livestock activities,

where:

X_{ikm} is the level of dryland crop management system m on land group k in producing area i;
CX_{ikm} is the yield of aftermath pasture from dryland crop management system

	m on land group k in producing area i;
Y_{ikn}	is the level of irrigated crop management system n on land group k in producing area i;
ry_{ikn}	is the yield of aftermath pasture from dryland crop management system n on land group k in producing area i;
Z_{ikm}	is the level of dryland crop management system m on irrigated land in land group k in producing area i;
DPP_i	is the number of acres of dryland pasture grazed in producing area i;
IPP_i	is the number of acres of irrigated pasture grazed in producing area i;
FLG_i	is the number of acres of forestland grazed in producing area i;
r_i	is the yields of nonlegume hay equivalent roughage per acre of the respective pasture type in producing area i;
L_{ip}	is the number of units of livestock type p in producing area i;
gf_{ip}	is the quantity of pasture consumed by livestock type p in producing area i;
EL_{ie}	is the number of units of exogenous livestock type e in producing area i; and
q_{ie}	is the quantity of pasture consumed by exogenous livestock type e in producing area i.
rx_{ikn}	is the yield of aftermath pasture from irrigated crop managerment system n on land group k in producing area i;

Restraints defined by water supply region

The water supply regions control the availability of water and regulate the flow and allocation of transfers. The water use restraint for region w is of the form:

$$WB_w \pm WT_w \pm WI_w - WO_w - WX_w - WE_w + WD_w - \sum_{i \varepsilon w} (IWH_i d_i - IPP_i d_i - \sum_k \sum_n Y_{ikn} dy_{in} - \sum_p L_{ip} dl_{ip} - PN_i d_{pi}) \geqq 0 \qquad (2.19)$$

i = 1, 2, ..., 223 for the producing areas,

k = 1, 2, ..., 9 for the land groups,

n = 1, 2, ..., for the irrigated crop management systems,

p = 1, 2, ..., for the livestock activities,

w = 1, 2, ..., 51 for the water supply regions, and

ε = a symbol for "included in,"

where:

WB_w is the number of acre feet of water purchased to generate the water supply in region w;

WT_w is the number of acre feet of gross water transfer from region w;

WI_w is the number of acre feet of gross interbasin flows from region w;

WO_w is the number of acre feet of water used for onsite requirements in region w;

WE_w is the number of acre feet of water exported under compact from region w;

WX_w is the number of acre feet of water required for use by the exogenous crops and livestock in region

w;

WD_w is the number of acre feet of water developed through desalting in water region w;

IWH_i is the number of acres of irrigated wild hay in producing area i;

IPP_i is the number of acres of irrigated permanent pasture grazed in producing area i;

d_i is the number of acre feet of water required per acre of the respective permanent roughage crops;

Y_{ikn} is the number of acres of irrigated crop management system n on land group k in producing area i;

dy_{in} is the number of acre feet of water required per acre of crop management system n in producing area i;

L_{ip} is the number of units of livestock type p in producing area i;

dl_{ip} is the number of acre feet of water required per unit of livestock type p in producing area i;

PN_i is the level of population in producing area i; and

dp_i is the number of acre feet of water required per capita for municipal and industrial needs in producing area i.

The water transfer restraint in each region w is of the form:

$$WT_w + WI_w + WE_w \leq .75WS_w \qquad (2.20)$$

$w = 1,2,\ldots,51$ for the water supply regions,

where:

WT_w is the number of acre feet of natural flow transfers from region w;
WI_w is the number of acre feet of interbasin flows from region w; and
WE_w is the number of acre feet of water exports from region w.

Restraints by market region

The only set of restraints defined at the market region level represents the commodity market balance for all the endogenously allocated commodities except cotton, sugar beets, and spring wheat. The restraint for commodity c is of the form:

$$\sum_{i\epsilon j} \Big(\sum \Big(\sum_m X_{ikm} \, cx_{ikmc} + \sum_n Y_{ikn} \, cy_{iknc} + \sum_m Z_{ikm} \, cx_{ikmc} \Big) \pm \sum_p L_{ip} \, cl_{ipc} - PN_i \, cp_{ic} \Big) \pm \sum_{t\epsilon j} T_{tc} \pm E_{jc} - EL_{ej} \, cy_{ejc} \geq 0 \qquad (2.21)$$

e = 1,2,...,5 for the exogenous livestock types,
i = 1,2,...,223 for the producing areas,
j = 1,2,...,30 for the market regions,
k = 1,2,...,9 for the land groups,
m = 1,2,..., for the dryland crop management systems,
n = 1,2,..., for the irrigated crop management systems,
p = 1,2,..., for the livestock activities defined endogenously,
t = 1,2,...,458 for the transportation routes in the model, and
ε = a symbol for "included in,"

where:

X_{ikm}	is the level of dryland crop management system m on land class k in producing area i;
CX_{ikmc}	is the yield of commodity c per unit of crop management system m on land class k in producing area i;
Y_{ikn}	is the level of irrigated crop management system n on land class k in producing area i;
CY_{iknc}	is the yield of commodity c per unit of crop management system n on land class k in producing area i;
Z_{ikm}	is the level of dryland crop management system m on irrigated land class k in producing area i;
L_{ip}	is the level of livestock activity p in producing area i;
cl_{ipc}	is the yield of or requirement for commodity c by livestock activity p in producing area i;
PN_{i}	is the level of population in producing area i;
cp_{ic}	is the per capita requirement for commodity c in producing area i;
T_{tc}	is the net transfer of commodity c from market region j through transportation activity t;
E_{jc}	is the net international export of commodity c from market region j;
EL_{ej}	is the level of employment of exogenous livestock activity e in market region j;
ce_{cej}	is the requirement of commodity c by exogenous livestock activity e in market region j;

Restraints at a national level

The restraints at the national level include international trade restraints and the national commodity balances for cotton, sugar beets, and spring wheat. The commodity balances are of the form:

$$\sum_i \Big(\sum_k \Big(\sum_m X_{ikm}\, cx_{ikmc} + \sum_n Y_{ink} cy_{inkc} + \sum_m Z_{ikm} cx_{ikmc}\Big) - PN_i cp_{ic}\Big) - E_c \geq 0 \qquad (2.22)$$

where all variables are defined in equation 2.21 except c = 4,10,12 (see footnote 1, p. 178).

The export restraints are of the form:

$$\sum_i E_{jc} \geq EX_c \qquad (2.23)$$

c = 1,2,...,17 for the commodities (see footnote 1, p. 178),
j = 1,2,...,30 for the market regions,

where:

E_{jc} is the export level of commodity c from market region j; and
EX_c is the national export level of commodity c stipulated;

and the imports are of the form:

$$\sum_i E_{ic} \leq IM_c \qquad (2.24)$$

c = 1,2,...,17 for the commodities (see

footnote 1, p. 178),
$i = 1,2,\ldots,223$ for the producing areas,

where:

E_{ie} is the net export level for commodity c from producing area i; and
IM_c is the national import level of commodity c stipulated.

Each of the above variables is also regulated by the nonnegativity restraints consistent with the model formulation as follows:

$$X_{ikm}, Y_{ikn}, Z_{ikm}, L_{ip}, DWH_i, IWH_i, DPP_i, IPP_i, FLG_i, FP_i, EL_i, WB_w, WT_w, WI_w, WD_w, WX_w, WE_w, PN_i, T_{tc}, E_{jc}, EC_i, EL_i \geq 0 \qquad (2.25)$$

Chapter Three

Determination of Coefficients

QUANTIFYING the interactions defined in the model represents the most time-consuming task associated with developing the model. The availability of the resources--land and water--for allocation to the endogenously determined uses must be quantified. The crop and livestock production activities must be delineated and their interaction coefficients determined. The demand sector needs to be developed to drive the model, and the transportation alternatives need to be delineated with costs quantified to allow for the interregional interactions. The following subsections of this report outline the procedures and the data sources used in developing the above interactions for the model.

The Land Base

The land base represents the major constraint on the productive capacity of the system. The number of acres of dryland and irrigated cropland for use by the endogenous crops,[2] nonrotation hays, and nonrotation pastures are determined by aggregating the county acreages as determined for the "National Inventory" [8].

Land base for the endogenous crops

The "National Inventory" [8] reports the acreage of privately owned land by use and by agricultural capability class, as determined from a two percent sample of all private lands in the nation. There are eight major capability classes with classes two through eight further subdivided to reflect the most severe hazard which prevents the land from being available for unrestricted use. The four hazards or subclasses reflect susceptibility to erosion (e), subsoil exposure (s), drainage problems (w), and climatic conditions preventing normal crop production (c).

The county acreages are aggregated, for dryland and irrigated uses, to the 223 producing areas by the 29 capability class-subclasses. The 29 capability classes are aggregated to give nine land groups that exhibit a range in erosion hazard, yield, and farming alternatives (Table 3.1). The land base used for the endogenous dryland or irrigated crops represents the sum of the acres in the component land classes of the "National Inventory" [8] designated as being used for row crops, close-grown crops, summerfallow, rotation hay and pasture, temporarily idled cropland, and land used for fruits and vegetables with an adjustment for the land used by the exogenous crops as described in the crop production sector.

Projected increases in irrigated lands in the western United States are added to the irrigated acreages in each of the relevant producing areas (Table 3.2). Only those irrigation projects that have been approved for construction before 1980 are considered. The

Table 3.1. Land class and subclasses aggregated to the nine land groups.[a]

Land Group	Inventory class-subclass	Land Group	Inventory class-subclass
1	I	6	IVe
2	IIe	7	IVs, IVc, IVw
3	IIs, IIc, IIw	8	all of V
4	IIIe	9	all of VI, VII & VIII
5	IIIs, IIIc, IIIw		

[a] Inventory classes and subclasses are as defined by the Soil Conservation Service for the "National Inventory" [8].

projected increase in acreage is weighted to the relevant land classes based on the proportion of the irrigated acreage presently in each group as determined from the "National Inventory" [8]. A corresponding number of acres is removed from dry cropland and pasture in proportion to their acreages in the area as indicated in the inventory. The total dryland and irrigated acreages by each of the nine land groups are reported in Table 3.3.

Table 3.2. Increases in acres of irrigated land occurring before 1980 by producing area.

Producing area	Acres	Producing area	Acres
99	392,500	184	100
108	5,500	185	38,000
109	129,600	187	56,300
110	140,000	189	5,300
111	5,600	191	119,800
127	16,000	192	597,100
138	500	193	6,300
140	62,500	194	3,500
154	2,000	195	500
157	49,600	199	17,000
160	6,200	200	28,000
163	15,700	201	34,400
164	18,900	208	184,317
165	800	209	162,317
167	74,150	210	143,966
168	62,650	213	7,350
169	33,500	216	6,900
181	58,500	219	5,000
182	400	223	7,350

Source: U.S. Dept. Interior [105].

Acreage available for the noncultivated hays and pastures

The noncultivated land base is divided into three land use categories based on the acreages from the "National Inventory" [8]. Dryland nonrotation pasture and rangeland are combined to give an upper bound for the improved

Table 3.3. Total dryland and irrigated acreages in the nine land groups.[a]

Land Group	Dryland acres (1000)	Irrigated acres[b] (1000)
1	23,458	5,632
2	76,672	7,257
3	73,748	4,796
4	65,598	3,648
5	45,838	4,120
6	29,034	1,410
7	10,738	1,168
8	305	14
9	12,829	287
Total	338,220	28,332

[a] Represents the total acres available for use by the endogenous crops.

[b] Includes only those acres under irrigation in the regions encompassed by the water supply regions, Figure 2.5.

or managed pasture activity by producing area. Irrigated, improved pasture acreages are obtained from the irrigated nonrotation pasture and rangeland categories.

The dryland and irrigated noncropland hay lands are aggregated to provide upper bounds for the dryland and irrigated permanent hay activities in the model. These acres represent wild hay and other hayland which is continuously harvested except for infrequent interruptions to reestablish or improve the stand.

The third permanent-use category represents the forest land grazed category from the "National Inventory" [8]. This land represents the relatively low yielding woodlands pastured on farms as well as the large tracts of forested lands under private control. The acreage in each of the permanent roughage categories is given in Table 3.4.

The Water Sector

This section outlines the determination of the water supplies, the prices associated with the water supplies, the natural flow and interbasin transfers, and the nonagricultural water requirements (Figure 3.1). The crop and livestock water use coefficients are developed in their respective sections of the report.

Water supplies

The water supply in each water supply region is a function of the total reservoir storage and the mean annual runoff in the region (Table 3.5). First, the total storage

Table 3.4. Acres of the permanent roughage crops by producing area.

Producing area	Permanent pasture dryland	Permanent pasture irrigated	Permanent hayland dryland	Permanent hayland irrigated	Forest grazed
			(000 acres)		
1	25.7		96.9		6.0
2	25.6		88.2		7.8
3	81.7		212.8		2.7
4	23.1		102.1		2.0
5	15.9		22.1		3.2
6	88.9		110.2		13.8
7	263.3		211.5		126.0
8	124.5		123.9		29.4
9	17.4		51.4		2.6
10	291.9		299.1		103.1
11	318.9		160.8		200.7
12	664.3		376.3		125.8
13	21.5		12.0		0.0
14	237.7		157.1		49.7
15	467.0		281.7		134.6
16	177.9		93.1		56.7
17	24.0		38.1		2.1
18	509.9		301.8		119.7
19	209.0		38.1		17.6
20	706.2		399.5		169.2
21	1,382.3		281.7		394.2
22	224.6		102.2		217.1
23	244.2		152.1		49.4
24	598.2		200.9		169.7
25	611.8		148.1		181.4
26	1,006.2		234.0		421.7
27	532.9		105.8		358.2
28	260.0		9.7		101.1
29	154.1		12.7		40.6
30	579.1		87.2		235.5
31	1,291.8		315.4		541.2
32	108.0		55.2		108.9
33	250.7		59.5		121.9
34	106.3		46.5		34.8
35	325.6		110.7		124.6
36	465.4		88.7		115.1
37	131.3		67.6		29.3
38	946.8		215.5		382.5
39	1,121.1		278.5		679.0
40	225.2		23.4		53.8

Table 3.4. (continued)

Producing area	Permanent pasture		Permanent hayland		Forest grazed
	dryland	irrigated	dryland	irrigated	
		(000 acres)			
41	363.4		63.9		143.8
42	379.5		29.7		135.7
43	426.7		94.0		161.0
44	1,929.9		190.5		395.6
45	1,505.6		220.6		768.5
46	1,052.3		74.9		368.7
47	859.5		91.5		425.3
48	989.8		124.1		279.3
49	1,794.4		212.7		589.5
50	986.3		106.9		551.6
51	723.2		95.3		571.9
52	798.5		70.7		968.2
53	1,763.3		314.8		722.2
54	1,295.6		100.4		823.7
55	352.1		49.1		92.3
56	1,460.2		128.8		600.1
57	779.7		104.0		286.1
58	1,144.2		127.0		459.8
59	606.1		19.7		1,652.6
60	2,262.6		10.7		2,342.8
61	442.6		14.3		1,021.5
62	1,108.3		6.2		1,969.3
63	170.5		2.1		363.2
64	382.9		209.5		280.6
65	237.4		55.2		61.0
66	110.5		2.5		34.3
67	595.0		36.9		165.9
68	698.8		52.7		484.9
69	1,025.3		51.3		412.3
70	1,554.2		161.0		1,004.6
71	654.3		88.6		395.8
72	722.1		112.4		308.4
73	597.3		79.3		321.2
74	1,812.4		182.0		3,326.8
75	558.3		26.8		533.9
76	1,793.0		74.7		1,710.3
77	595.5		19.3		835.3
78	498.4		19.6		605.1
79	553.6		47.0		1,788.2
80	1,068.0		87.9		877.8
81	318.4		25.7		323.0
82	1,117.7		48.4		2,085.8
83	466.3		24.1		342.4
84	190.7		5.4		776.9
85	571.6		10.3		993.1

Table 3.4. (continued)

Producing area	Permanent pasture		Permanent hayland		Forest grazed
	dryland	irrigated	dryland	irrigated	
	(000 acres)				
86	131.2		2.0		227.1
87	1,004.1		85.5		3,764.4
88	829.7		26.0		2,171.0
89	65.8		26.7		49.3
90	740.6		79.5		717.6
91	99.5		113.2		168.3
92	439.9		117.0		447.4
93	376.8		57.3		261.4
94	817.9		111.1		514.5
95	17.0		39.9		12.9
96	985.9		353.9		726.4
97	889.9		217.5		169.7
98	1,842.7		550.4		662.1
99	3,790.6		1,034.8		26.9
100	1,213.0		269.6	0.1	44.6
101	509.8		41.7	0.4	44.4
102	1,285.3		38.3		501.4
103	1,161.4		87.4		506.7
104	1,061.2		51.2		455.1
105	631.6		101.3	0.2	190.0
106	759.4		42.2		127.8
107	719.1	1.7	55.6	0.8	40.7
108	841.4		37.6	0.4	49.2
109	6,065.1		136.6	9.9	31.1
110	2,399.3		50.0	28.9	47.5
111	5,646.1	0.2	76.5	18.5	55.6
112	2,187.0		227.3		755.4
113	1,271.4		197.5		722.1
114	2,976.1		344.6		2,521.6
115	542.7		18.9		166.2
116	1,699.6		120.1		115.9
117	3,719.9		289.4		454.3
118	4,504.1		70.7	3.5	20.1
119	4,307.0		99.3	5.0	44.0
120	1,637.5		3.8		657.3
121	1,199.8		13.2		713.2
122	5,690.2		22.9	0.4	1,539.8
123	1,760.2		10.3		123.0
124	1,525.6		1.7		287.0
125	4,388.0		267.8	0.1	4,452.5
126	1,732.5		86.9		2,286.9
127	12,540.3	12.8	22.9	2.7	1,198.3
128	3,353.6		117.8		559.1
129	6,495.5	15.5	42.6		950.9
130	2,228.6		7.4		1,064.4

Table 3.4. (continued)

Producing area	Permanent pasture		Permanent hayland		Forest grazed
	dryland	irrigated	dryland	irrigated	
	(000 acres)				
131	10,843.5	22.2	1.7	3.3	1,470.0
132	871.3		39.8		1,986.4
133	2,853.6		66.9	0.4	3.049.7
134	2,214.3	12.9	73.9		987.6
135	1,419.4	2.3	69.7	2.4	1,927.6
136	4,211.6	26.3	49.6		2,280.1
137	11,834.3	32.4	1.3		101.7
138	1,964.8	37.0	2.0		0.0
139	6,347.3	18.9	0.0	3.0	239.0
140	1,476.4		245.6		49.2
141	5,313.0		478.2	3.7	70.7
142	11,969.0		1,319.9	4.5	62.0
143	2,020.1		139.9	1.6	7.2
144	6,024.9		852.7	0.9	111.0
145	2,453.6		67.5	7.2	67.1
146	7,126.0		253.8	33.1	163.2
147	8,267.2		370.8	89.6	833.3
148	2,394.7	1.5	70.4	13.6	13.8
149	9,371.5	33.4	207.5	45.3	417.5
150	6,211.3	0.1	137.2	131.7	101.2
151	5,518.2	29.9	80.4	112.5	108.5
152	6,809.4	14.5	196.5	61.5	499.7
153	2,297.8	61.7	72.5	122.8	233.3
154	6,743.3	5.8	42.6	253.2	588.6
155	3,927.4	10.6	55.9	34.4	163.9
156	2,703.7	36.4	89.4	83.9	417.0
157	2,659.7	213.3	47.6	252.2	309.1
158	46.0	2.1	25.2	4.6	345.2
159	1,646.2	160.9	145.6	200.0	1,943.9
160	11,762.7	33.4	71.2	642.6	437.3
161	7,083.7	61.0	81.3	92.6	543.2
162	8,705.6	45.3	36.2	112.0	1,301.2
163	1,711.1	28.9	13.5	93.0	694.3
164	781.8	50.9	0.0	124.1	976.2
165	330.0	64.0	1.0	69.0	390.4
166	1,250.1	213.8	0.0	214.0	238.6
167	309.6	58.7	10.8	21.2	383.3
168	2,749.3	81.3	15.4	57.6	1,002.2
169	5,391.6	37.9	0.0	48.0	3,300.9
170	1,995.1	0.0	0.0	0.9	17.3
171	7,499.2	3.5	2.4	8.8	156.0
172	1,090.1	5.8	0.0	0.0	0.0
173	2,473.2	77.3	0.4	7.4	0.0
174	4,902.0	16.0	0.4	22.0	902.5
175	5,838.8	21.8	0.4	19.5	0.0

Table 3.4. (continued)

Producing area	Permanent pasture		Permanent hayland		Forest grazed
	dryland	irrigated	dryland	irrigated	
	(000 acres)				
176	12,297.7	4.9	0.0	2.6	428.3
177	6,916.3				85.6
178	8,163.4	6.1	1.5	4.9	951.7
179	7,343.3	4.4	0.8	6.7	805.1
180	2,530.1	0.8	0.0	2.2	57.4
181	3,849.3	0.0	4.7	341.1	171.0
182	1,450.2	0.0	0.0	108.4	850.0
183	1,822.6	0.0	1.5	19.2	757.4
184	638.0	86.8	52.5	64.9	311.1
185	3,682.5	282.6	59.3	148.7	302.0
186	2,077.6	8.3	40.5	140.8	386.7
187	1,656.5	0.0	5.3	89.0	1,148.3
188	2,014.5	0.0	2.7	58.4	992.7
819	193.1	1.1	120.6	4.1	457.3
190	1,590.9	0.4	53.4	3.9	1,103.7
191	4,028.5	180.1	42.2	86.1	791.0
192	3,561.8		89.2	134.1	1,857.0
193	1,385.7			88.5	757.9
194	3,469.6		73.2	34.8	1,646.5
195	2,134.9		5.0	23.0	608.9
196	2,270.6			94.8	448.0
197	179.7		53.3	5.0	27.9
198	77.4		31.6		71.0
199	25.3				86.5
200	156.0		11.8		182.0
201	304.2		140.7	28.4	912.0
202	16.6		7.4		
203	4,144.1	128.8		208.1	99.6
204	829.6	13.9		19.8	76.3
205	83.0	24.5		5.7	5.3
206	1,855.9	124.2		70.2	94.9
207	634.9	48.7		5.4	38.0
208	2,012.7	284.5	51.0	270.8	2,608.2
209	59.5	2.5	0.8	1.0	568.0
210	1,138.1	93.3	6.6	146.3	700.8
211	3,144.5			10.2	1,280.4
212	993.8	3.0	74.7	124.2	1,651.9
213	1,115.7	40.4	39.5	4.2	897.8
214	7,562.4	7.2		5.7	6,358.3
215	4,110.6	6.1		4.9	1,491.2

Table 3.4. (continued)

Producing area	Permanent pasture		Permanent hayland		Forest grazed
	dryland	irrigated	dryland	irrigated	
			(000 acres)		
216	5,893.1	4.1	1.9	13.0	2,394.3
217	3,730.0	18.4		4.0	1,117.9
218	8,553.8	7.0		0.4	482.1
219	301.2			16.9	63.2
220	875.2	7.5		66.9	32.0
221		2.1			
222	922.2	10.4	14.7	4.9	630.2
223	1,693.3	15.3	19.1	0.6	1,122.0
Total	476,101.8	2,969.4	222,376.1	5,541.8	136,339.0

SOURCE: "National Inventory" [8].

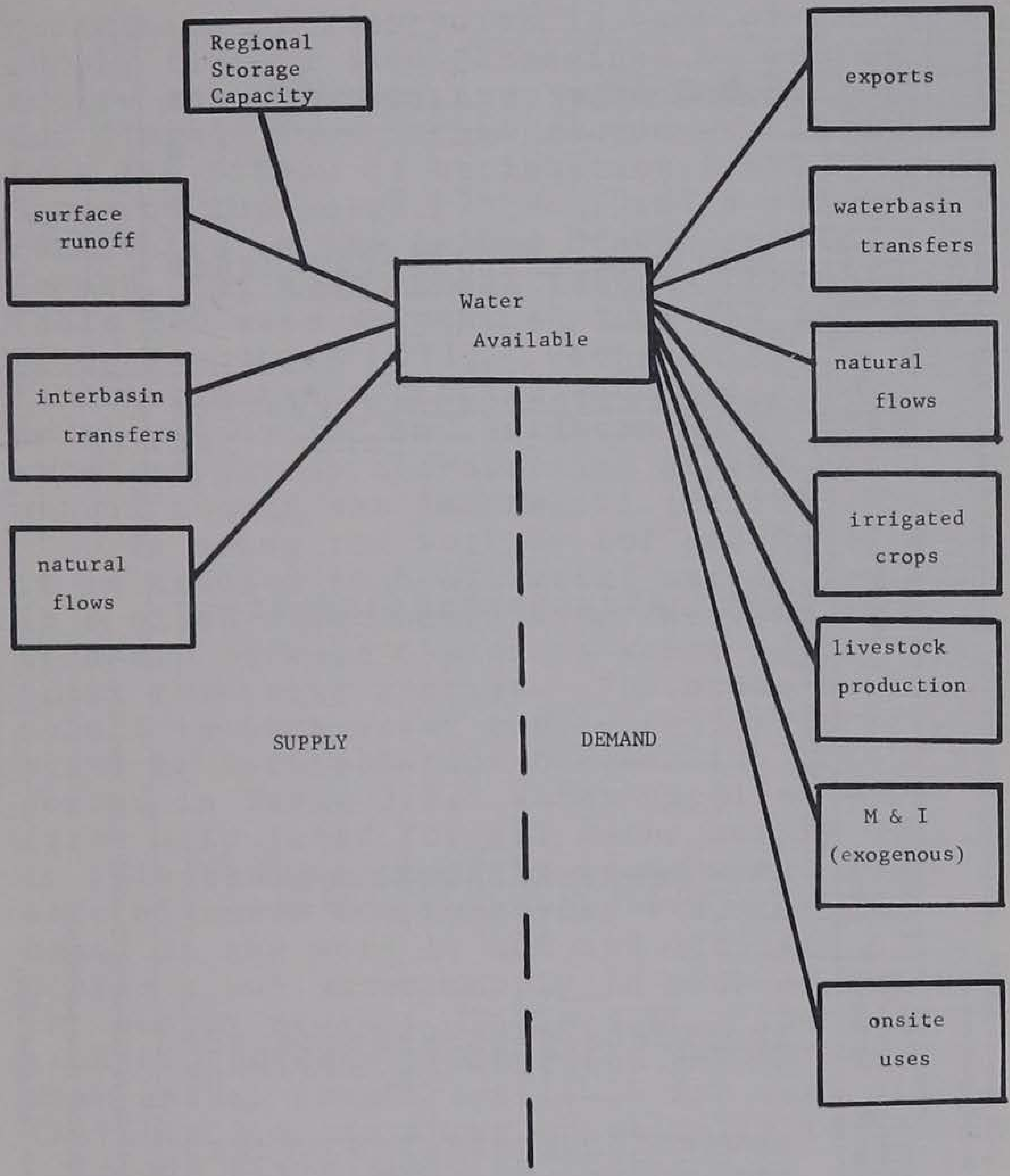

Figure 3.1. Factors affecting the availability and use of water.

Table 3.5. Mean annual runoff, total reservois storage, and estimated water supply in 2000 in the 51 water supply regions.

Region	Mean Annual Runoff[a]	Total Reservoir Storage	Estimated Net Water Supply	Region	Mean Annual Runoff[a]	Total Reservoir Storage	Estimated Net Water Supply
				(Million Acre Feet Per Year)			
1	39.20	4.80	12.18	27	2.36	4.63	1.91[b]
2	60.40	0.72	37.56	28	5.59	2.61	3.06
3	14.87	1.26	3.45	29	3.78	14.88	3.02[b]
4	27.60	1.83	5.25	30	10.00	1.76	3.36
5	7.53	12.20	7.00[b]	31	2.73	4.92	2.18[b]
6	3.25	1.13	1.86	32	1.87	2.01	1.41
7	11.16	0.98	2.66	33	3.21	37.33	2.57[b]
8	0.99	0.33	0.58	34	2.34	7.38	1.87[b]
9	29.55	9.94	16.61	35	3.98	0.18	0.49
10	23.05	0.44	13.18	36	5.75	3.37	2.74
11	7.94	4.65	6.30	37	3.82	0.15	0.50
12	9.73	5.38	7.56	38	5.53	3.23	2.69
13	29.00	1.77	10.73	39	12.02	4.23	4.71
14	2.99	3.67	2.58[c]	40	4.68	1.85	1.54
15	2.46	2.71	1.81	41	7.43	4.41	2.94
16	1.23	1.48	0.49	42	0.04	0.00	0.01
17	33.83	28.88	23.36	43	6.92	1.76	1.80
18	3.36	1.37	0.73	44	20.30	6.83	6.28
19	1.05	0.41	0.54	45	31.36	5.73	5.83
20	0.13	0.00	0.01	46	20.32	6.37	5.99
21	1.39	0.47	0.68	47	3.06	4.54	2.26[b]
22	4.03	2.08	2.30	48	2.44	7.27	1.81[b]
23	5.54	5.37	4.33[c]	49	0.90	0.00	0.51
24	6.78	2.06	3.29	50	13.56	13.35	5.40
25	2.73	22.81	2.21[b]	51	30.10	6.36	6.30
26	1.21	19.00	0.98[b]	Total	535.09	280.89	239.51

[a] Source: U.S. Water Resources Council [111, Part 6].

[b] Maximum regulated flow possible.

[c] Near maximum regulated flow.

capacities of reservoirs in each of the water supply regions were determined by adding the active conservation and joint-use capacities[3] for storage dams in the region as obtained from the Bureau of Reclamation,[4] the Army Corps of Engineers [75-94], and a survey of reservoirs in the United States in 1963 [34]. Second, the mean annual runoffs reported in Table 3.5 were determined from The Nation's Water Resources [111]. Then, using the relationship between storage and mean annual flow developed by Lof and Hardison [33], the net water supply as a proportion of the mean annual runoff was determined (Table 3.5).

In using the work by Lof and Hardison, it is assumed that all water supply regions in a given river basin have the same relationship between the gross water supply and total reservoir storage. The gross surface runoff in each water supply region is determined by interpolation between the points reported in Table 3.6. Water supplies were first calculated for all water supply regions in this manner; then the gross water supplies were adjusted for reservoir evaporation, based on the work by Lof and Hardison [33], giving a net water supply in each of the water supply regions (Table 3.5). The relationship between storage and percent of the mean annual runoff available for use, given in Table 3.6, is shown graphically for the Colorado River Basin in Figure 3.2. For example, using the higher curve and given a ratio of total storage to mean annual runoff equal to 1.003, the gross water supply would equal 0.85 multiplied by the mean annual flow. From the lower curve, the net water supply would equal 0.79 multiplied by the mean annual flow.

Table 3.6. Storage to mean annual flow ratios to make the indicated percent mean annual flow available with 95 percent probability of adequacy.

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

SOURCE: Lof and Clayton [33].

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

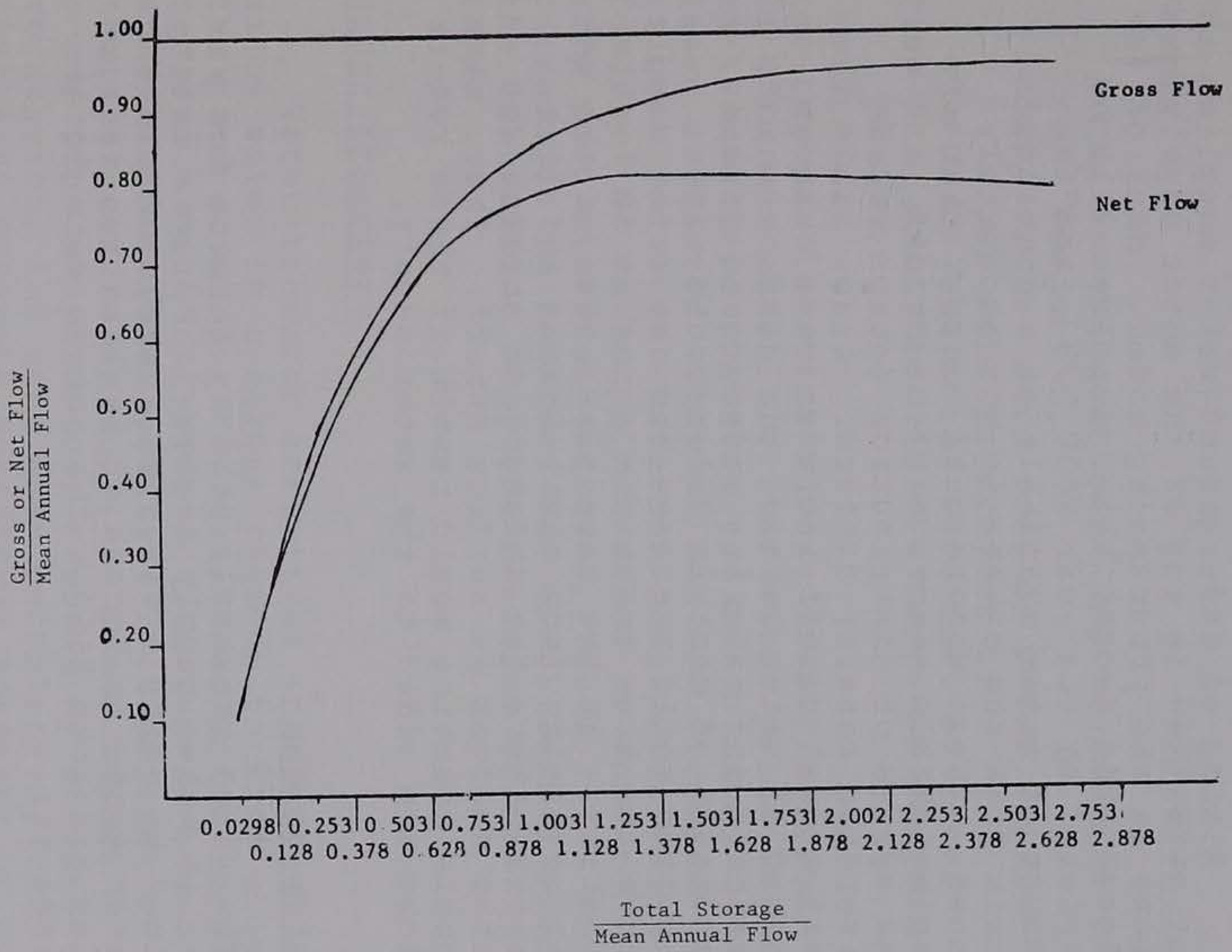

Figure 3.2. Storage and flow in the Colorado River Basin.

Mining of underground water supplies is not permitted in any of the water supply regions in the programming model. Many of the closed underground water supplies will be depleted by the year 2000 [28], and the amount of water available on a continuous basis from the others is not accurately known. Those underground sources that are replenishable remove surface runoff, and only the system of distribution (pumps versus diversion canals) differs. Also, since the mean annual runoff includes some unknown amount of water leaving the surface runoff channels and entering underground streams, inclusion of certain underground water supplies would increase the net water supply above its true amount as a result of double counting. At the same time, some of the water returning from canal losses and farm wastes enters the underground streams and later emerges as surface runoff. Thus, more double counting would result if these return flows are added to the water supply.

Water prices

The price presently paid by farmers for water in water supply region j, P_j, was determined by using a weighted average of present water costs in Bureau of Reclamation irrigation projects [65]. The prices were determined as:

$$P_j = \sum_{i \varepsilon j} (CA_i / AF_i)(WD_i) / \sum_{i \varepsilon j} WD_i \qquad (3.1)$$

$$i = 1,\ldots,116$$
$$j = 1,\ldots,51,$$

where:

CA_i is the cost per acre to farmers in project i;
AF_i is the acre feet of water applied per acre in project i;
WD_i is the total acre feet of water delivered to the farms in project i.

For regions in which Bureau of Reclamation data is not available, the water price in the most immediate upstream region is used. These estimated water prices are increased to account for farm waste and deep percolation to give the water prices based on cost per acre foot of water consumed, Table 3.7. No correction is required for canal losses since the deliveries, WD_i, are measured at the farm.

Water transfers

Water transfer activities are defined to allow water in upstream regions to flow along the natural slopes to downstream water supply regions. Each of these activities is bound at a maximum level equal to 70.0 percent of the upstream water supply. Since losses occur from evaporation, removal by natural vegetation, and some deep percolation, this restraint prevents downstream movement of water with 100.0 percent efficiency. The costs associated with these natural flow transfers are set at a level such that the upstream water price plus the transfer cost is greater than the price of water in the receiving region. For some of these activities, the cost

Table 3.7. Present prices paid by farmers for water in the 51 water supply regions.[a]

Region	Dollars Per Acre Foot	Region	Dollars Per Acre Foot
1	2.04	27	8.65
2	4,01	28	2.30
3	2.29	29	5.13
4	2.29	30	2.13
5	2.94	31	2.52
6	2.04	32	10.74
7	2.29	33	3.06
8	2.51	34	2.67
9	2.63	35	8.85
10	2.05	36	6.10
11	1.83	37	3.05
12	2.73	38	3.05
13	1.91	39	6.10
14	5.88	40	6.10
15	30.28	41	4.22
16	57.96	42	4.22
17	8.32	43	11.58
18	3.05	44	4.22
19	2.47	45	11.58
20	2.47	46	6.10
21	4.13	47	2.20
22	3.11	48	8.28
23	1.50	49	8.28
24	2.58	50	8.28
25	0.85	51	8.28
26	3.87		

SOURCE: Statistical Reporting Service [65].

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

would be zero if water in the upstream region is priced higher than water in the downstream region. This procedure is included to force regions to use locally available water before using the upstream water. This guarantees that all water used in the region be priced at a level at least equal to local water.

Existing interbasin transfers are simulated by transfer activities for those projects shown in Table 3.8. Due to the fixed nature of the facilities and since present water prices reflect their variable cost, no cost is directly attached to the transfer, and an upper bound set at the projected capacity of the project to transfer water in the year 2000 controls the level of flow.

One water export activity is defined to transfer water in accord with the Mexican Treaty of 1944 [55]. The lower bound on this activity is set at 1.5 million acre feet, and the water is transferred from water supply region 26 (the Lower Colorado basin). Another activity allows for the transfer of 1.1 million acre feet from water supply region 33 (the Dakotas) to the Souris-Red-Rainy River basin as is projected with the completion of the Garrison diversion project [38]. A depletion activity is defined for water supply region 29 (northern Montana) to account for the expected increased depletion of the Milk River by Canada in the year 2000 [38].

Unbounded desaltation activities are defined for all sea coast water supply regions to allow for augmentation of the water supply. The price of $100.00 per acre foot placed on these activities approximates the best available estimates of the cost of large-scale desalting schemes under present technologies [27].

Table 3.8. Existing interbasin water transfers and the maximum amount of water transferable in 2000.

Project	Million Acre Feet Transferable
Colorado-Big Thompson Project	.337
Boulder Canyon Project	4.400
Platte-Niobrara Subbasin to Kansas River Subbasin	.190
Canadian River Subbasin to Colorado River Subbasin	.051
Central Arizona Project	1.135

Sources: Missouri Basin Interagency Committee [36-38]; Pacific Southwest Interagency Committee [55]; and Upper Colorado Region Interagency Committee [73, 74).

Nonagricultural water uses

Per capita water consumption for recreation, municipal and industrial uses, and rural domestic and thermal electric power are assumed equal to the estimates in the Type One Studies 6, 7, 36, 38, 41, 50, 51, 52, 53, 54, 55, 56, 73, 74, 108, 109, 110 . These projected regional demands are then multiplied by the projected population and the total subtracted from the available water supply in the region (Table 3.9). On-site

Table 3.9. Water use for onsite needs, exogenous crops, exogenous livestock, and municipal and industrial uses in 2000.

Water Region	Exogenous crops	Exogenous livestock	Onsite needs	Municipal-Industrial	Water Region	Exogenous crops	Exogenous livestock	Onsite needs	Municipal-Industrial
1	8			2,300	31	140		75	69
2	19			576	32	76	1	48	892
3	6			1,107	33	12	8	102	551
4	209	1		983	34	34	2	74	254
5	356			225	35	1	1	17	394
6	310			109	36	7	1	154	226
7	86			447	37		5	276	1,124
8				9	38		1	60	98
9	8			421	39	2			1,253
10	15			137	40	21	2		344
11	155	1		188	41	1			367
12	559	2		284	42	14			269
13	51		474	124	43	2			182
14	333	1	47	1,603	44	9	1		3,737
15	787		21	288	45	7			3,008
16	1,267	1	55	4,284	46	52			494
17	8,719	3	751	1,682	47	118	1		367
18	3,135	1	77	309	48	298	3		855
19	1		315	158	49	28			872
20			24	10	50	610	7	107	4,376
21			97	65	51	695		120	11,641
22	17	2	840	801					
23		1	112	639	Total	18,645	56	4,797	51,322
24	15	1	41	78					
25	28	1	45	361					
26	178	1	261	478					
27	206		324	979					
28	2	1	51	223					
29		1	51	146					
30	50	1	72	942					

uses are determined from the same sources and reflect the requirements in 2000 as an additional need over the present levels (Table 3.9). Present water supplies reflect the levels of use of water for onsite needs consistent with present demands; thus adjustments are needed only for the increased requirement.

An example of the water sector

The Lower Colorado River basin provides an opportunity to exhibit all the interactions of the water sector. The physical transfer network involves natural flows, interbasin transfers, and the export activity (Figure 3.3). The only option not included is the possibility for desalting water which would provide an additional input of water to a region adjacent to ocean water. Adding the demand activities, water uses, to the flow network provides the complete interaction within this basin (Figure 3.4).

Crop Production Coefficients

Activities representing the production of the endogenous crops are defined on each land class in each producing area of the programming model. These activities represent crop management systems incorporating a rotation of from one to four crops, covering from one to eight years, with a given conservation treatment and a given tillage practice (Figure 3.5). The crop rotations defined in each producing area are selected from 330 unique rotations developed from the Soil Conservation Service Questionnaire (Appendix A).

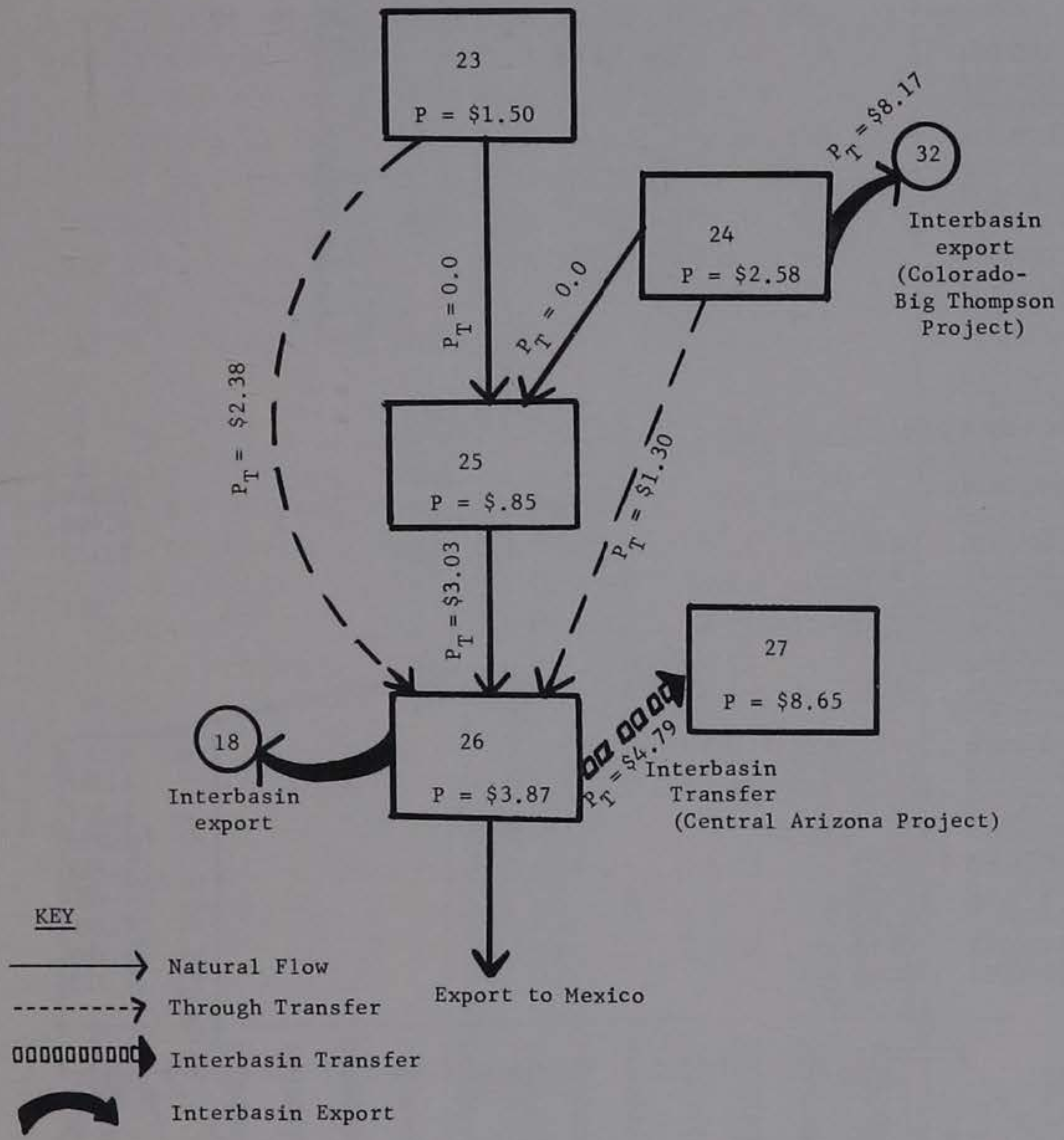

Figure 3.3. The conceptual flow system of the Colorado River Basin.

column codes / row codes	OBJ00001	WTR00023	WTR00024	WTR00025	WTR00026	WTR00027	WTT00023	WTT00024	WTT00025	WTT00026	WTR00018	WTR00032	Bound level
RHS →		≥0	≥0	≥0	≥0	≥0	≥0	≥0	≥0	≥0	≥0	≥0	
LVST0027						-a							
LVST0026					-a								
LVST0025				-a									
LVST0024			-a										
LVST0023		-a											
RTN00027						-a							
RTN00026					-a								
RTN00025				-a									
RTN00024			-a										
RTN00023		-a											
FXU00027						-1							b
FXU00026					-1								b
FXU00025				-1									b
FXU00024			-1										b
FXU00023[1]		-1											b
WXZZ0026					-1					-1			1,500
WTZZ2618										-1	1		4,400
WTZZ2627	4.79								-1				1,135
WTZZ2526	3.03				1				-1				
WTZZ2432	8.17							-1				1	337
WTZZ2426	1.30				1			-1					
WTZZ2425				1				-1					
WTZZ2326	2.38				1		-1						
WTZZ2325				1			-1						
WNZZ0026					-1								
WNZZ0025				-1					1				1,547
WNZZ0024			-1					1					2,302
WNZZ0023		-1					1						3,028
WBZZ0027	8.65					1							1,912
WBZZ0026	3.87				1								980
WBZZ0025	.85			1									2,210
WBZZ0024	2.58		1										3,289
WBZZ0023	1.50	1											4,325

a = the per acre or per unit water requirement of the rotation or livestock activities employed in the area.

b = the bound on the activities consistent with the acre-feet withdrawn from the region

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[1] Represents the fixed uses for population and industry, onsite uses, and exogenous crops and livestock.

Figure 3.4. A linear programming tableau of the water sector of the Colorado River Basin.

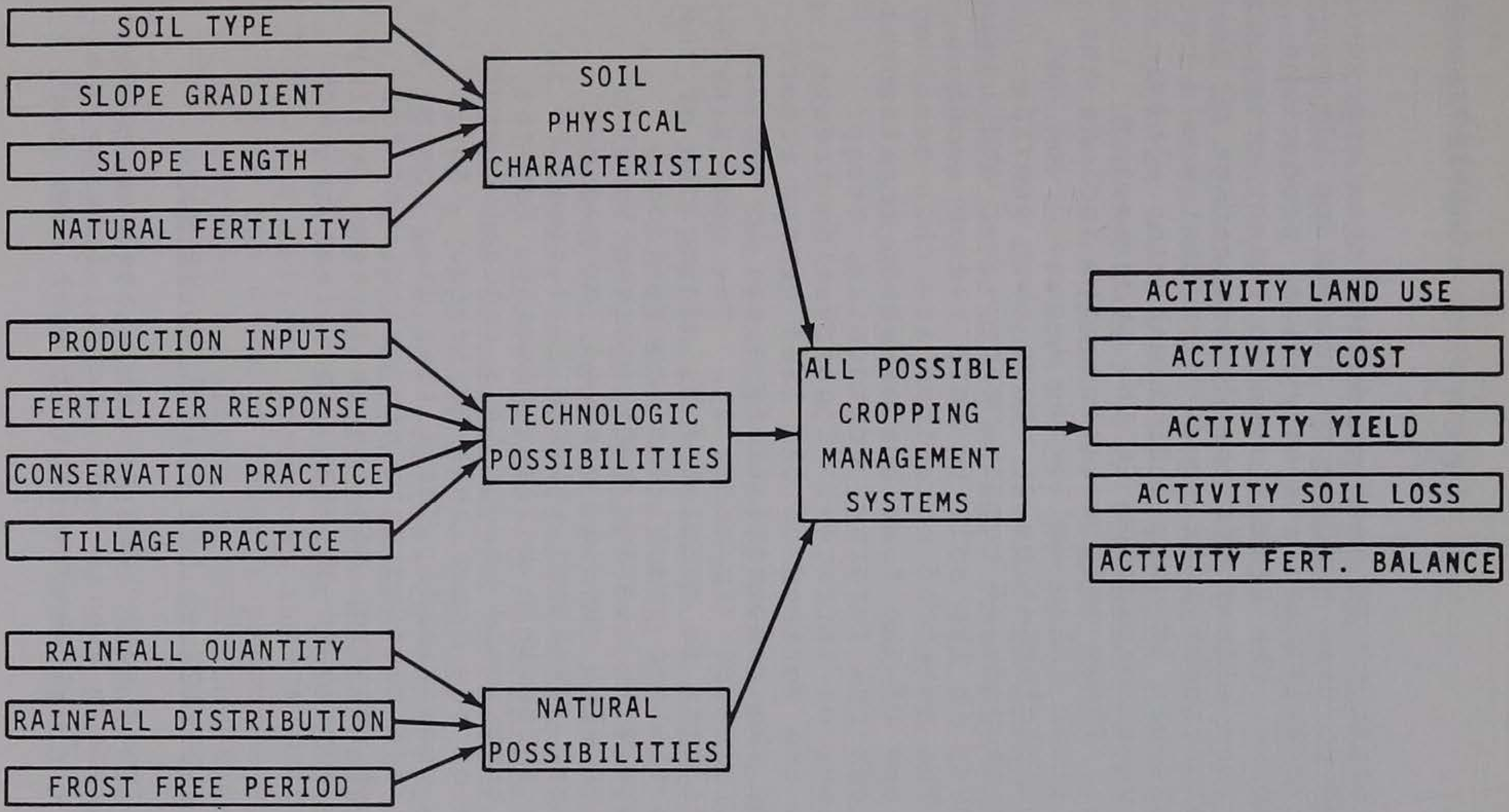

Figure 3.5. Schematic of the development of crop management system coefficients.

The rotations in each producing area are selected to give a range of production alternatives consistent with historical production patterns. The system used to select cropping rotations allows for the determination of interrelationships in production that would not be possible if only individual crop activities were considered in the programming model. These interrelationships include the fertilizer value following legume crops and the characteristics of crops that provide large amounts of residue carry-over and humus build-up in the soil to help reduce erosion.

The selected rotations are then combined with one of the four conservation treatments: straight row farming, contouring, strip farming, or terraces. Conservation treatments are defined on the land groups according to the recommendations given in the SCS Questionnaire (Appendix A). The crop management system is completed by adding one of the three tillage practices: conventional tillage with residue left, conventional tillage with residue removed, or reduced tillage. (Reduced tillage is defined to include a feasible tillage practice for the area that would result in a reduced disturbance of the upper soil horizons.) Soil loss, crop yields, fertilizer use, costs, and water use coefficients are calculated for each of the crop management systems (activities) developed on each land class in each producing area.

Determination of the soil loss levels

Gross soil loss as calculated represents the average annual tons of soil leaving the field. This measurement of soil loss does not represent the amount reaching the stream or bodies of water, since some soil particles settle out or are diverted as the runoff passes through grassed areas or onto flatter terrain, thereby changing the water's capacity to transport soil particles. Two separate procedures were used to determine the gross soil loss per acre. For the areas east of the Rocky Mountains, the "Universal Soil Loss Equation" as described by Wischmeier and Smith [116] is used to develop the gross soil loss coefficients. The soil loss equation is presented by:[5]

$$A = R \times K \times L \times S \times C \times P \qquad (3.2)$$

where:

A is the average annual per acre soil loss;
R is a rainfall erosive factor based on the local area's rainfall patterns;
K is a soil erodibility factor for the specified soil determined from its erosion under continuous fallow on a nine percent slope, 72.6 feet long;
L is the slope length factor relative to a 72.6 foot slope length;
S is the slope gradient factor relative to a nine percent slope;
C is the crop management factor which relates to a particular crop rotation and tillage practice; and
P is the erosion control practice factor which relates to the conservation practice.

Further detail on the factors and on the computational procedures used to calculate them is available from Wischmeier and Smith [116] and from the Soil Conservation Service [63]. For the areas east of the Rocky Mountains, the above variables are defined as the dominant value existing on each soil class and subclass in the area of reporting. The soil loss is then computed by Land Resource Area for each feasible combination of crop rotation, conservation practice, tillage method, and soil class defined from the SCS questionnaire (Appendix A).

The soil loss defined above for the relevant of the 29 major soil classes and subclasses is aggregated using weighting functions determined from the "National Inventory" [8] to get soil loss by the nine soil classes. The soil loss by cropping management system is weighted to the producing area from the SCS data area as follows:

$$S_{ijm} = \sum_{k} SL_{ijk} \; A_{jkm} / A_{jm} \qquad (3.3)$$

$i = 1, \ldots,$ the number of crop management systems defined in the producing area,
$j = 1, \ldots, 9$ for the land classes,
$k = 1, \ldots,$ for the parts of the 165 SCS data areas,
$m = 1, \ldots, 223$ for the producing area,

where:

S_{ijm} is the soil loss for crop management system i on soil group j in producing area m;
SL_{ijk} is the soil loss from crop management system i on soil group j consistent with SCS data area k;
A_{jkm} is the acres of tillable soil group j in the part of SCS data

area k in producing area m; and

A_{jm} is the total tillable acres of soil group j in producing area m.

These coefficients are attached to the appropriate crop production activity and reflect the severity of erosion for the conditions on which the cropping management system is defined.

For those agricultural lands in the mountain valleys and on the West Coast, the data required for the soil loss equation have not been completely developed, and an alternative procedure is used to estimate the soil loss from these lands. The SCS data questionnaire (Appendix A) asked for crop management systems consistent with the production possibilities of the SCS data area. The SCS personnel estimated the tons of soil loss associated with the crop management system on each land class and subclass defined in the SCS data area. These estimates are, for purposes of this model, treated as if they were developed from the same procedure as the estimates in the eastern area. This "assumed consistency" allows the soil losses from each SCS data area to be treated equally in weighting to the producing areas in the model. This capability is required because some producing areas overlap SCS data areas in which the soil loss is developed using the eastern procedure, and other areas have the soil loss estimated with the western procedure. Each of the activities representing the production of irrigated crops is considered to have a soil loss similar to the corresponding dryland activities. The assumptions which are needed to enable this transformation include: good management of the irrigation system; a larger quantity of residue left from crops receiving irrigation, which helps to "bind" the soil during the subsequent applications of water; and the heavier growth resulting from irrigation increases the canopy protection of the soil by the plants, reducing dislodging during rainfalls. The soil loss coefficients form the first of the bank of total coefficients required to completely define each activity.

Development of the crop yield coefficients

A unique yield is determined for each of the irrigated and dryland crops as a function of the producing area, soil class, the crop rotation, the conservation practice, and the tillage method. The development of the yields began with a series of state functions capable of projecting to the future. These are weighted to producing area functions and the projected yields adjusted for crop rotation, land class, and conservation and tillage practice.

The state projection functions, Table 3.10, are modifications of the functions developed by Stoecker [71]. For each crop the function is of the form:

$$Y(t) = Y_o(t) + (1 - .8^{X(t)})*PF(t) \quad (3.4)$$

where:

$Y(t)$ is the estimated average per acre yield of the crop in year t;

$Y_o(t)$ is the estimated average per acre yield on unfertilized land in year t, developed from a linear trend function;

$X(t)$ is the number of units of fertilizer applied to each acre of the

Table 3.10. Yield projection function data inputs by crop and state.

			Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
State [a]	Crop [b]	Code [c]	intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
ME	Corn	TOT	50.78	0.910	0.753	0.001	0.753	0.007	52.10	28.00	5.50	19.20
	C. sil.	TOT	11.26	0.065	0.453	0.008	0.653	0.007	7.99	31.80	10.00	19.60
	Lg. hay	TOT	1.65	0.011	0.324	0.001	0.324	0.015	1.40	0.00	3.50	24.60
	nLg. hay	TOT	1.22	0.010	0.324	0.001	0.324	0.015	1.50	11.60	6.30	19.30
	Oats	TOT	36.05	0.300	0.324	0.001	0.324	0.015	70.13	17.90	8.70	11.50
	Wheat	TOT	25.65	0.480	0.219	0.026	0.820	0.009	10.75	3.40	1.20	1.40
NH	Corn	TOT	50.78	0.610	0.753	0.003	0.753	0.007	58.10	28.00	5.50	19.20
	C. sil.	TOT	12.26	0.065	0.753	0.003	0.753	0.007	7.99	31.80	10.00	19.60
	Lg. hay	TOT	1.70	0.011	0.324	0.001	0.324	0.015	1.40	0.00	3.50	24.60
	nLg. hay	TOT	1.17	0.007	0.324	0.006	0.324	0.015	1.50	11.60	6.30	19.30
	Oats	TOT	31.05	0.110	0.324	0.001	0.324	0.015	70.13	17.90	8.70	11.50
VT	Corn	TOT	51.78	0.710	0.753	0.001	0.753	0.007	58.10	28.00	5.50	19.20
	C. sil.	TOT	10.26	0.055	0.753	0.001	0.753	0.007	7.99	31.80	10.00	19.60
	Lg. hay	TOT	1.76	0.012	0.324	0.001	0.324	0.015	1.40	0.00	3.50	24.60
	nLg. hay	TOT	1.31	0.016	0.324	0.006	0.324	0.015	1.50	11.60	6.29	19.30
	Oats	TOT	23.05	0.010	0.324	0.004	0.324	0.015	70.13	17.90	8.70	11.50
	Wheat	TOT	24.65	0.380	0.219	0.026	0.820	0.009	20.90	8.59	6.79	12.79
MA	Corn	TOT	50.78	0.710	0.753	0.001	0.753	0.007	58.10	28.00	5.50	19.20
	C. sil.	TOT	3.26	0.065	0.753	0.001	0.753	0.007	16.99	31.80	10.00	19.70
	Lg. hay	TOT	1.58	0.011	0.324	0.011	0.324	0.015	1.40	0.00	3.50	24.60
	nLg. hay	TOT	1.49	0.012	0.324	0.006	0.324	0.015	1.50	11.60	6.29	19.30
	Oats	TOT	26.05	0.010	0.324	0.004	0.324	0.015	70.13	17.90	8.70	11.50
	Wheat	TOT	12.65	0.380	0.219	0.026	0.820	0.009	20.90	8.59	6.79	12.79
RI	Corn	TOT	41.78	0.610	0.753	0.001	0.753	0.007	55.10	28.00	5.50	19.20
	C. sil.	TOT	1.26	0.065	0.753	0.001	0.753	0.007	16.99	31.80	10.00	19.70
	Lg. hay	TOT	1.61	0.011	0.329	0.001	0.324	0.015	1.40	0.00	3.50	24.60
	nLg. hay	TOT	1.26	0.012	0.329	0.006	0.324	0.015	1.50	11.60	6.29	19.30
	Oats	TOT	20.05	0.211	0.324	0.001	0.324	0.015	70.13	17.90	8.70	11.50
	Wheat	TOT	25.65	0.280	0.219	0.026	0.824	0.009	20.90	8.59	6.79	12.79

Table 3.10. (continued)

			Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
State[a]	Crop[b]	Code[c]	intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
CT	Corn	TOT	44.78	0.710	0.753	0.001	0.753	0.007	55.10	28.00	5.50	19.20
	C. sil.	TOT	5.26	0.065	0.753	0.001	0.753	0.007	16.99	31.80	10.00	19.70
	Lg. hay	TOT	2.13	0.012	0.324	0.004	0.324	0.015	1.40	0.00	3.50	24.60
	nLg. hay	TOT	1.34	0.016	0.324	0.006	0.324	0.015	1.50	11.60	6.29	19.30
	Oats	TOT	41.05	0.100	0.324	0.001	0.324	0.015	70.13	17.90	8.70	11.50
	Wheat	TOT	24.65	0.290	0.219	0.021	0.824	0.009	20.90	8.59	6.79	12.79
NY	Barley	TOT	28.70	0.372	0.219	0.021	0.824	0.009	27.20	7.10	4.70	13.80
	Corn	TOT	67.64	0.813	0.346	0.030	0.808	0.010	17.69	3.20	1.10	2.20
	C. sil.	TOT	10.66	0.061	0.346	0.030	0.808	0.010	2.69	3.20	1.30	2.50
	Lg. hay	TOT	1.55	0.010	0.219	0.021	0.824	0.009	1.40	0.00	3.50	24.60
	nLg. hay	TOT	1.57	0.010	0.219	0.021	0.824	0.009	1.50	11.59	6.29	19.30
	Oats	TOT	49.79	0.789	0.219	0.003	0.824	0.009	19.70	6.20	2.40	12.10
	Soybns.	TOT	15.28	0.349	0.346	0.030	0.028	0.006	14.60	1.20	4.50	5.10
	S. beets	TOT	12.15	0.100	0.543	0.030	0.808	0.010	3.50	8.50	19.10	9.80
	Wheat	TOT	27.65	0.286	1.219	0.026	0.824	0.009	10.75	3.40	1.20	1.40
NJ	Barley	TOT	3.74	0.691	0.091	0.043	0.730	0.010	48.14	3.30	1.80	3.40
	Corn	TOT	34.61	0.833	0.375	0.003	0.895	0.001	74.11	20.20	8.00	15.20
	C. sil.	TOT	9.48	0.069	0.375	0.003	0.895	0.001	9.11	25.60	9.70	21.30
	Lg. hay	TOT	2.05	0.011	0.533	0.013	0.356	0.025	1.40	0.00	3.50	24.60
	nLg. hay	TOT	0.14	0.009	0.533	0.003	0.350	0.025	2.76	11.60	6.30	19.30
	Oats	TOT	41.86	0.280	0.533	0.003	0.356	0.025	21.71	5.60	4.90	9.30
	Soybns.	TOT	21.80	0.471	0.349	0.004	0.217	0.006	12.41	1.20	3.40	9.50
	S. beets	TOT	14.15	0.100	0.533	0.013	0.895	0.001	3.50	8.50	19.10	9.80
	Wheat	TOT	20.88	0.453	0.605	0.016	0.737	0.014	20.91	8.60	6.80	12.80
PA	Barley	TOT	3.74	0.691	0.091	0.043	0.730	0.010	48.14	3.30	1.80	3.40
	Corn	TOT	20.96	0.810	0.107	0.026	0.855	0.006	79.10	17.30	5.30	9.50
	C. sil.	TOT	7.66	0.080	0.107	0.026	0.855	0.006	7.90	17.30	5.30	9.50
	Lg. hay	TOT	1.79	0.021	0.274	0.023	0.734	0.001	1.40	0.00	3.50	24.60
	nLg. hay	TOT	0.90	0.007	0.274	0.023	0.734	0.001	1.60	3.28	2.90	11.00
	Oats	TOT	15.12	0.240	0.274	0.023	0.734	0.001	57.16	4.90	2.40	4.60
	Soybns.	TOT	14.98	0.364	0.704	0.006	0.500	0.015	16.17	0.00	4.00	7.60
	Wheat	TOT	2.34	0.241	0.249	0.036	0.879	0.006	30.21	4.00	1.90	3.30

Table 3.10. (continued)

State [a]	Crop [b]	Code [c]	Unfertilized trend intercept	Unfertilized trend slope	Percent of optimal fertilization intercept	Percent of optimal fertilization slope	Percent of acres fertilized intercept	Percent of acres fertilized slope	Spillman function data A	Spillman function data lbs. N	Spillman function data lbs. P	Spillman function data lbs. K
DE	Barley	TOT	27.00	0.671	0.565	0.006	0.807	0.009	22.07	4.20	2.00	3.90
	Corn	TOT	45.92	0.880	0.922	0.001	0.782	0.011	24.83	14.00	3.20	6.10
	C. sil.	TOT	6.39	0.051	0.922	0.001	0.782	0.011	7.44	13.50	3.10	8.80
	Lg. hay	TOT	2.37	0.027	0.299	0.001	0.867	0.007	1.40	0.00	3.50	24.60
	nLg. hay	TOT	0.65	0.013	0.599	0.001	0.867	0.007	1.60	3.30	2.90	11.00
	Oats	TOT	34.81	0.312	0.594	0.001	0.867	0.007	28.67	7.00	3.30	6.40
	Soybns.	TOT	18.84	0.404	0.594	0.006	0.165	0.040	6.84	0.00	3.30	6.90
	Wheat	TOT	27.68	0.201	0.707	0.001	0.879	0.006	16.80	5.80	2.70	5.00
MD	Barley	TOT	24.26	0.384	0.437	0.017	0.836	0.006	37.05	11.10	4.80	9.20
	Corn	TOT	13.80	0.470	0.125	0.018	0.857	0.007	92.47	21.00	6.70	12.70
	C. sil.	TOT	8.51	0.011	0.125	0.018	0.857	0.007	9.24	34.00	9.20	27.10
	Lg. hay	TOT	1.78	0.022	0.575	0.023	0.836	0.006	1.40	0.00	3.50	24.60
	nLg. hay	TOT	0.60	0.010	0.575	0.023	0.836	0.006	1.65	3.30	2.90	11.00
	Oats	TOT	28.58	0.433	0.575	0.023	0.836	0.006	36.96	9.00	3.90	7.40
	Soybns.	TOT	11.50	0.411	0.704	0.006	0.858	0.006	19.25	0.00	6.40	11.10
	Wheat	TOT	12.75	0.224	0.189	0.019	0.836	0.006	38.11	11.90	5.20	9.90
MI	Barley	TOT	39.44	0.599	0.629	0.001	0.804	0.001	24.32	7.50	9.00	6.40
	Corn	TOT	45.48	0.911	0.152	0.048	0.700	0.016	33.54	15.50	3.50	6.50
	C. sil.	TOT	9.30	0.030	0.152	0.048	0.700	0.016	3.35	15.50	3.50	6.50
	Lg. hay	TOT	1.74	0.014	0.550	0.001	0.804	0.001	1.44	0.00	3.50	24.60
	nLg. hay	TOT	0.73	0.010	0.550	0.001	0.804	0.001	1.65	3.30	2.90	11.00
	Oats	TOT	40.48	0.614	0.552	0.001	0.804	0.001	29.64	13.70	6.10	8.10
	Soybns.	TOT	10.00	0.380	0.704	0.006	0.276	0.021	14.21	5.10	2.70	5.10
	S. beets	TOT	15.15	0.100	0.704	0.006	0.804	0.004	3.53	8.50	19.10	9.80
	Wheat	TOT	18.95	0.251	0.187	0.041	0.804	0.010	24.03	10.90	4.00	6.50
WI	Barley	TOT	35.16	0.664	0.591	0.016	0.466	0.002	37.45	10.10	4.40	11.60
	Corn	TOT	48.81	0.950	0.079	0.041	0.729	0.013	40.49	13.00	2.80	5.00
	C. sil.	TOT	7.04	0.090	0.079	0.041	0.729	0.013	5.82	13.90	4.30	13.80
	Lg. hay	TOT	2.25	0.018	0.591	0.001	0.466	0.002	1.45	0.00	3.50	24.60
	nLg. hay	TOT	0.94	0.022	0.591	0.001	0.466	0.002	3.65	3.30	2.90	11.00
	Oats	TOT	49.38	0.766	0.591	0.001	0.466	0.002	24.68	6.60	2.60	4.40
	Soybns.	TOT	16.21	0.283	0.500	0.008	0.169	0.008	12.97	0.80	1.30	9.10
	Wheat	TOT	17.45	0.308	0.327	0.009	0.276	0.031	24.35	5.30	3.60	8.40

Table 3.10. (continued)

State [a]	Crop [b]	Code [c]	Unfertilized trend intercept	Unfertilized trend slope	Percent of optimal fertilization intercept	Percent of optimal fertilization slope	Percent of acres fertilized intercept	Percent of acres fertilized slope	Spillman function data A	Spillman function data lbs. N	Spillman function data lbs. P	Spillman function data lbs. K
IL	Barley	TOT	24.83	0.460	0.890	0.003	0.201	0.019	22.70	0.00	0.00	0.00
	Corn	TOT	30.42	1.150	0.013	0.039	0.263	0.035	72.21	25.20	4.70	8.00
	C. sil.	TOT	8.20	0.040	0.013	0.039	0.203	0.035	7.20	25.19	4.70	8.00
	Lg. hay	TOT	1.90	0.011	0.890	0.003	0.200	0.020	1.58	0.00	2.70	15.10
	nLg. hay	TOT	1.04	0.020	0.890	0.003	0.200	0.020	1.74	20.80	3.10	6.50
	Oats	TOT	33.55	0.919	0.899	0.003	0.200	0.020	33.95	6.20	3.90	3.40
	Sorg.	TOT	28.00	0.600	0.013	0.039	0.263	0.035	45.73	21.80	4.80	2.40
	Sorg. sil.	TOT	10.30	0.030	0.575	0.009	0.263	0.035	4.57	21.80	4.80	2.40
	Soybns.	TOT	27.92	0.352	0.646	0.016	0.021	0.007	11.32	0.00	6.20	12.30
	S. beets	TOT	8.10	0.060	0.646	0.016	0.021	0.007	4.41	5.70	13.30	3.90
	Wheat	TOT	12.85	0.301	0.176	0.018	0.551	0.015	38.29	15.80	9.80	9.10
IA	Barley	TOT	28.08	0.466	0.391	0.032	0.264	0.014	20.30	0.00	0.00	0.00
	Corn	TOT	58.72	1.081	0.144	0.064	0.257	0.034	41.01	17.80	3.30	4.40
	C. sil.	TOT	10.80	0.060	0.144	0.064	0.257	0.034	4.10	17.80	3.30	4.40
	Lg. hay	TOT	2.07	0.016	0.394	0.024	0.264	0.014	1.58	0.00	2.69	15.10
	nLg. hay	TOT	1.51	0.015	0.394	0.024	0.264	0.014	1.74	20.80	3.10	6.50
	Oats	TOT	25.76	0.768	0.394	0.024	0.264	0.014	36.22	5.30	2.30	2.50
	Sorg.	TOT	43.00	0.600	0.290	0.062	0.159	0.047	45.73	21.80	4.80	2.40
	Sorg. sil.	TOT	11.60	0.030	0.454	0.029	0.040	0.013	4.50	21.80	4.80	2.40
	Soybns.	TOT	25.91	0.255	0.058	0.038	0.004	0.017	9.10	0.00	4.80	6.30
	S. beets	TOT	9.10	0.060	0.454	0.038	0.257	0.034	4.41	5.70	13.30	3.90
	Wheat	TOT	21.98	0.216	0.164	0.008	0.264	0.014	30.74	16.50	5.50	1.20
MO	Barley	TOT	16.00	0.600	0.246	0.063	0.548	0.022	21.64	6.10	2.10	3.40
	Corn	TOT	25.63	0.975	0.166	0.031	0.422	0.029	43.85	18.30	3.80	5.80
	C. sil.	TOT	7.10	0.060	0.166	0.031	0.420	0.029	4.38	18.30	3.80	5.80
	Cotton	TOT	264.20	4.630	0.080	0.006	0.640	0.019	457.27	11.50	3.70	7.10
	Lg. hay	TOT	1.10	0.017	0.552	0.059	0.348	0.024	1.58	0.00	2.70	15.10
	nLg. hay	TOT	0.57	0.013	0.552	0.059	0.348	0.024	1.32	9.40	2.80	3.80
	Oats	TOT	18.76	0.669	0.552	0.059	0.348	0.024	20.14	4.50	1.40	2.00
	Sorg.	TOT	5.71	0.769	0.089	0.031	0.507	0.014	63.66	15.20	3.30	6.80
	Sorg. sil.	TOT	10.30	0.010	0.252	0.011	0.027	0.007	6.30	15.20	3.30	6.80
	Soybns.	TOT	18.43	0.237	0.325	0.007	0.007	0.008	25.46	0.00	3.30	5.90
	S. beets	TOT	9.00	0.039	0.454	0.059	0.348	0.024	4.41	5.70	13.30	3.90
	Wheat	TOT	4.61	0.400	0.169	0.026	0.748	0.008	26.73	7.40	2.30	4.30

Table 3.10. (continued)

State [a]	Crop [b]	Code [c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
MN	Barley	TOT	26.35	0.588	0.013	0.036	0.129	0.034	19.99	5.50	2.70	1.10
	Corn	TOT	51.57	0.998	0.039	0.050	0.219	0.036	34.39	12.80	3.20	4.00
	C. sil.	TOT	8.09	0.060	0.035	0.050	0.219	0.036	3.43	12.80	3.20	4.00
	Lg. hay	TOT	2.22	0.011	0.227	0.009	0.038	0.020	1.44	0.00	3.50	24.60
	nLg. hay	TOT	1.03	0.011	0.227	0.009	0.038	0.020	1.65	3.30	2.90	11.00
	Oats	TOT	32.25	0.247	0.227	0.009	0.038	0.024	54.10	5.90	3.40	2.80
	Soybns.	TOT	20.73	0.312	0.490	0.009	0.017	0.009	6.42	0.80	2.00	2.80
	S. beets	TOT	7.01	0.070	0.488	0.009	0.219	0.016	9.76	16.40	10.10	19.70
	Wheat	TOT	9.07	0.286	0.010	0.034	0.163	0.037	20.88	5.80	2.80	1.60
OH	Barley	TOT	31.89	0.870	0.468	0.023	0.740	0.010	20.35	6.20	4.50	8.90
	Corn	TOT	57.86	1.256	0.468	0.023	0.920	0.003	25.11	17.70	1.90	3.80
	C. sil.	TOT	12.00	0.060	0.468	0.023	0.920	0.003	2.50	17.70	1.90	3.80
	Lg. hay	TOT	1.29	0.025	0.468	0.023	0.920	0.003	1.73	0.00	3.50	24.60
	nLg. hay	TOT	0.50	0.011	0.468	0.023	0.920	0.003	1.74	20.80	3.10	6.50
	Oats	TOT	35.65	0.680	0.468	0.023	0.920	0.003	37.14	8.40	4.20	8.40
	Soybns.	TOT	22.68	0.147	0.665	0.012	0.086	0.014	11.96	0.00	1.60	3.10
	S. beets	TOT	12.37	0.010	0.960	0.001	0.086	0.020	9.62	17.40	20.50	41.00
	Wheat	TOT	21.79	0.462	0.794	0.001	0.924	0.003	16.56	5.50	3.90	4.70
IN	Barley	TOT	36.48	0.612	0.623	0.001	0.664	0.012	22.26	14.80	5.30	8.50
	Corn	TOT	35.42	0.877	0.060	0.024	0.900	0.005	79.85	32.60	7.50	22.20
	C. sil.	TOT	10.10	0.010	0.060	0.024	0.900	0.005	7.90	32.60	7.50	22.20
	Lg. hay	TOT	1.43	0.013	0.528	0.020	0.938	0.001	1.58	0.00	2.70	15.10
	nLg. hay	TOT	0.71	0.020	0.528	0.022	0.938	0.001	1.74	20.80	3.10	6.50
	Oats	TOT	28.17	0.642	0.528	0.022	0.938	0.001	37.66	9.80	3.20	3.50
	Sorg.	TOT	30.10	0.400	0.122	0.043	0.047	0.046	58.71	22.50	6.90	19.20
	Sorg. sil.	TOT	12.60	0.040	0.479	0.020	0.086	0.004	5.87	22.50	6.90	19.20
	Soybns.	TOT	24.81	0.327	0.294	0.005	0.350	0.006	14.09	0.00	4.70	11.60
	Wheat	TOT	10.34	0.329	0.190	0.022	0.938	0.001	36.50	15.70	6.50	5.70

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
ND	Barley	TOT	28.58	0.459	0.039	0.048	0.092	0.024	15.26	4.70	2.00	1.00
		DRY	28.98	0.221	0.599	0.036	0.451	0.008	15.14	4.74	1.96	0.97
		IRR	42.98	0.421	0.599	0.036	0.451	0.008	15.27	4.70	2.00	1.00
	Corn	TOT	46.21	0.633	0.009	0.039	0.180	0.004	26.09	15.30	4.30	2.30
		DRY	43.42	0.658	0.461	0.034	0.262	0.005	26.07	15.30	4.36	2.32
		IRR	72.13	0.578	0.357	0.010	0.262	0.005	26.09	15.30	4.30	2.30
	C. sil.	TOT	4,90	0.010	0.116	0.013	0.102	0.025	5.01	30.20	5.00	1.30
		DRY	3.50	0.018	0.885	0.034	0.263	0.036	2.52	6.59	1.39	1.72
		IRR	7.56	0.037	0.880	0.030	0.263	0.036	7.92	26.98	1.33	0.08
	Lg. hay	TOT	0.80	0.016	0.015	0.060	0.099	0.014	1.58	0.00	2.70	15.10
		DRY	1.03	0.011	0.478	0.033	0.046	0.003	1.58	0.00	2.69	0.00
		IRR	1.43	0.031	0.638	0.030	0.506	0.502	2.07	0.00	2.60	0.00
	nLg. hay	TOT	0.81	0.008	0.015	0.060	0.003	0.014	1.74	20.80	3.10	6.50
		DRY	1.23	0.011	0.478	0.033	0.506	0.012	1.13	27.16	11.79	0.00
		IRR	1.73	0.031	0.638	0.030	0.506	0.502	1.12	11.90	14.40	0.00
	Oats	TOT	38.61	0.410	0.015	0.060	0.013	0.014	21.48	4.00	1.70	0.00
		DRY	39.77	0.175	0.649	0.048	0.211	0.013	19.07	4.04	1.71	0.00
		IRR	42.77	0.375	0.650	0.030	0.211	0.013	21.48	4.00	1.70	0.00
	Soybns.	TOT	13.13	0.251	0.528	0.127	0.089	0.007	3.30	0.30	0.70	0.00
	S. beets	TOT	12.70	0.100	0.871	0.001	0.180	0.004	4.41	5.70	13.30	3.90
		DRY	9.60	0.100	0.870	0.001	0.780	0.004	4.41	13.30	3.90	0.00
		IRR	10.10	0.120	0.870	0.010	0.380	0.040	5.73	3.40	0.00	0.00
	Wheat	TOT	19.40	0.198	0.013	0.046	0.027	0.038	8.79	2.80	1.50	0.00
		DRY	18.40	0.187	0.680	0.046	0.545	0.037	8.27	2.84	1.59	0.00
		IRR	20.90	0.687	0.599	0.036	0.545	0.037	8.80	2.80	1.50	0.00
SD	Barley	TOT	28.92	0.422	0.073	0.062	0.017	0.007	20.85	9.20	2.80	0.40
		DRY	26.55	0.290	0.693	0.051	0.094	0.007	22.73	9.20	2.80	0.40
		IRR	47.12	0.487	0.794	0.051	0.123	0.007	20.85	9.20	2.80	0.40
	Corn	TOT	33.82	0.269	0.116	0.013	0.102	0.025	50.14	30.20	5.00	1.30
		DRY	25.97	0.352	0.274	0.013	0.261	0.036	46.65	30.14	4.97	1.30
		IRR	63.74	0.530	0.357	0.013	0.960	0.017	50.14	30.20	5.00	1.30

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend intercept	Unfertilized trend slope	Percent of optimal fertilization intercept	Percent of optimal fertilization slope	Percent of acres fertilized intercept	Percent of acres fertilized slope	Spillman function data A	Spillman function data lbs. N	Spillman function data lbs. P	Spillman function data lbs. K
SD	C. sil.	TOT	4.60	0.018	0.885	0.034	0.263	0.036	2.52	6.59	1.39	1.72
		DRY	5.70	0.010	0.116	0.013	0.102	0.025	5.01	30.20	5.00	1.30
		IRR	7.56	0.037	0.880	0.030	0.263	0.036	7.29	26.98	1.33	0.08
	Lg. hay	TOT	1.53	0.011	0.939	0.036	0.045	0.003	1.58	0.00	2.69	0.40
		DRY	1.04	0.010	0.140	0.034	0.041	0.011	1.58	0.00	2.70	15.10
		IRR	1.83	0.031	0.638	0.036	0.173	0.003	2.07	0.00	2.60	0.40
	nLg. hay	TOT	1.01	0.010	0.140	0.034	0.040	0.011	1.74	20.80	3.10	6.50
		DRY	1.01	0.011	0.939	0.036	0.045	0.003	0.79	7.55	1.66	0.48
		IRR	1.93	0.031	0.638	0.036	0.173	0.003	0.93	10.90	1.00	0.40
	Oats	TOT	35.68	0.406	0.144	0.034	0.041	0.011	34.35	8.50	2.10	0.10
		DRY	32.32	0.320	0.498	0.030	0.128	0.011	34.39	8.51	2.09	0.11
		IRR	37.85	0.515	0.651	0.030	0.128	0.011	34.36	8.50	2.10	0.10
	Sorg.	TOT	33.23	0.689	0.222	0.060	0.016	0.006	20.81	8.60	1.80	0.10
		DRY	33.15	0.302	0.609	0.050	0.075	0.006	21.19	8.67	1.76	0.09
		IRR	62.62	0.465	0.609	0.059	0.077	0.006	20.81	8.60	1.80	0.10
	Sorg. sil.	TOT	6.30	0.020	0.898	0.070	0.014	0.004	2.08	5.60	1.80	0.10
		DRY	5.40	0.018	0.885	0.034	0.263	0.036	2.52	8.66	1.76	0.08
		IRR	10.56	0.037	0.880	0.030	0.263	0.036	2.08	8.60	1.80	0.10
	Soybns.	TOT	17.95	0.367	0.507	0.034	0.067	0.003	8.90	0.97	2.10	1.00
		DRY	16.90	0.329	0.195	0.050	0.020	0.002	8.42	0.90	2.10	1.00
		IRR	23.95	0.367	0.520	0.037	0.067	0.003	8.42	0.90	2.10	1.00
	Wheat	TOT	15.41	0.143	0.002	0.032	0.077	0.015	16.08	8.30	3.80	0.10
		DRY	13.73	0.127	0.445	0.031	0.139	0.022	10.60	8.35	3.80	0.06
		IRR	17.97	0.327	0.604	0.036	0.145	0.002	16.08	8.30	3.80	0.10
NE	Barley	DRY	17.18	0.179	0.062	0.045	0.239	0.025	14.05	5.23	1.35	0.00
		IRR	29.03	0.409	0.362	0.045	0.573	0.025	21.04	5.20	1.40	0.00
	Corn	DRY	26.12	0.752	0.391	0.019	0.529	0.051	56.86	27.12	3.42	0.00
		IRR	72.83	0.563	0.795	0.048	0.324	0.051	56.99	27.10	3.50	0.00
	C. sil.	DRY	8.43	0.044	0.874	0.042	0.493	0.036	2.13	5.93	3.74	0.06
		IRR	10.51	0.040	0.874	0.042	0.614	0.016	8.89	22.80	1.13	0.07
	Lg. hay	DRY	2.20	0.020	0.673	0.041	0.032	0.002	1.78	0.00	2.60	0.00
		IRR	1.25	0.018	0.673	0.041	0.414	0.027	2.27	0.00	2.60	0.40

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
NE	nLg. hay	DRY	1.00	0.020	0.673	0.041	0.032	0.002	1.30	6.71	5.49	0.00
		IRR	1.25	0.020	0.673	0.041	0.414	0.027	1.08	13.00	5.30	0.00
	Oats	DRY	20.85	0.242	0.690	0.040	0.221	0.014	41.38	10.39	2.36	0.00
		IRR	22.18	0.431	0.786	0.043	0.609	0.014	38.79	10.40	2.30	0.00
	Sorg.	DRY	55.73	0.170	0.403	0.028	0.538	0.078	21.86	17.85	2.33	0.00
		IRR	56.98	0.251	0.887	0.060	0.176	0.078	41.92	17.90	2.30	0.00
	Sorg. sil.	DRY	8.93	0.044	0.874	0.042	0.493	0.036	2.13	17.84	2.33	0.00
		IRR	14.51	0.040	0.874	0.042	0.614	0.016	4.19	17.90	2.30	0.00
	Soybns.	DRY	25.69	0.248	0.399	0.001	0.156	0.007	12.68	3.39	1.95	1.45
		IRR	25.41	0.348	0.720	0.067	0.422	0.007	14.04	3.00	1.70	0.80
	S. beets	IRR	12.20	0.120	0.830	0.030	0.980	0.001	5.73	3.40	0.00	0.00
	Wheat	DRY	18.61	0.108	0.913	0.035	0.286	0.020	13.20	5.68	1.37	0.00
		IRR	8.81	0.685	0.186	0.035	0.942	0.001	12.15	5.70	1.40	0.00
KS	Barley	DRY	24.90	0.228	0.419	0.010	0.325	0.012	27.57	16.04	3.14	1.21
		IRR	48.59	0.628	0.419	0.010	0.325	0.012	27.18	16.00	3.20	1.20
	Corn	DRY	53.13	0.535	0.134	0.008	0.696	0.063	53.75	66.63	8.62	17.94
		IRR	57.91	0.555	0.134	0.028	0.936	0.063	57.40	15.90	2.60	2.21
	C. sil.	DRY	7.92	0.047	0.732	0.045	0.700	0.064	3.78	15.77	2.43	5.85
		IRR	8.98	0.076	0.732	0.045	0.936	0.064	9.04	30.09	1.57	0.12
	Lg. hay	DRY	2.03	0.030	0.054	0.030	0.147	0.005	1.78	2.60	0.00	0.00
		IRR	2.95	0.031	0.243	0.083	0.244	0.005	2.27	0.00	2.60	0.40
	nLg. hay	DRY	1.53	0.030	0.054	0.030	0.147	0.005	0.95	23.23	2.45	2.49
		IRR	2.35	0.031	0.243	0.083	0.244	0.005	1.07	10.10	0.50	0.00
	Oats	DRY	8.39	0.065	0.753	0.037	0.497	0.012	38.80	5.00	1.00	0.00
		IRR	20.39	0.065	0.790	0.010	0.497	0.012	38.80	5.00	1.00	0.00
	Sorg.	DRY	26.52	0.236	0.746	0.050	0.431	0.056	23.84	20.66	2.48	1.69
		IRR	67.10	0.636	0.837	0.050	0.749	0.056	45.54	58.80	6.70	7.10
	Sorg. sil.	DRY	8.92	0.047	0.732	0.045	0.700	0.064	2.78	20.25	2.48	1.69
		IRR	12.38	0.076	0.732	0.045	0.939	0.064	4.55	5.09	1.57	0.11
	Soybns.	DRY	19.62	0.336	0.223	0.057	0.116	0.007	7.03	5.11	7.53	8.21
		IRR	29.62	0.536	0.220	0.057	0.116	0.007	10.35	5.10	7.50	8.20
	S. beets	IRR	11.50	0.130	0.840	0.020	0.460	0.010	5.73	3.40	0.00	0.00
	Wheat	DRY	23.52	0.175	0.572	0.105	0.422	0.031	8.92	14.24	2.92	0.96
		IRR	25.67	0.775	0.572	0.105	0.508	0.031	12.30	14.20	2.90	1.00

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
VA	Barley	TOT	40.80	0.384	0.090	0.043	0.073	0.001	44.59	9.00	3.90	7.40
	Corn	TOT	48.72	0.407	0.107	0.010	0.850	0.006	46.90	27.20	3.80	9.00
	C. sil.	TOT	11.26	0.030	0.107	0.016	0.850	0.006	4.69	27.19	3.79	9.00
	Cotton	TOT	183.23	3.240	0.704	0.006	0.050	0.015	255.29	29.30	9.60	18.20
	Lg. hay	TOT	2.27	0.010	0.107	0.016	0.050	0.006	1.58	0.00	2.70	15.10
	nLg. hay	TOT	1.20	0.001	0.107	0.016	0.050	0.006	2.56	5.50	3.60	8.30
	Oats	TOT	23.05	0.473	0.274	0.023	0.765	0.001	41.24	7.80	3.40	6.50
	Sorg.	TOT	39.42	0.670	0.366	0.020	0.200	0.002	28.85	28.70	3.90	7.30
	Sorg. sil.	TOT	10.70	0.050	0.366	0.020	0.200	0.002	2.88	28.70	3.90	7.30
	Soybns.	TOT	21.88	0.245	0.704	0.006	0.500	0.015	3.30	0.00	3.30	12.40
	Wheat	TOT	34.76	0.157	0.249	0.016	0.087	0.006	28.92	12.60	5.50	10.50
WV	Barley	TOT	14.59	0.492	0.416	0.020	0.717	0.010	39.18	7.40	4.00	7.40
	Corn	TOT	15.06	0.150	0.178	0.014	0.519	0.020	91.43	34.00	6.00	14.90
	C. sil.	TOT	8.60	0.010	0.178	0.014	0.519	0.020	9.10	28.00	4.00	10.90
	Lg. hay	TOT	1.25	0.006	0.170	0.010	0.510	0.020	1.58	0.00	2.70	15.10
	nLg. hay	TOT	0.90	0.005	0.170	0.010	0.640	0.008	1.56	5.50	3.60	8.30
	Oats	TOT	25.38	0.410	0.170	0.010	0.646	0.008	47.75	8.20	4.40	8.20
	Soybns.	TOT	15.60	0.147	0.655	0.012	0.086	0.014	11.95	0.00	1.60	3.10
	Wheat	TOT	15.81	0.249	0.409	0.005	0.834	0.004	29.57	9.20	4.90	9.20
NC	Barley	TOT	35.69	0.361	0.416	0.037	0.783	0.014	29.16	16.30	3.50	6.60
	Corn	TOT	30.63	0.659	0.248	0.039	0.894	0.006	57.82	29.50	4.40	12.90
	C. sil.	TOT	8.90	0.050	0.248	0.039	0.894	0.006	5.70	29.50	4.40	12.90
	Cotton	TOT	206.02	3.280	0.060	0.005	0.999	0.000	409.01	18.30	3.90	11.30
	Lg. hay	TOT	0.70	0.013	0.580	0.010	0.750	0.016	1.58	0.00	2.70	15.10
	nLg. hay	TOT	0.51	0.007	0.580	0.010	0.750	0.016	1.56	5.50	3.60	8.30
	Oats	TOT	45.24	0.395	0.589	0.010	0.750	0.016	25.20	10.80	3.60	6.80
	Sorg.	TOT	35.42	0.779	0.898	0.001	0.873	0.005	28.85	28.70	3.90	7.30
	Sorg. sil.	TOT	12.94	0.030	0.256	0.012	0.278	0.006	2.88	28.69	3.89	7.29
	Soybns.	TOT	12.58	0.334	0.475	0.026	0.612	0.003	15.12	0.00	3.00	6.60
	Wheat	TOT	11.30	0.372	0.204	0.028	0.822	0.011	32.18	14.20	3.60	5.70

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
SC	Barley	TOT	13.51	0.200	0.127	0.030	0.695	0.002	63.90	18.80	4.80	10.70
	Corn	TOT	7.35	0.728	0.086	0.043	0.936	0.003	52.40	19.80	3.80	10.20
	C. Sil.	TOT	6.80	0.060	0.086	0.043	0.936	0.003	5.23	19.80	3.80	10.20
	Cotton	TOT	30.85	3.520	0.086	0.043	0.936	0.003	378.11	19.80	4.40	10.70
	Lg. hay	TOT	1.21	0.019	0.621	0.002	0.695	0.002	1.02	0.00	2.60	4.80
	nLg. hay	TOT	0.10	0.007	0.331	0.020	0.409	0.015	1.72	3.20	1.90	5.30
	oats	TOT	25.23	0.360	0.621	0.002	0.695	0.002	49.21	14.80	5.10	11.50
	Sorg.	TOT	8.35	0.480	0.044	0.047	0.623	0.007	41.88	11.70	3.50	7.10
	Sorg sil.	TOT	6.50	0.060	0.044	0.047	0.633	0.007	4.18	11.70	3.50	7.10
	Soybns.	TOT	14.83	0.380	0.440	0.470	0.633	0.007	7.38	0.00	2.00	8.20
	Wheat	TOT	12.90	0.416	0.000	0.059	0.882	0.001	26.21	15.00	3.90	9.10
GA	Barley	TOT	22.03	0.200	0.562	0.001	0.406	0.027	51.88	13.50	4.00	7.80
	Corn	TOT	4.64	0.709	0.109	0.073	0.406	0.020	43.20	19.10	3.90	10.40
	C. sil.	TOT	8.20	0.080	0.164	0.022	0.406	0.027	4.31	19.00	3.90	10.40
	Cotton	TOT	180.75	3.420	0.035	0.013	0.984	0.001	331.01	15.50	3.30	9.00
	Lg hay	TOT	1.47	0.019	0.164	0.022	0.325	0.010	1.02	0.00	2.60	4.80
	nLg. hay	TOT	0.48	0.004	0.164	0.022	0.325	0.010	3.32	23.90	3.10	8.00
	Oats	TOT	27.94	0.410	0.562	0.001	0.406	0.027	47.22	15.50	3.40	9.10
	Sorg.	TOT	14.76	0.618	0.109	0.073	0.406	0.027	29.35	11.60	2.50	6.20
	Sorg sil.	TOT	9.50	0.032	0.164	0.022	0.325	0.007	2.90	11.60	2.52	6.20
	Soybns.	TOT	11.23	0.304	0.164	0.022	0.501	0.009	16.34	3.10	3.40	9.60
	Wheat	TOT	9.99	0.300	0.562	0.011	0.882	0.009	29.70	9.80	2.50	6.10
FL	Corn	TOT	6.68	0.623	0.254	0.013	0.536	0.025	50.13	17.80	5.30	9.90
	C. sil.	TOT	8.30	0.027	0.254	0.013	0.536	0.025	5.01	17.79	5.30	9.90
	Cotton	TOT	363.28	3.792	0.112	0.001	0.992	0.001	410.43	14.30	6.30	8.70
	Lg. hay	TOT	1.13	0.017	0.180	0.012	0.020	0.067	1.02	0.00	2.60	4.80
	nLg. hay	TOT	1.33	0.025	0.180	0.012	0.020	0.067	1.01	22.20	5.10	10.20
	Oats	TOT	46.60	0.450	0.018	0.001	0.020	0.067	46.63	13.70	3.60	9.60
	Soybns.	TOT	16.33	0.326	0.180	0.010	0.872	0.001	12.95	0.20	5.50	10.70
	Wheat	TOT	1.93	0.290	0.890	0.017	0.117	0.039	32.34	8.70	3.80	7.20

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
AL	Corn	TOT	0.57	0.810	0.287	0.032	0.907	0.004	37.96	14.20	3.50	6.70
	C. sil.	TOT	5.50	0.053	0.287	0.032	0.907	0.004	3.70	14.20	3.50	6.69
	Cotton	TOT	256.44	2.610	0.078	0.010	0.976	0.001	351.21	11.30	3.50	6.80
	Lg. hay	TOT	1.16	0.012	0.089	0.017	0.117	0.039	1.02	0.00	2.60	4.80
	nLg. hay	TOT	0.46	0.014	0.089	0.017	0.117	0.039	1.71	8.70	2.60	4.90
	Oats	TOT	15.42	0.428	0.534	0.017	0.117	0.039	36.41	4.60	1.80	3.40
	Sorg.	TOT	2.69	0.615	0.534	0.008	0.407	0.021	37.26	5.20	2.10	3.90
	Sorg. sil.	TOT	8.70	0.029	0.534	0.008	0.193	0.009	3.72	5.20	2.10	3.90
	Soybns.	TOT	16.29	0.229	1.351	0.034	0.522	0.012	6.30	0.00	1.70	3.20
	Wheat	TOT	5.94	0.201	0.089	0.017	0.117	0.039	32.34	8.70	3.80	7.20
MS	Corn	TOT	0.27	0.910	0.213	0.029	0.807	0.007	41.67	21.90	3.90	5.50
	C. sil.	TOT	9.10	0.039	0.213	0.029	0.807	0.007	4.10	21.90	3.90	5.50
	Cotton	TOT	314.74	4.250	0.121	0.010	0.967	0.001	369.33	11.10	2.20	1.60
	Lg. hay	TOT	1.01	0.018	0.541	0.020	0.504	0.011	1.02	0.00	2.60	4.80
	nLg. hay	TOT	0.46	0.014	0.089	0.017	0.117	0.039	1.71	8.70	2.60	4.90
	Oats	TOT	20.40	0.405	0.541	0.020	0.504	0.011	35.13	8.40	0.70	1.20
	Sorg.	TOT	4.84	0.617	0.201	0.039	0.081	0.050	39.02	14.30	2.30	3.40
	Sorg. sil.	TOT	11.10	0.013	0.062	0.012	0.129	0.017	3.90	14.30	2.30	3.40
	Soybns.	TOT	17.26	0.432	0.062	0.012	0.129	0.019	4.35	0.00	2.00	1.30
	Wheat	TOT	5.51	0.285	0.093	0.044	0.006	0.042	22.11	7.50	0.50	0.60

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
KY	Barley	TOT	24.13	0.425	0.302	0.009	0.093	0.040	31.20	0.00	0.00	0.00
	Corn	TOT	32.38	0.705	0.062	0.056	0.636	0.017	35.45	12.20	2.00	3.90
	C. sil.	TOT	11.30	0.060	0.062	0.056	0.636	0.017	3.54	12.20	2.00	3.89
	Cotton	TOT	196.45	6.540	0.062	0.056	0.847	0.004	208.09	2.60	1.10	2.10
	Lg. hay	TOT	1.74	0.020	0.302	0.009	0.121	0.050	1.02	0.00	2.60	4.80
	nLg. hay	TOT	0.93	0.018	0.302	0.009	0.121	0.050	1.11	5.50	3.60	8.30
	Oats	TOT	36.65	0.215	0.302	0.009	0.121	0.050	18.14	2.70	0.90	1.10
	Sorg.	TOT	37.00	0.500	0.578	0.016	0.600	0.005	33.27	11.70	3.80	5.70
	Sorg. sil.	TOT	12.00	0.030	0.885	0.044	0.064	0.003	3.32	10.69	3.80	5.70
	Soybns.	TOT	22.44	0.424	0.062	0.026	0.186	0.002	11.07	0.00	1.10	3.50
	Wheat	TOT	15.32	0.266	0.302	0.009	0.445	0.026	30.47	9.80	5.20	9.80
TN	Barley	TOT	24.23	0.375	0.357	0.011	0.408	0.015	28.16	7.20	4.20	3.50
	Corn	TOT	4.41	0.510	0.012	0.025	0.636	0.018	80.02	42.20	9.90	18.80
	C. sil.	TOT	6.30	0.030	0.012	0.025	0.636	0.018	10.00	36.20	7.89	14.80
	Cotton	TOT	345.37	4.450	0.019	0.004	0.820	0.008	653.78	32.00	13.00	24.80
	Lg. hay	TOT	1.52	0.015	0.331	0.020	0.409	0.015	1.02	0.00	2.60	4.80
	nLg. hay	TOT	0.15	0.007	0.331	0.020	0.409	0.015	1.72	3.20	1.90	5.30
	Oats	TOT	24.68	0.345	0.331	0.020	0.409	0.015	41.55	9.80	5.70	4.70
	Sorg.	TOT	7.89	0.614	0.186	0.047	0.228	0.055	50.00	10.60	4.60	8.80
	Sorg. sil.	TOT	8.20	0.060	0.332	0.037	0.235	0.015	4.99	10.60	4.60	8.80
	Soybns.	TOT	10.95	0.000	0.382	0.001	0.193	0.012	33.03	0.00	3.40	6.40
	Wheat	TOT	10.95	0.129	0.081	0.009	0.691	0.006	56.75	23.90	13.90	11.60
AR	Barley	TOT	20.72	0.327	0.258	0.013	0.083	0.046	21.90	0.00	0.00	0.00
	Corn	TOT	12.47	0.970	0.301	0.009	0.401	0.024	38.79	20.30	3.00	3.00
	C. sil.	TOT	4.60	0.051	0.301	0.009	0.401	0.024	3.87	20.30	3.00	3.00
	Cotton	TOT	284.57	3.720	0.159	0.018	0.848	0.009	249.82	9.50	2.00	5.60
	Lg. hay	TOT	1.84	0.021	0.194	0.013	0.440	0.019	1.02	0.00	2.60	4.80
	nLg. hay	TOT	0.91	0.015	0.194	0.013	0.440	0.019	1.41	20.80	4.40	6.90
	Oats	TOT	28.29	0.329	0.194	0.013	0.444	0.019	56.51	10.70	2.70	4.90
	Sorg.	TOT	31.31	0.257	0.105	0.008	0.192	0.015	38.88	13.30	3.00	5.80
	Sorg. sil.	TOT	9.60	0.040	0.077	0.006	0.044	0.009	10.80	13.30	3.00	5.80
	Soybns.	TOT	13.88	0.260	0.273	0.018	0.162	0.003	12.86	0.00	1.60	5.50
	Wheat	TOT	9.26	0.336	0.094	0.017	0.103	0.038	29.10	13.80	2.10	3.20

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
LA	Corn	TOT	20.38	0.875	0.394	0.026	0.615	0.014	27.72	21.70	3.30	6.30
	C. sil.	TOT	10.00	0.130	0.394	0.020	0.615	0.014	2.70	21.70	3.30	6.30
	Cotton	TOT	76.38	1.385	0.583	0.002	0.584	0.009	720.27	24.70	4.40	8.70
	Lg. hay	TOT	1.16	0.022	0.580	0.002	0.580	0.009	1.02	0.00	2.60	4.80
	nLg. hay	TOT	1.11	0.012	0.580	0.002	0.580	0.009	1.75	25.80	6.10	6.60
	Oats	TOT	40.88	0.300	0.582	0.002	0.582	0.009	21.18	14.40	1.90	3.90
	Sorg.	TOT	1.86	0.600	0.064	0.077	0.290	0.065	33.64	15.70	2.00	3.80
	Sorg. sil.	TOT	10.40	0.070	0.107	0.006	0.060	0.007	3.36	15.70	2.00	3.80
	Soybns.	TOT	15.59	0.348	0.113	0.052	0.014	0.007	9.78	0.00	3.20	6.10
	Wheat	TOT	9.26	0.330	0.090	0.020	0.103	0.038	20.10	11.63	2.01	3.01
OK	Barley	DRY	23.33	0.348	0.680	0.047	0.392	0.058	20.98	11.52	2.89	2.62
		IRR	33.23	0.448	0.680	0.047	0.392	0.058	16.71	6.10	2.10	1.10
	Corn	DRY	12.05	0.336	0.131	0.008	0.619	0.024	58.39	31.83	4.13	7.76
		IRR	54.15	0.036	0.134	0.008	0.619	0.024	51.12	31.80	4.10	7.80
	C. sil.	DRY	8.27	0.040	0.738	0.039	0.500	0.024	2.96	17.83	3.13	11.26
		IRR	11.33	0.046	0.730	0.030	0.994	0.024	5.55	32.57	2.80	0.15
	Cotton	DRY	97.02	1.200	0.180	0.012	0.345	0.026	449.26	11.49	3.27	5.85
		IRR	168.60	6.014	0.679	0.044	0.923	0.026	254.35	7.02	1.41	2.42
	Lg. hay	DRY	2.04	0.020	0.132	0.006	0.169	0.008	1.78	0.00	2.60	0.00
		IRR	1.66	0.023	0.444	0.032	0.605	0.008	2.07	0.00	2.60	1.60
	nLg. hay	DRY	1.44	0.020	0.132	0.006	0.169	0.008	1.24	35.92	4.75	9.40
		IRR	1.70	0.023	0.444	0.032	0.605	0.008	1.03	30.50	2.90	1.60
	Oats	DRY	36.68	0.230	0.715	0.041	0.498	0.031	22.69	15.81	3.25	4.58
		IRR	29.28	0.430	0.570	0.010	0.498	0.031	35.94	10.47	2.03	1.15
	Sorg.	DRY	20.23	0.243	0.194	0.014	0.374	0.055	26.57	16.81	3.65	6.91
		IRR	38.02	0.594	0.324	0.020	0.660	0.055	41.20	14.89	2.34	4.47
	Sorg. sil.	DRY	8.27	0.040	0.738	0.039	0.500	0.024	2.96	16.81	3.65	6.91
		IRR	12.23	0.046	0.730	0.030	0.994	0.024	4.12	14.89	2.33	4.47
	Soybns.	DRY	5.46	0.201	0.516	0.018	0.472	0.012	12.25	1.04	1.87	2.04
		IRR	18.46	0.301	0.510	0.010	0.472	0.012	11.10	1.00	1.90	2.00
	Wheat	DRY	22.41	0.197	0.532	0.109	0.453	0.040	6.71	9.31	2.32	2.29
		IRR	26.41	0.497	0.532	0.109	0.007	0.040	9.31	6.93	1.84	1.02

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
TX	Barley	DRY	10.50	0.180	0.554	0.010	0.245	0.037	25.13	6.44	1.48	1.75
		IRR	10.90	0.200	0.401	0.080	0.479	0.057	44.90	10.00	1.74	0.00
	Corn	DRY	23.28	0.492	0.091	0.010	0.539	0.054	15.74	11.90	3.67	4.26
		IRR	60.96	0.863	0.218	0.020	0.961	0.054	54.70	61.13	8.50	3.77
	C. sil.	DRY	5.22	0.049	0.056	0.030	0.534	0.054	2.58	4.50	1.88	4.75
		IRR	10.12	0.049	0.747	0.030	0.919	0.054	6.10	11.50	1.22	0.01
	Cotton	DRY	145.78	1.900	0.717	0.026	0.208	0.016	170.81	8.62	1.62	0.52
		IRR	191.01	3.600	0.438	0.052	0.753	0.016	291.76	10.36	0.32	0.28
	Lg. hay	DRY	1.68	0.024	0.409	0.016	0.177	0.008	1.58	0.00	1.40	0.04
		IRR	2.58	0.030	0.462	0.037	0.796	0.008	2.07	0.00	1.40	0.40
	nLg. hay	DRY	1.28	0.024	0.409	0.016	0.177	0.008	1.23	8.86	2.84	4.00
		IRR	1.33	0.030	0.462	0.037	0.796	0.008	1.07	16.72	1.42	0.04
	Oats	DRY	31.65	0.151	1.085	0.001	0.264	0.023	17.10	9.00	1.74	0.08
		IRR	2.65	0.151	0.574	0.115	0.700	0.023	57.29	6.74	1.80	0.00
	Sorg.	DRY	29.74	0.254	0.260	0.049	0.209	0.020	15.02	10.25	2.73	0.73
		IRR	60.21	0.654	0.260	0.049	0.880	0.054	34.34	31.80	3.53	1.54
	Sorg. sil	DRY	7.82	0.049	0.056	0.030	0.534	0.054	2.50	13.64	6.90	0.00
		IRR	13.92	0.049	0.747	0.030	0.919	0.054	3.43	31.79	3.52	1.54
	Soybns.	DRY	13.55	0.280	0.988	0.076	0.226	0.017	5.05	0.00	1.51	0.21
		IRR	23.25	0.380	0.988	0.076	0.881	0.053	7.04	0.00	1.75	0.00
	S. beets	DRY	13.50	0.100	0.838	0.058	0.753	0.016	4.41	4.10	1.10	0.00
		IRR	11.30	0.100	0.438	0.058	0.753	0.016	9.10	6.50	1.10	0.00
	Wheat	DRY	11.28	0.169	0.511	0.020	0.173	0.013	12.90	4.25	1.34	0.21
		IRR	7.08	0.419	0.511	0.046	0.848	0.067	28.94	5.47	0.23	0.01
MT	Barley	DRY	34.24	0.326	0.598	0.038	0.159	0.010	21.05	9.28	4.34	0.00
		IRR	49.63	0.230	0.086	0.085	0.282	0.010	30.83	9.20	4.40	0.00
	Corn	DRY	13.52	0.515	0.539	0.049	0.467	0.073	31.95	8.00	7.40	0.00
		IRR	49.78	0.515	0.218	0.020	0.560	0.073	51.91	7.97	7.37	0.00
	C. sil.	DRY	4.78	0.076	0.197	0.015	0.172	0.014	3.68	15.30	12.50	0.00
		IRR	15.09	0.036	0.526	0.036	0.619	0.041	3.89	15.31	12.52	0.00
	Lg. hay	DRY	1.20	0.030	0.267	0.010	0.083	0.005	1.58	0.00	5.00	0.00
		IRR	1.55	0.025	0.340	0.030	0.483	0.009	2.07	0.00	5.00	0.00
	nLg. hay	DRY	0.90	0.030	0.267	0.010	0.083	0.005	1.27	23.56	6.17	0.00
		IRR	1.55	0.025	0.340	0.030	0.083	0.005	1.06	19.30	5.00	0.00

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
MT	Oats	DRY	44.98	0.226	0.532	0.015	0.022	0.010	23.73	7.25	3.43	0.00
		IRR	54.23	0.476	0.999	0.015	0.130	0.010	23.89	7.30	3.40	0.00
	S. beets	IRR	7.40	0.130	0.940	0.060	0.610	0.020	9.34	12.80	0.00	0.00
	Wheat	DRY	20.39	0.197	0.562	0.037	0.293	0.021	10.43	7.22	3.45	0.00
		IRR	27.93	0.397	0.948	0.164	0.616	0.021	10.57	7.30	3.40	0.00
ID	Barley	DRY	20.82	0.130	0.605	0.023	0.411	0.030	24.16	6.50	0.00	0.00
		IRR	35.61	0.230	0.170	0.071	0.602	0.030	30.36	6.50	0.00	0.00
	Corn	IRR	61.40	0.500	0.292	0.072	0.933	0.034	33.32	22.60	2.80	0.00
	C. sil.	IRR	10.98	0.041	0.277	0.075	0.948	0.035	9.03	16.40	2.80	0.00
	Lg. hay	DRY	1.16	0.030	0.462	0.022	0.057	0.010	1.78	0.00	2.00	0.00
		IRR	1.32	0.025	0.804	0.040	0.274	0.040	2.27	0.00	2.00	0.00
	nLg. hay	DRY	1.06	0.030	0.462	0.022	0.057	0.010	1.78	13.96	3.29	0.00
		IRR	1.32	0.025	0.804	0.040	0.274	0.040	1.14	15.50	2.00	0.00
	Oats	DRY	38.30	0.193	0.907	0.036	0.348	0.017	18.92	5.63	0.00	0.00
		IRR	44.78	0.193	0.145	0.061	0.348	0.017	25.79	5.60	0.00	0.00
	Sorg. sil.	IRR	15.98	0.041	0.277	0.075	0.948	0.033	4.47	17.81	5.86	2.19
	S. beets	IRR	10.30	0.100	0.404	0.083	0.594	0.019	9.98	5.80	0.00	0.00
	Wheat	DRY	31.48	0.184	0.104	0.045	0.345	0.019	9.38	13.50	0.00	0.00
		IRR	27.07	0.084	0.404	0.083	0.594	0.019	33.44	13.50	0.00	0.00
WY	Barley	DRY	15.16	0.303	0.430	0.035	0.003	0.023	25.66	5.30	0.80	0.00
		IRR	39.70	0.383	0.430	0.035	0.465	0.022	31.82	5.38	0.86	0.00
	Corn	DRY	19.34	0.137	0.495	0.034	0.201	0.021	34.60	9.90	1.40	0.00
		IRR	42.27	0.537	0.721	0.060	0.680	0.021	38.06	9.90	1.40	0.00
	C. sil.	DRY	5.61	0.015	0.117	0.081	0.083	0.011	3.21	11.20	1.50	0.00
		IRR	7.21	0.047	0.117	0.081	0.590	0.011	8.27	11.20	1.50	0.00
	Lg. hay	DRY	0.85	0.016	0.820	0.053	0.014	0.010	1.58	0.00	1.30	0.00
		IRR	0.17	0.016	0.976	0.067	0.132	0.060	2.07	0.00	1.30	0.00
	nLg. hay	DRY	0.67	0.016	0.820	0.053	0.014	0.010	1.40	14.90	2.20	0.00
		IRR	0.87	0.016	0.976	0.067	0.132	0.060	1.10	14.84	1.31	0.00
	Oats	IRR	17.51	0.020	0.746	0.063	0.001	0.010	53.71	3.60	0.80	0.00
		DRY	14.39	0.010	0.746	0.063	0.461	0.023	41.76	3.58	0.76	0.00

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
WY	S. beets	IRR	11.80	0.120	0.945	0.060	0.685	0.030	7.32	4.60	0.00	0.00
	Wheat	DRY	6.55	0.112	0.945	0.067	0.001	0.080	13.32	5.00	1.20	0.00
		IRR	19.39	0.498	0.945	0.067	0.285	0.050	29.24	5.00	1.20	0.00
CO	Barley	DRY	22.80	0.234	0.373	0.003	0.013	0.021	28.09	4.90	1.20	0.00
		IRR	46.98	0.355	0.777	0.045	0.319	0.023	26.15	13.82	4.65	0.00
	Corn	DRY	11.39	0.320	0.533	0.014	0.305	0.022	24.50	11.80	1.10	0.00
		IRR	74.01	0.730	0.762	0.033	0.637	0.022	34.36	8.44	0.82	0.00
	C. sil.	DRY	7.34	0.048	0.379	0.017	0.332	0.024	3.17	19.20	2.60	0.00
		IRR	12.12	0.030	0.816	0.034	0.667	0.024	7.88	16.56	2.27	0.00
	Lg. hay	DRY	0.86	0.023	0.520	0.023	0.041	0.010	2.47	0.00	9.90	0.00
		IRR	1.89	0.023	0.520	0.023	0.144	0.008	2.90	0.00	9.90	0.00
	nLg. hay	DRY	0.96	0.023	0.520	0.023	0.041	0.010	1.47	14.40	2.20	0.00
		IRR	1.49	0.023	0.520	0.023	0.144	0.008	1.21	18.56	9.99	0.00
	Oats	DRY	17.08	0.092	0.973	0.042	0.027	0.010	51.15	7.10	3.10	0.00
		IRR	30.70	0.192	0.973	0.042	0.142	0.017	58.34	14.43	3.25	0.00
	Sorg.	DRY	19.96	0.250	0.827	0.070	0.047	0.005	26.02	8.39	1.66	0.00
		IRR	35.49	0.150	0.827	0.070	0.442	0.034	38.67	11.40	1.40	0.00
	Sorg. sil.	DRY	7.34	0.048	0.379	0.017	0.332	0.024	2.92	18.50	6.30	0.00
		IRR	15.02	0.030	0.816	0.034	0.667	0.024	3.87	11.40	1.40	0.00
	S. beets	IRR	12.00	0.130	0.270	0.100	0.421	0.040	7.74	4.40	5.60	0.00
	Wheat	DRY	14.51	0.146	0.270	0.108	0.047	0.014	10.69	2.36	0.82	0.00
		IRR	8.75	0.449	0.270	0.108	0.421	0.004	46.89	10.00	2.90	0.00
NM	Corn	DRY	28.43	0.116	0.181	0.014	0.348	0.010	29.44	22.30	2.80	0.00
		IRR	53.36	0.669	0.487	0.010	0.475	0.036	25.16	21.30	1.50	0.00
	C. Sil.	IRR	12.80	0.030	0.244	0.040	0.544	0.043	6.72	33.10	6.90	0.00
	Cotton	DRY	253.19	2.865	0.151	0.000	0.243	0.016	316.27	32.50	8.10	8.00
		IRR	370.99	2.865	0.522	0.000	0.709	0.016	316.27	32.51	8.11	7.98
	Lg. hay	DRY	0.79	0.011	0.799	0.010	0.592	0.069	2.14	0.00	11.20	3.80
		IRR	2.80	0.022	0,899	0.053	0.688	0.019	2.70	0.00	11.20	3.80

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
NM	nLg. hay	DRY	0.69	0.018	0.799	0.010	0.592	0.069	0.91	12.00	6.20	0.00
		IRR	1.10	0.022	0.899	0.053	0.688	0.019	1.06	14.67	5.37	0.00
	Oats	DRY	22.00	0.030	0.692	0.020	0.010	0.010	25.78	6.87	2.72	0.00
		IRR	37.90	0.200	0.900	0.042	0.140	0.010	43.47	14.17	1.91	0.00
	Sorg.	DRY	13.14	0.394	0.126	0.003	0.102	0.009	29.98	28.50	12.40	5.50
		IRR	69.18	0.405	0.360	0.003	0.729	0.060	38.48	28.46	12.39	5.50
	Sorg. sil.	DRY	7.66	0.041	0.128	0.019	0.122	0.011	2.72	14.25	6.20	2.75
		IRR	14.00	0.030	0.244	0.040	0.544	0.043	3.85	14.46	6.39	2.75
	S. beets	IRR	12.70	0.120	0.246	0.070	0.825	0.062	6.14	5.20	0.00	0.00
	Wheat	DRY	11.67	0.081	0.003	0.048	0.291	0.055	11.07	15.30	6.40	0.00
		IRR	27.51	0.281	0.246	0.070	0.825	0.102	22.41	15.30	6.40	0.00
AZ	Barley	IRR	59.20	0.291	0.172	0.038	0.712	0.034	22.86	14.40	3.10	0.00
	Corn	DRY	18.08	0.105	0.010	0.066	0.302	0.010	16.87	14.70	1.50	0.00
		IRR	53.71	0.219	0.410	0.066	0.478	0.008	37.49	14.70	1.50	0.00
	C. sil.	IRR	14.55	0.062	0.973	0.060	0.724	0.004	6.21	13.67	2.03	0.00
	Cotton	IRR	580.12	4.450	0.622	0.155	0.949	0.011	376.80	14.00	2.10	0.00
	Lg. hay	IRR	3.20	0.029	0.910	0.069	0.590	0.033	3.00	0.00	8.00	0.00
	nLg. hay	DRY	1.10	0.020	0.248	0.016	0.298	0.033	0.84	12.00	6.20	0.00
		IRR	0.60	0.029	0.910	0.069	0.590	0.033	1.34	12.00	6.20	0.00
	Oats	IRR	62.60	0.200	0.200	0.020	0.540	0.010	22.18	10.80	2.70	0.00
	Sorg.	IRR	38.90	0.400	0.994	0.076	0.972	0.029	38.34	10.60	1.90	0.00
	Sorg. sil.	IRR	16.35	0.062	0.973	0.060	0.724	0.004	3.83	10.60	1.90	0.00
	S. beets	IRR	12.20	0.140	0.837	0.041	0.964	0.080	5.32	7.00	0.00	0.00
	Wheat	IRR	30.40	0.296	0.837	0.041	0.964	0.089	33.12	20.80	3.80	0.00
UT	Barley	DRY	19.12	0.200	0.760	0.043	0.009	0.028	20.29	9.60	0.00	0.00
		IRR	27.13	0.110	0.330	0.043	0.302	0.016	47.38	9.58	0.00	0.00
	Corn	IRR	31.77	0.356	0.821	0.045	0.696	0.051	55.95	7.92	2.63	0.00
	C. sil.	IRR	10.87	0.060	0.777	0.038	0.606	0.033	8.82	13.70	0.00	0.00
	Lg. hay	DRY	1.38	0.011	0.255	0.052	0.017	0.010	2.98	0.00	10.20	3.90
		IRR	1.65	0.028	0.882	0.052	0.247	0.012	3.40	0.00	10.20	3.90

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
UT	nLg. hay	DRY	1.68	0.018	0.255	0.052	0.017	0.010	0.98	12.00	6.90	0.00
		IRR	1.45	0.028	0.882	0.052	0.247	0.012	1.17	18.98	10.26	0.00
	Oats	DRY	30.43	0.030	0.696	0.020	0.010	0.010	25.78	6.87	2.72	0.00
		IRR	41.63	0.216	0.696	0.020	0.080	0.014	41.09	5.27	3.34	0.00
	Sorg.	IRR	65.62	0.410	0.994	0.076	0.972	0.029	25.27	11.78	11.84	0.00
	Sorg. sil.	IRR	16.67	0.040	0.777	0.038	0.606	0.033	2.53	11.77	11.84	0.00
	S. beets	IRR	14.30	0.130	0.655	0.016	0.266	0.060	4.82	7.00	0.00	0.00
	Wheat	DRY	18.77	0.030	0.355	0.016	0.104	0.006	10.65	10.80	0.00	0.00
		IRR	39.15	0.130	0.355	0.016	0.266	0.006	43.80	10.76	0.00	0.00
NV	Barley	IRR	17.73	0.218	0.728	0.024	0.539	0.034	44.41	11.40	2.00	0.00
	C. sil.	IRR	11.74	0.050	0.253	0.093	0.799	0.053	6.95	30.50	4.10	0.00
	Cotton	IRR	305.12	4.450	1.622	0.155	0.949	0.011	376.80	14.00	2.10	0.00
	Lg. hay	IRR	2.61	0.018	0.416	0.064	0.180	0.007	2.50	0.00	10.20	4.50
	nLg. hay	DRY	0.68	0.018	0.530	0.022	0.052	0.007	0.77	14.50	7.70	0.00
		IRR	1.31	0.018	0.416	0.064	0.180	0.007	1.15	15.19	0.39	0.00
	Oats	IRR	17.05	0.300	0.201	0.095	0.541	0.033	48.20	21.50	2.80	0.00
	S. beets	IRR	14.30	0.130	0.655	0.016	0.266	0.060	4.82	7.00	0.00	0.00
	Wheat	IRR	17.84	0.365	0.455	0.019	0.689	0.024	42.16	13.40	2.00	0.00
WA	Barley	DRY	33.54	0.100	0.873	0.024	0.611	0.025	23.35	14.59	3.24	0.11
		IRR	21.64	0.470	0.990	0.059	0.840	0.025	49.61	14.60	3.20	0.10
	Corn	DRY	37.68	0.360	0.742	0.010	0.540	0.010	37.64	53.00	7.80	9.10
		IRR	84.83	0.436	0.685	0.048	0.990	0.029	55.35	53.06	7.85	9.04
	C. sil.	DRY	15.22	0.040	0.864	0.010	0.568	0.019	4.86	24.60	5.00	5.00
		IRR	16.72	0.020	0.449	0.033	0.967	0.019	7.32	24.59	4.99	4.98
	Lg. hay	DRY	1.42	0.020	0.595	0.018	0.089	0.004	2.98	0.00	2.18	4.50
		IRR	2.78	0.025	0.595	0.018	0.539	0.004	3.48	0.00	2.20	4.50
	nLg. hay	DRY	1.76	0.020	0.595	0.018	0.089	0.004	1.08	8.94	2.14	2.84
		IRR	2.18	0.025	0.595	0.018	0.539	0.004	1.39	11.90	2.10	4.50
	Oats	DRY	42.09	0.500	0.888	0.004	0.762	0.067	20.03	11.32	0.85	1.78
		IRR	45.07	0.200	0.732	0.010	0.766	0.067	34.89	11.30	0.90	1.80

Table 3.10. (continued)

			Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
State[a]	Crop[b]	Code[c]	intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
WA	Sorg.	IRR	0.00	0.000	0.000	0.000	0.000	0.000	62.21	37.34	0.00	0.00
	Sorg. sil.	IRR	19.32	0.020	0.449	0.033	0.967	0.019	3.22	16.50	0.00	0.00
	S. beets	IRR	17.80	0.150	0.615	0.090	0.918	0.010	8.10	5.60	7.90	0.00
	Wheat	DRY	30.03	0.156	0.215	0.067	0.770	0.030	12.50	13.86	1.92	3.05
		IRR	10.48	0.464	0.215	0.094	0.918	0.010	53.90	13.90	1.90	3.00
OR	Barley	DRY	37.76	0.377	0.043	0.010	0.487	0.012	12.17	11.46	1.21	0.00
		IRR	33.73	0.243	0.592	0.020	0.629	0.028	41.32	11.50	1.20	0.00
	Corn	DRY	26.97	0.440	0.160	0.010	0.975	0.032	73.25	34.80	0.00	0.00
		IRR	77.72	0.463	0.806	0.014	0.975	0.032	23.53	34.78	0.00	0.00
	C. sil.	DRY	10.38	0.038	0.464	0.020	0.980	0.038	2.57	8.28	2.91	0.00
		IRR	16.95	0.038	0.141	0.030	0.980	0.023	5.10	20.51	0.00	0.00
	Lg. hay	DRY	1.25	0.017	0.676	0.011	0.166	0.012	2.98	0.00	9.60	0.00
		IRR	1.49	0.020	0.676	0.011	0.334	0.012	3.48	0.00	9.60	0.00
	nLg. hay	DRY	1.65	0.017	0.676	0.011	0.166	0.012	1.11	9.46	4.35	0.00
		IRR	1.69	0.020	0.676	0.011	0.334	0.012	1.10	23.10	9.60	0.00
	Oats	DRY	38.91	0.341	0.693	0.010	0.486	0.014	26.45	6.70	0.00	0.00
		IRR	50.21	0.485	0.481	0.015	0.553	0.014	26.45	6.70	0.00	0.00
	S. beets	IRR	13.20	0.140	0.769	0.030	0.887	0.020	9.42	8.00	0.00	0.00
	Wheat	DRY	19.40	0.126	0.410	0.014	0.676	0.015	18.94	12.70	0.19	0.00
		IRR	25.00	0.313	0.769	0.031	0.887	0.015	37.28	12.70	0.20	0.00
CA	Barley	DRY	21.38	0.168	0.775	0.010	0.495	0.038	15.78	11.20	0.00	0.00
		IRR	34.56	0.368	0.254	0.045	0.750	0.038	25.41	11.20	0.00	0.00
	Corn	DRY	59.97	0.809	0.182	0.030	0.400	0.023	21.00	36.40	0.00	0.00
		IRR	77.86	0.409	0.430	0.030	0.983	0.023	25.69	36.40	0.00	0.00
	C. sil.	DRY	10.23	0.030	0.322	0.020	0.136	0.020	7.43	23.10	0.00	0.00
		IRR	11.03	0.049	0.773	0.029	0.959	0.021	8.33	23.13	0.00	0.00
	Cotton	IRR	469.73	4.107	0.617	0.023	0.902	0.006	497.48	23.55	6.00	0.00
	Lg. hay	DRY	0.48	0.025	0.927	0.010	0.222	0.039	2.43	0.00	6.50	8.20
		IRR	3.11	0.035	0.378	0.241	0.595	0.039	2.93	0.00	6.50	8.20
	nLg. hay	IRR	1.28	0.025	0.927	0.010	0.222	0.039	1.00	12.90	0.00	0.00
		DRY	1.21	0.035	0.378	0.241	0.595	0.039	1.01	18.00	6.50	0.00

Table 3.10. (continued)

State[a]	Crop[b]	Code[c]	Unfertilized trend		Percent of optimal fertilization		Percent of acres fertilized		Spillman function data			
			intercept	slope	intercept	slope	intercept	slope	A	lbs. N	lbs. P	lbs. K
CA	Oats	DRY	15.72	0.351	0.546	0.010	0.611	0.024	33.15	14.19	0.00	0.00
		IRR	37.72	0.551	0.346	0.054	0.860	0.024	30.20	14.20	0.00	0.00
	Sorg.	DRY	50.46	0.119	0.170	0.044	0.377	0.033	29.91	37.60	0.00	0.00
		IRR	46.45	0.319	0.170	0.061	0.929	0.033	35.99	37.59	0.00	0.00
	Sorg. sil.	DRY	13.23	0.030	0.322	0.020	0.136	0.020	2.42	18.80	0.00	0.00
		IRR	15.03	0.049	0.773	0.029	0.959	0.021	3.60	18.76	0.00	0.00
	S. beets	IRR	11.50	0.130	0.850	0.014	0.884	0.028	8.40	9.20	0.00	0.00
	Wheat	DRY	18.33	0.140	0.850	0.014	0.455	0.028	9.52	2.80	0.00	0.00
		IRR	38.67	0.460	0.850	0.014	0.884	0.028	16.96	10.50	0.00	0.00

SOURCE: Stoecker [71].

[a] Abbreviations of state names taken from zip code listing developed by the U.S. Post Office. They are:

AL = Alabama
AZ = Arizona
AR = Arkansas
CA = California
CO = Colorado
CT = Connecticut
DE = Delaware
FL = Florida
GA = Georgia
ID = Idaho
IL = Illinois
IN = Indiana

IA = Iowa
KS = Kansas
KY = Kentucky
LA = Louisiana
ME = Maine
MD = Maryland
MA = Massachusetts
MI = Michigan
MN = Minnesota
MS = Mississippi
MO = Missouri
MT = Montana

NE = Nebraska
NV = Nevada
NH = New Hampshire
NJ = New Jersey
NM = New Mexico
NY = New York
NC = North Carolina
ND = North Dakota
OH = Ohio
OK = Oklahoma
OR = Oregon
PA = Pennsylvania

RI = Rhode Island
SC = South Carolina
SD = South Dakota
TN = Tennessee
TX = Texas
UT = Utah
VT = Vermont
VA = Virginia
WA = Washington
WV = West Virginia
WI = Wisconsin
WY = Wyoming

[b] Crop abbreviations symbolize the following: C. sil. = corn silage, Lg. hay = legume hay, nLg. hay= nonlegume hay, Sorg. = sorghum, Sorg. sil. = sorghum silage, soybns. = soybeans, and S. beets = sugar beets. The other crops are as written.

[c] Code abbreviations are TOT = total, DRY = dry, and IRR = irrigated.

crop in year t;

PF(t) is the proportion of the acreage of the crop receiving fertilizer in year t, developed from a linear trend of the proportion of the crop acres receiving fertilizer; and

t is years after 1949.

The X(t) defined above represents:

$$X(t) = PO(t)*(\ln(Px/Pc) - \ln A - (\ln(-\ln .8)))/\ln .8 \quad (3.5)$$

where:

ln is the natural log of base e;

Px is the weighted price of a unit of fertilizer;

Pc is the price of a unit of crop c;

PO(t) is the proportion of the optimum rate of fertilizer applied in year (t), developed from a linear trend of the proportion of the optimum rates applied.

The above equation represents an estimate of the optimum application of fertilizer obtained by solving the marginal conditions of a profit maximization system adjusted for the proportion of optimability which farmers are projected to be using.

The second step in the determination of yields is to weight the state functions by the proportion of the acres in each producing area and aggregate the producing area parts into functions which can predict the yield on a producing area basis. The weights are developed from the 1964 Census of Agriculture [99] and are represented by:

$$W_{ikn} = A_{ikn} / \sum_m A_{ikm} \quad (3.6)$$

$i = 1,\ldots,15$ for the crop number,
$k = 1,\ldots,223$ for the producing areas,
$n = 1,\ldots,48$ for the continental states,

where:

W_{ink} is the weight for crop i from state n to producing area k;
A_{ikn} is the acres of crop i in production area k and state n.
A_{ik} is the acre of crop i in producing area k.

These weights are multiplied by each of the function coefficients and summed over m for each i and k to give the producing area yield prediction equation. This procedure is used to transfer the yield, proportion of acres fertilized, and proportion of optimal fertilizer-applied functions and the prices of fertilizer and commodities into the producing areas.

The producing area yield is calculated for each crop based on the functions developed and the projected levels of fertilizer use. If the rotation in which any crop is defined includes a legume crop, the carry-over nitrogen from these sources is accounted for in predicting the yields. The fertilizer value of the legume crops will be covered in the fertilizer-use part of this section of the report. In many instances the legume, especially alfalfa hay, produced more fertilizer-equivalent nitrogen than would have been applied commercially. When this occurred, the fertilizer-equivalent nitrogen from the legume is used in the yield equation giving a larger yield than under trend fertilizer uses.

The next step in determining the yields for the cropping system is to adjust for land class, conservation practice, and tillage method. The data obtained in the SCS questionnaire (Appendix A) included a set of ratios giving the relative land class yields of each crop category as compared to the most productive land class of the area. These ratios initially are weighted to the nine land groups and are adjusted such that land group 1 has a relative yield value of 1.00. The acreage weights used are the acres of the respective crop categories, row crops, close-grown crops, and rotation hay and pasture, from the "National Inventory" [8]. The producing area yield is assumed to be determined as a weighted average yield over the land groups in the producing area. Using the relative yield indices, the weighted average function can be expressed as:

$$\begin{aligned} Y_{ij} &= W_{ij1}\ Y_{ij1} + W_{ij2}\ R_{ij2}\ Y_{ij1} \\ &\quad + \dots + W_{ij9}\ R_{ij9}\ Y_{ij1} \\ &= (\sum_k W_{ijk}\ R_{ijk})\ Y_{ij1} \qquad (3.7) \end{aligned}$$

i = 1,2,...,223 for the producing areas,
j = 1,2,...,30 for the crops dryland and irrigated,
k = 1,2,...,9 for the land classes,

where:

Y_{ij} is the average yield of crop j in producing area i;

W_{ijk} is the weight of acres in producing area i which are on land group k for crop j;

R_{ijk} is the relative yield factor for crop j on land class k in producing area i with land group 1 = 1.00; and

Y_{ij1} is the yield of crop j on land group 1 in producing area i.

The above equation can be transposed and solved for Y_{ij1}, and each of the other land group yields can subsequently be determined from the group 1 yield using the relative yield indexes.

The conservation and tillage yield ratios, obtained from the SCS questionnaire, are used equally on each land class to adjust the yields for both conservation and tillage effects. The national average ratio is used as a proxy for the adjustment ratio in a producing area if the area's data was missing. This substitution is only used where a practice and land group exist in a producing area, and the specific data needed was not provided in the SCS questionnaire (Appendix A). These adjustments completed the calculation of the crop yields as determined from the response function of the area, the land class, the rotation, the conservation practice, and the tillage method.

Associated with the crop output determination is an estimate of the available aftermath pasture. This is pasture available for livestock after harvesting the major crop and allowing the animals to run on the field to graze the aftermath and fence rows. Jennings estimates the yield of aftermath pasture in acres of cropland pasture equivalent for each of the 48 states [31]. This total yield is divided by the total acres of cropland and hayland in the state [99] to give an average yield per acre of dryland and irrigated land cropped. Each county in the state was assumed to have this yield of aftermath pasture, and the producing area yield was obtained as a weighted average yield of all the counties in the producing areas. These yields are included as roughage production in conjunction with the annual crop activities, except soybean and cotton, or added to the roughage production of the hay crops in the respective producing areas.

Fertilizer use coefficients for the crops

The fertilizer use coefficients developed from the functions were independent of the land class, the conservation practice, or the tillage method. The yield functions developed from Stoecker's procedure [71] provided the basis for determining the level of nitrogen supplementation required. The level of commercial fertilization required to meet the projected yields is determined by taking the optimum level of fertilizer use as determined from the function and subtracting the amount provided by the legumes, if any, in the rotation. The legume nitrogen data were developed from results reported in agronomy publications [32;40;58;60;61] and through consultation with William Shrader.[6] An estimate of a function was developed which related nitrogen fertilizer equivalent carry-over of the legume as a function of the yield of the legume. Only those legumes which offer the potential of high nitrogen production are included when developing the function. This selectivity allowed for the switch to equal yielding but higher management legume varieties in order to harvest the carry-over nitrogen. The legume hays provided carry-over for a two-year period after a good yielding stand, and functions relate the first- and second-year production of nitrogen. The first-year function is:

$$N_1 = 50.0*Y - 5.0Y^2 + .2Y^3 \qquad (3.8)$$

and the second-year function is:

$$N_2 = 81.5 - (81.5).8^Y \qquad (3.9)$$

where N_1 and N_2 are the pounds of nitrogen supplied by the legume for the crop following the first and second year after plowing, respectively, and Y represents the annual yield in tons of dry weight hay equivalent of the legume hay during the years it is harvested. The effect of legumes does not include a green manuring response but rather only the response coming after a legume hay crop. This type of relationship allows for utilization of the roughage for feed and also the nitrogen carry-over.

A similar functional relationship has been developed for nitrogen carry-over from soybeans. Shrader and Voss have shown that soybeans provide a carry-over of approximately one pound of nitrogen equivalent per bushel of soybean yield for the crop in the following year [62]. The nitrogen coefficient for the cropping management system is determined by adjusting the fertilizer use, determined by optimizing the production relationships, for the amount of nitrogen supplied by the previous years' legume crop.

The source of nitrogen is determined endogenously in the model. Nitrogen can be obtained through the purchase of commercial nitrogen fertilizer or the use of livestock wastes. The nonnitrogen fertilizer required to satisfy the calculated optimum application rate is assumed to be purchased, and the cost of this fertilizer is included in with the production costs to give the exogenously allocated variable costs for the crop management system.

Development of the crop production costs

The source of the basic data used in determining the production costs is Eyvindson [20]. Eyvindson developed a set of crop budgets for the crops barley, corn, corn silage, cotton, tame hay, wild hay, oats, sorghum, sorghum silage, soybeans, and wheat. In areas where irrigation is relevant, he developed both dryland and irrigated budgets. The procedure used was one of budgeting each crop based on the most common production technique in the area in 1964. This entailed determining machinery sequences for each crop machinery size, average length of life of the machines, repairs needed, and the acres covered with the machines. These data are combined with the costs of the machinery and supporting inputs to provide the cost and labor coefficients for each of the crop budgets. The budgets were developed to include all costs except return to land or any fixed cost associated with the land. Eyvindson's machinery, labor, pesticide, nonnitrogen fertilizer, and miscellaneous costs are weighted to the 223 producing areas for each of the 11 endogenous crops[7] using the acreage of the respective crop from the 1964 Agricultural Census [99] as the weights and the following relationship:

$$C_{ijk} = \sum_n C_{ijmnk} * \frac{A_{jnk}}{A_{jk}} \qquad (3.10)$$

i = 1,...,5 for machinery, labor, pesticides, fertilizer, and miscellaneous costs,
j = 1,...,11 for the endogenous crops,
k = 1,...,223 for the producing areas,
m = 1,...,157 for the areas in Eyvindson's analysis,
n = 1,..., number of parts of Eyvindson's areas in producing area k,

where:

C_{ijk} is the value of cost i for crop j in producing area k;
C_{ijmnk} is the value of cost i for crop j in Eyvindson area m consistent with part n of producing area k;
A_{jnk} is the acres of crop j in part n of producing area k; and
A_{jk} is the acres of crop j in producing area k.

Each part of Eyvindson's region is assumed to reflect the cost of that region. The acreages used as the weights are from the Census of Agriculture [99]. Labor costs were adjusted to account for increases in technology consistent with a continuation of the 1949 to 1969 trend.[8] Total variable costs for each crop are projected to 2000 using the assumption of constant per unit costs.

Adjustments for conservation practice and tillage method are determined from the SCS data (Appendix A). A base of straight row cropping is used for conservation practices, and adjustments are made in machinery and labor efficiency for contouring, strip cropping, and terracing. Similarly, adjustments are made for the tillage practices when conventional tillage with no residue management serves as the base. The variations included conventional tillage with residue management and reduced tillage.

A further adjustment is made for reduced tillage operations to reflect the tradeoff between tillage operations and the use of herbicides for weed control. In areas which are not moisture deficient,[9] Figure 3.6, a direct tradeoff has been determined with the saving in machinery cost being equally offset by increased herbicide costs [2;15;35;57]. In arid areas the adjustment consisted of a \$3.00 increase in herbicide costs for each \$1.00 reduction in nonherbicide costs [59]. This is consistent with the extensive farming methods used and the relatively lower machinery cost per acre when compared to the fixed herbicide application cost.

The costs reflect regional average costs of production, and a response to summerfallow is required for those crops normally grown in a summerfallow rotation. From the _Selected U.S. Crop Budgets_ [17;18] a relative use of fertilizer and herbicides was obtained for the plains area where summerfallowing is common (Figure 3.7). The adjustments reflected a 4 percent reduction in pesticide after summerfallow and an increase of 50 percent if summerfallow is not part of the rotation. The wide variation in the adjustments results from the average being close to the after-summerfallow data as a result of the large percent of all acres in a summerfallow rotation. A similar adjustment is made for fertilizer use with crops in summerfallow ro-

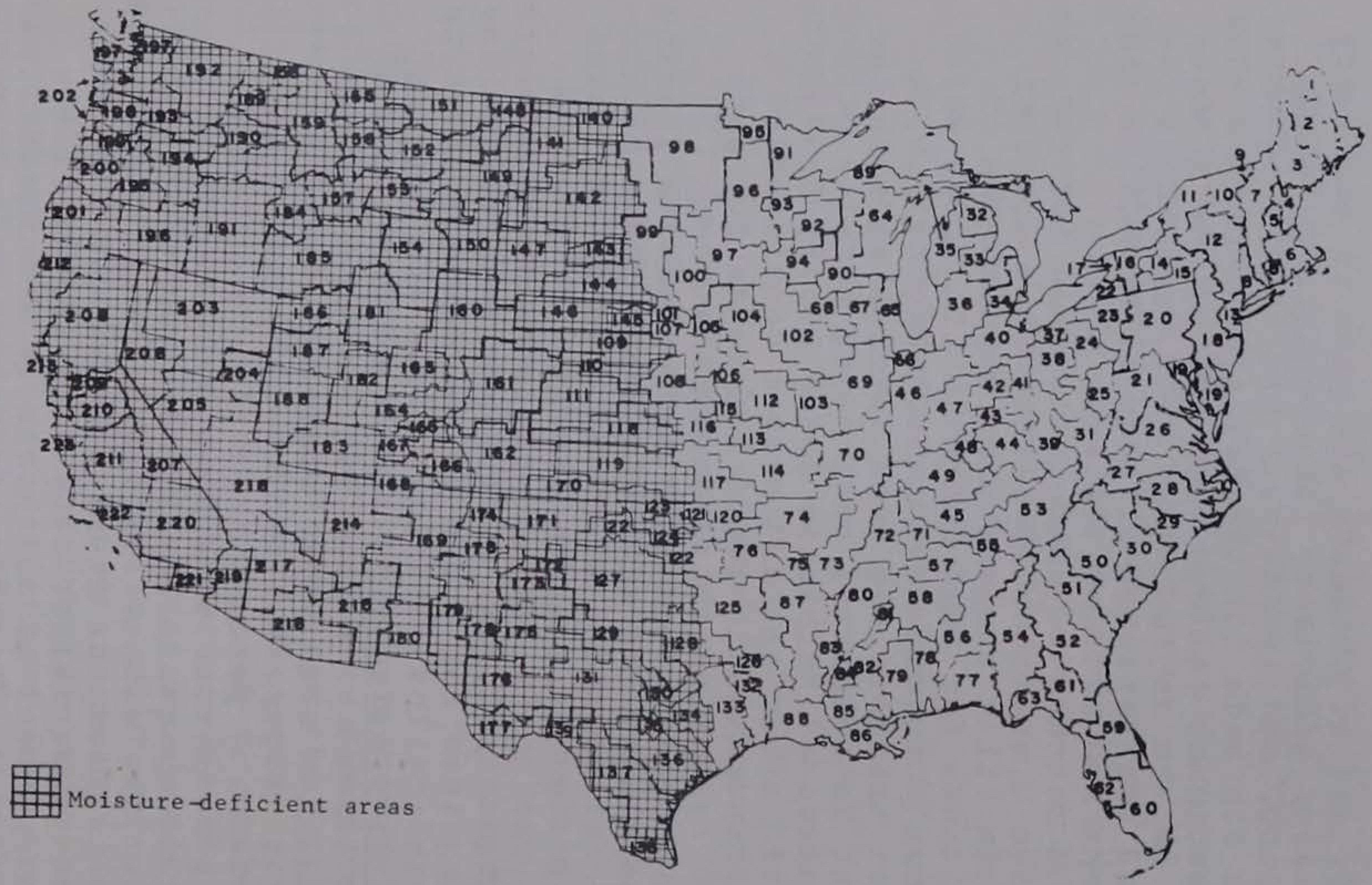

Figure 3.6. Moisture-deficient areas of the nation.

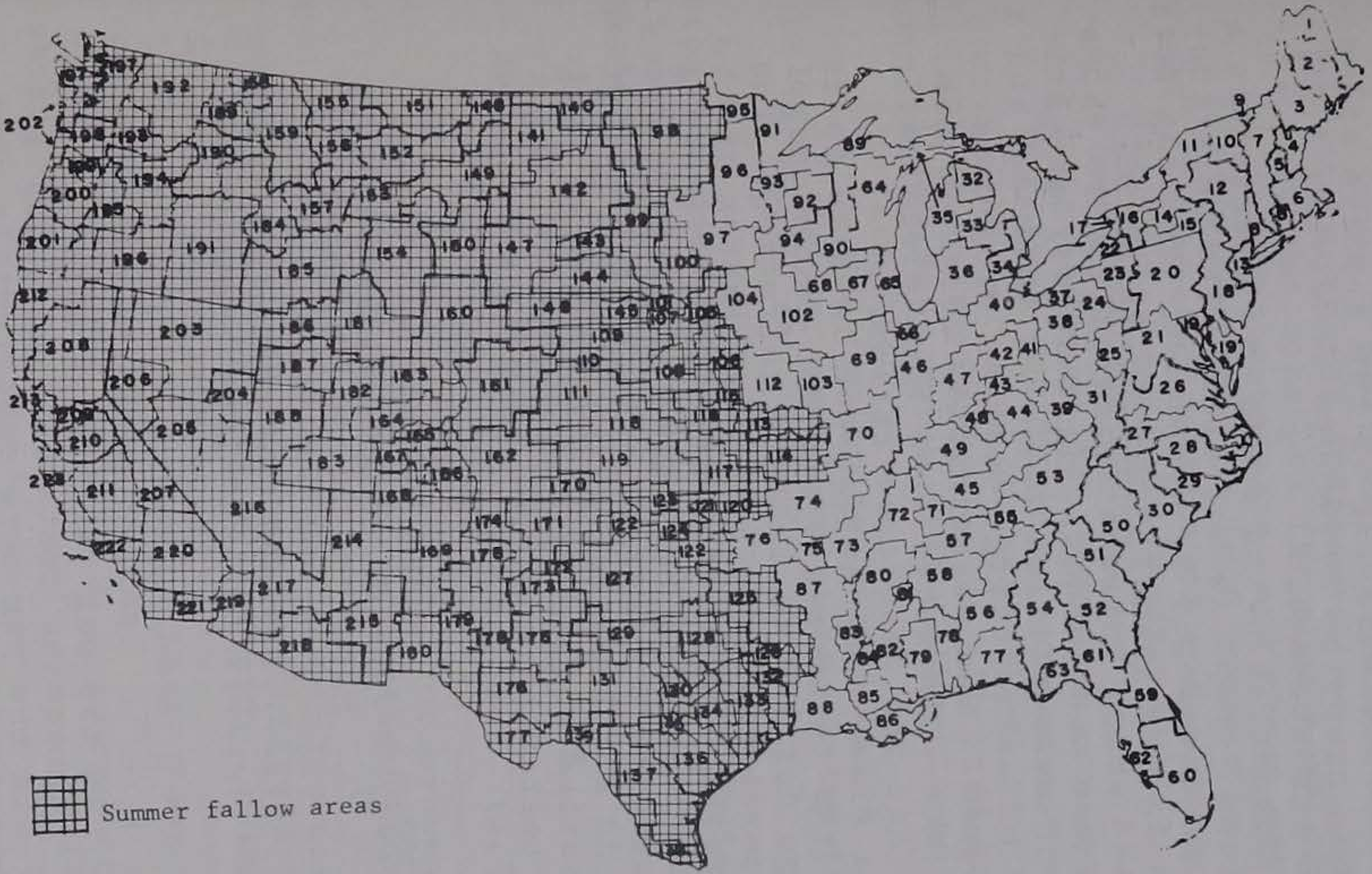

Figure 3.7. Summer fallow areas of the nation.

tations receiving .92 of the average and continuous cropping sequences receiving 1.18 times the average.

Summerfallowing costs are treated as a separate "crop" in the area. The relationship is developed by comparing the crop rotations in the Selected U.S. Crop Budgets [17;18] which include summerfallow to those which are continuous. In this way an estimate of summerfallow costs is obtained and a ratio of summerfallow cost to crop cost is developed. The summerfallow costs in the model are calculated from the determined crop costs and the developed ratios.

A final cost adjustment is made to reflect the terracing costs for those cropping systems defined to include terracing. The SCS questionnaire provided estimates of the construction costs for terraces. The data are provided only for those classes on which terracing is a feasible alternative and other lands do not have terracing as one of their alternative conservation practices. The average terracing cost per acre is calculated as:

$$TC_{ij} = \frac{.1}{PLTij}(CC_{ij} + PW_{ij} W_{ij} + PT_{ij} T_{ij}) \qquad (3.11)$$

$i = 1,\ldots,223$ for the producing area,
$j = 1,\ldots,9$ for the land groups,

where:

TC_{ij} is the per cultivated acre terracing costs on land group j;
CC_{ij} is the per acre construction cost of terraces on land group j;
PW_{ij} is the proportion of acres of land

group j terraced having grassed waterways for drainage;

W_{ij} is the cost per terraced acre for grassed waterways consistent with the terraces on land group j;

PT_{ij} is the proportion of acres of land group j terraced having tiled outlets for drainage;

T_{ij} is the cost per terraced acre of tiling and drainage consistent with the terraces on land class j;

PLT_{ij} is the proportion of all land in class j which is feasible to terrace; and

.1 is the factor to adjust for a 10-year amortized life of the terrace.[10]

From the cost components the final production is determined for each cropping management system as:

$$C_{ijk} = \sum_{m} (M_{ijm} + L_{ijm} + P_{ijm} + F_{ijm} + MS_{ijm})\, R_{ijm} + TC_{jk} \qquad (3.12)$$

i = 1,..., for the number of cropping management systems in the producing area,

j = 1,...,223 for the producing areas,

k = 1,...,18 for the land classes, 1,...,9 dryland, and 10,...,18 irrigated land groups,

m = 1,...,15 for only those crops in the cropping system,

where:

C_{ijk} is the cost per acre for crop management system i in producing area j on land class k;

M_{ijm} is the projected per acre machine cost for crop m in cropping system i in producing area j;

L_{ijm} is the projected per acre labor cost for crop m in cropping system i in producing area j;

P_{ijm} is the projected per acre pesticide cost for crop m in cropping system i in producing area j;

F_{ijm} is the projected per acre nonnitrogen fertilizer cost for crop m in cropping system i in producing area j;

MS_{ijm} is the projected per acre other costs for crop m in cropping system i in producing area j;

R_{ijm} is the rotation weight for crop m in cropping system i in producing area j; and

TC_{jk} is the terracing cost per cultivated acre on land class k in producing area j.

Crop water use coefficients

Water use coefficients for each crop activity in the model reflect the net diversion requirements to provide the crop with the amount of water needed for growth in addition to that provided from precipitation. Withdrawal coefficients are also calculated to indicate the diversion requirements needed to supply the water consumed. Gross delivery requirements in area i for crop j are:

$$GDR_{ij} = \frac{CU_{ij} - EP_{i}}{(IE_{j})(CE_{i})} \qquad (3.13)$$

$i = 1,\ldots,223$ for the producing areas,
$j = 1,\ldots,19$ for the endogenous crops,[11]

where:

GDR_{ij} is the gross delivery requirement in acre feet for crop j in producing area i;

CU_{ij} is the amount of water required by crop j in producing area i as determined from regional publications on consumptive use of water by crops [3; 13; 19; 26; 72];

EP_i is the effective precipitation in producing area i representing water available after evaporation and deep percolation are subtracted from the rainfall;

IE_j is the irrigation efficiency or the efficiency of the crops in using the water applied (Table 3.11). This is affected by the surface of the land exposed between plants and the ability of the plants to hold the water in the ground for use; and

CE_i is the canal efficiency or efficiency of the delivery system between the diversion point and the farm delivery gate. This was calculated for each region from data on Bureau of Reclamation projects [106].

The net diversion requirements, NDRij, or the water use coefficients for each of the activities, are calculated as:

$$NDR_{ij} = CU_{ij} - EP_i + (1 - RF_i)$$

Table 3.11. Assumed irrigation efficiencies of various crops.

Crop	Efficiency of Irrigation
Alfalfa	75
Clover	60
Pasture	70
Grains and Silage	70
Cotton	70
Vegetables	65
Rice	65
Sugar beets	65
Citrus and Nuts	75
Subtropical Fruits and Vines	75

Source: Pacific Southwest Interagency Committee [53].

$$GDR_{ij} - (CU_{ij} - EP_i) = CIR_j + (1 - RF_i)\ GDR_{ij} - CIR_{ij} \qquad (3.14)$$

$i = 1,\ldots,223$ for the producing areas,
$j = 1,\ldots,19$ for the endogenous crops,

where:

GDR_{ij} is the gross delivery requirement in acre feet for crop j in producing area i;
CU_{ij} is the consumptive use requirement in acre feet for crop j in producing area i [3; 13; 19; 26; 72];
EP_i is the effective precipitation in producing area i;

CIR_{ij} is the crop irrigation requirement of crop j in producing area i; and

RF_i is percent of the water not used by the plant which is returned for reuse in the region. This return flow is assumed to be 55 percent for all river basins except the Columbia-NorthPacific where 60 percent is used [107].

The noncropland roughage sector

The noncropland roughage sector includes the production of permanent pasture and hay and the forest-grazed sources of roughage. The land available for such uses has been outlined in conjunction with the definition of the land base. This section will outline the costs and yields associated with these activities. The activities are divided into dryland and irrigated permanent pasture, dryland and irrigated permanent hay, and forest land grazed.

The costs of the permanent pasture activities were determined from the preharvest costs of hay as determined by Eyvindson [101]. The yields are developed as a function of the hay yields in the area. Nonirrigated cropland pasture is assumed to have a yield equal to 75.0 percent of the tame hay yield, if the tame hay yield is less than four tons, and 70.0 percent of the tame hay yield if the yield is more than four tons. Irrigated yields on cropland pasture are determined by a similar relationship, with the yield being equal to 85.0 percent of the irrigated tame hay yield, if it is less than four tons, and 80.0 percent of the tame hay yield if it is greater than four tons.[12]

Heady and Mayer estimate that improved pasture yields are equal to 88 percent of cropland production [25]. This yield is used to give an estimate of production from the acres in the pasture category of the "Nationl Inventory." These costs and yields are weighted to give the coefficients for the permanent pasture activity.

Bounded activities are also defined for dryland and irrigated nonrotation hay. These activities represent wild hay and other hayland which is continuously harvested except for infrequent interruptions to reestablish or improve the stand. The acreage bounds for these activities are obtained from the hayland category in the "National Inventory" [8]. The costs are determined from Eyvindson's permanent hay and wild hay costs by weighting these together for the region. An estimate of wild hay acreage was made from the 1964 Census of Agriculture [99], and this was subtracted from the inventory acreage to give the permanent hay acreage. The yield coefficients are determined from an adjusted 50 year time trend for dryland and irrigated tame hay and wild hay. The trends were determined from annual crop summaries [1;4;65-67;69;70] and the Census of Agriculture [96-99]. The 50-year aggregate state trend is used to reduce the more rapidly rising 16-year trend for the dryland and irrigated yields of the census. The relevant producing area yield is determined by weighting the county's yield adjusted for its value relative to the state yield into the producing area bound on acreages from the 1964 Census of Agriculture [99].

A final noncropland roughage activity incorporates the forest land grazed category from the "National Inventory" [8]. The roughage production from these acres represents grazing of lands mostly in trees where productivity is low. The yield coefficient is determined using the relationships developed by Jennings [31]. These gave the yield relationship between woodland pasture and cropland pasture by state. It was assumed this relationship would hold to the year 2000. The cost for the forest land grazed activity is determined from the grazing rates charged on public lands in the area [21;102-104].

The noncropland pasture activities interact with the nitrogen sector. Little if any fertilizer is applied to the permanent roughage crops; however, in order to maintain the relationships within the livestock waste-nitrogen balance sector, the livestock wastes deposited while the animals are grazing these lands must be included. The nitrogen production from wastes of beef cows per unit of TDN consumed was determined, and this quantity was multiplied by the units of TDN produced per acre of pasture to give a nitrogen utilization per acre. This procedure requires the assumption that the nitrogen wastes of livestock, especially beef cows, are produced uniformly over the year in proportion to the TDN consumption and are distributed with the same efficiency as wastes from the winter feeding period.

The Exogenous Crop Sector

The exogenous crop sector defines the use of land by region and land group, fertilizer nitrogen and water for use by the crops not endogenously allocated by the model. These crops include broomcorn, buckwheat, cowpeas, dry beans, dry peas, flax, hops, orchards and vineyards, peanuts, potatoes, proso-millet, rice, rye, safflower, sugar cane, sunflowers, sweet potatoes, tobacco, and vegetables. Soil loss from lands utilized by these crops is not considered in the total accumulation of soil loss, as data and alternative cropping patterns are not available.

Water allocation for the exogenous crop sector is determined directly from water use coefficients developed similarly to those for the endogenous crops. The per acre water use rates are applied to the acres of each crop. The water use for all exogenous crops is aggregated to become a fixed water requirement which is subtracted from each region's supply to leave the quantity available for the endogenously allocated uses. The allocation of land and nitrogen fertilizer is outlined in the following sections.

Acreages allocated for use by the exogenous crops

The acreage defined for use in each land group is adjusted to reflect the requirement for the production of the exogenous crops in 2000. The 1969 production and the production in 2000 by state for most of the exogenous crops is obtained from the OBERS work of the Economic Research Service.[13] Acreages by state for each crop in 1969 are obtained from the Census of Agriculture [100] and an average state yield is determined for 1969.[14] Dean reports yields for the exogenous crops produced in California in 1969 and projected yields for each of the crops in 2000 [14].[15] The ratio--yield in 2000/yield in 1969--is determined for each crop in the California study [14]. It is assumed that the yields in each state will increase proportionately to those in California, and the above ratios are used to adjust all state yields from 1969 to 2000. Acreage requirements for the year 2000 are computed by dividing the estimated production by the projected yields per acre.

All projections in the exogenous crop sector are made at the state level. The acreage is allocated to the counties within the state on the basis of the proportion of each crop grown in the county as reported in the _1964 Census of Agriculture_ [99].[16] The acreages of each of the exogenous crops in each producing area are determined by summing the projected acreage of the relevant crops in the producing area over the subset of counties consistent with the definition of the producing area.

Within each producing area the exogenous crops are grouped into three categories according to their method of cultivation. These categories are row crops, close-grown crops, and orchards and vineyards. Acreages of these three categories are then allocated to different land groups in proportion to the calculated acres of other row crops,[17] close-grown crops, and orchards and vineyards as determined by land class in the "National Inventory" [8]. This same procedure is used for both dryland and irrigated acreages. If the projected acreage requirement for the exogenous crops is greater than the acreage available in the land group, the excess acres are allocated either to the land group next closest in erosion-hazard characteristic or to the same land group in an adjoining producing area depending on the agronomic characteristics of the land groups, producing areas, and cropping patterns required to produce the exogenous crops.

Nitrogen for the exogenous crops

The use of nitrogen by the exogenous crops represents a significant demand for nitrogen especially in the Gulf and West Coast areas. The amounts of nitrogen required by the specific crops are determined from the work of Ibach and Adams [128]. The quantity used per acre for each of the exogenous crops is multiplied by the acres calculated in the region. The assumption is made that by 2000 the average application rate for all acres will be equal to the application rate on the acres fertilized in Ibach and Adams data.[18] The regions' nitrogen requirement for the exogenous crops is determined as:

$$RN_i = \sum_m A_{im} N_{im} \qquad (3.15)$$

$i = 1,\ldots,223$ for the producing areas,
$m = 1,\ldots,19$ for the exogenous crops.

where:

A_{im} is the projected acreage of crop m in producing area i in 2000;
Nim is the projected per acre use of nitrogen by crop m in producing area i in 2000;
RN_i is the total projected fertilizer nitrogen equivalent of all crops in producing area i in 2000.

The Livestock Sector

Within the total livestock sector the dairy, pork, and beef production enterprises are allocated endogenously while the remainder of the livestock categories have exogenously determined rations and regional production patterns. In all livestock categories the rations alternatives combine with the technologies available to give the output and input requirements for the livestock sector, Figure 3.8. The following sections will outline the procedures used in determining the rations, the production levels, the nitrogen balance interactions, and the regional distribution patterns for the exogenous livestock.

Determination of the livestock activities

The livestock activities within the model include diary, pork, beef cows, beef feeding, broilers, turkeys, eggs, sheep and lambs, and a general category for "other animals" such as horses, mules, ducks, geese, and zoo animals. Production coefficients are required for all categories but cost data are needed only for the endogenously allocated enterprises.

The endogenous livestock activities include hogs, beef cows, beef feeding and dairy. Eyvindson's data [101] are used as the basis for defining the initial coefficients for projecting the data for each activity. The livestock budgets were developed using a procedure similar to the crop budgets as described on page 111. Eyvindson defined six different methods of producing feed beef. Four of these activities were based on feeding calves after weaning until ready for

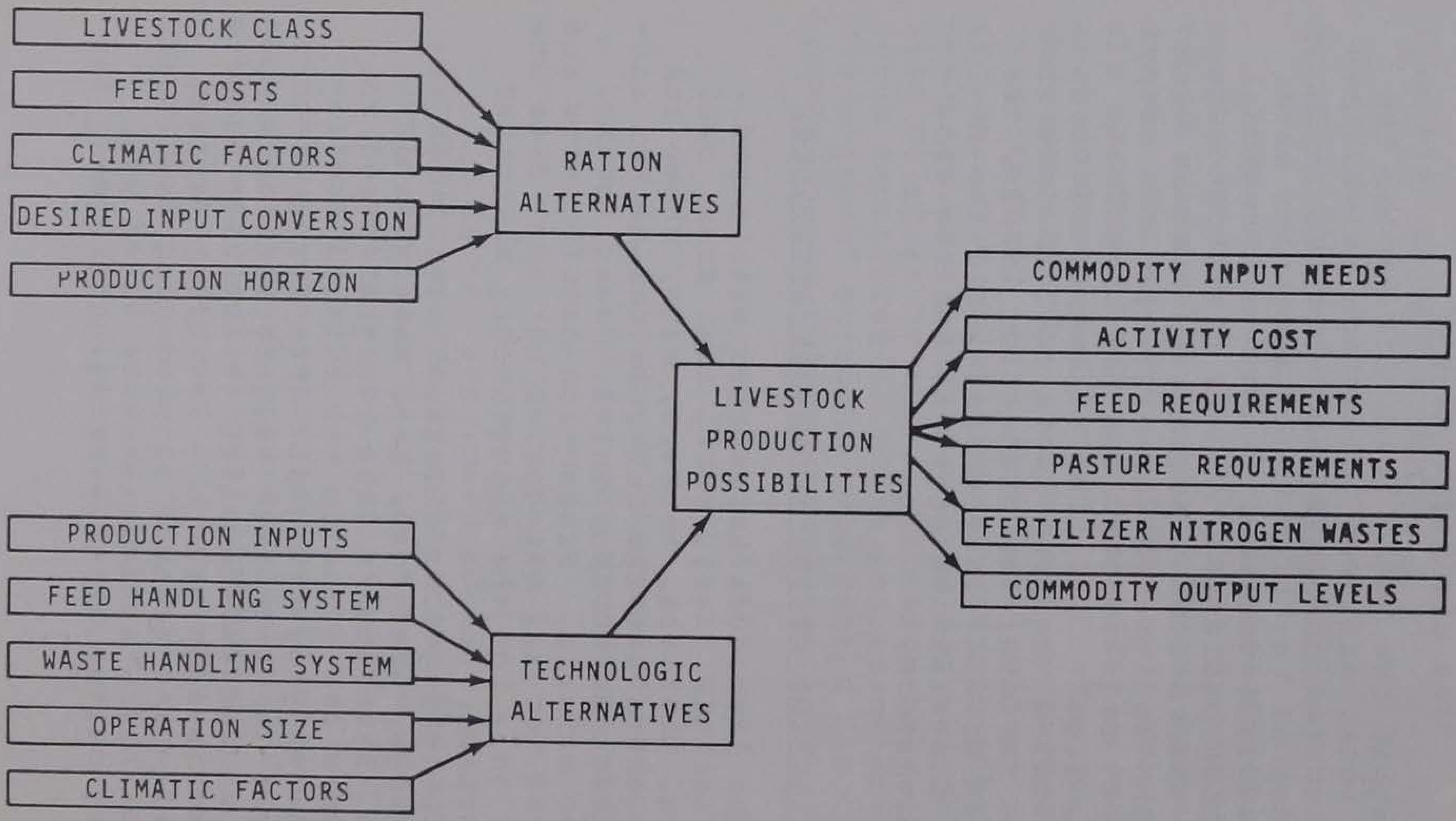

Figure 3.8. Schematic of the development of the livestock production possibility coefficients.

slaughter and the other two were based on placing animals on feed after they had grown out in a yearling activity. No data are available indicating the proportions of animals fed under each system to allow the different activities to be weighted together. Also, size restraints on the model prevent the inclusion of more than one beef feeding activity per area. The beef feeding activity selected fed a high roughage ration to the feeder during the early feeding period and a larger proportion of concentrates as the weight of the feeder increased. This provided a cost component consistent with the rates of gain assumed in calculating the ratios.

Weights are determined to combine Eyvindson's data from his three farm sizes which were determined from the economic farm size categories on the Census of Agriculture [265]. The weights for hogs are based on the number of hogs marketed by economic farm class, for beef cows are based on the number of beef cows on hand as of January 1, 1964 for each of the economic farm classes, and for dairy cows are based on the number of dairy cows on the farm on January 1, 1964 for each of the economic farm classes. Weights are calculated for the beef feeding activity based on the number of steers and heifers on hand on January 1st not needed for replacement as calculated from the number of steers, heifers and cows reported on the farm by the economic farm classes [265]. From these weighted coefficients it is apparent that the Midwest and East Coast producing areas would not be competitive due to the greater proportion of smaller and less efficient feedlots in these areas. Over time those areas which give way to a technological advantage will alter their technology to make it competitive or they will change to the production of other products for which they hāve the technological or locational advantage. In order to allow some shift in the technology of fed beef production it is assumed that by the year 2000 all areas will be feeding cattle in lots equivalent to those of Eyvindson's farm size one (his larger size operations).

After weighing Eyvindson's data into aggregate coefficients, except for beef feeding, the cost of production is adjusted to reflect labor costs and interest charges on capital required for production:

$$FC_{ij} = {}_{m\ i}(C_{jm}+L_{jm}W_m)(1+r_m) \qquad (3.16)$$

$i = 1,\ldots,157$

$j = 1,\ldots,4$

$m = 1,\ldots, 3{,}067$

where:

C_{jm} is the cost per unit of livestock activity j in county m included in Eyvindson producing area i;

L_{jm} is the hours of labor required per unit of livestock activity j in county m included in Eyvindson producing area i;

W_m is the wage rate per hour in county m as determined from the state wage rates [210];

r_m is the interest charge on productive capital in county m as determined from the interest rate charged on productive capital in the respective state [46]; and

FC_{ij} is the final cost of livestock activity j in Eyvindson producing area i.

The coefficients, TDN requirement, cost, and output levels, are weighted to the 223 producing areas from Eyvindson's regions consistent with the total number of animal units in each overlapping part of the regions.

$$WC_{ijk} = N_{jn} / N_{ij} \cdot EC_{jkm} \qquad (3.17)$$

$i = 1, \ldots, 223$ for the producing areas,
$j = 1, \ldots, 4$ for the livestock type--pork, dairy, beef cow or beef feeding;
$k = 1, 2, 3$ for the coefficients--cost, TDN requirement or output,
$m = 1, \ldots, 157$ for Eyvindson's producing areas consistent with the overlap part of n; and
$n = 1, \ldots,$ the number of overlap parts of Eyvindson's regions in producing area i.

where:

WC_{ijk} is the weighted coefficient k for livestock type j in producing area i;
N_{jn} is the number of units of livestock type j in overlap part n as determined from the _1964 Census of Agriculture_ [265];
N_{ij} is the number of units of livestock type j in producing area i as determined from the _1964 Census of Agriculture_ [265]; and
EC_{jkm} is the value of coefficient k for livestock type j in Eyvindson's region m.

The coefficients by producing area are then adjusted to the year 2000.

Projections of the livestock sector

Changes in feed consumption by the various classes of livestock, Table 3.12, are developed to correspond to past trends in feed consumption patterns with some restrictions to keep projected feed consumptions within the physical capacity of the animal and also provide the estimated nutrient requirements given the projected changes in production techniques. For the hog and beef feeding activities the adjustments give a feed conversion rate near the feed conversions obtained presently by the commercial operators.

Table 3.12. Factors to adjust the 1964 TDN requirements for each of the livestock classes in 2000.

Livestock Activity	TDN
Dairy	1.00
Beef cows	1.00
Beef feeding	0.95
Hogs	0.865

The beef cow and dairy cow activities do not show large changes in projected feed consumption since the trends have indicated a shift in composition of the ration especially for dairy but little change in quantity consumed.

Changes in feed efficiency for these two activities arise from greater projected output levels. The calving rate is assumed to increase on the basis of the past state trends, Table 3.13. The increase in efficiency of feed conversions from the dairy cow activities is a result of both the increase in calves weaned and the increase in milk output per cow, Table 3.13. The trends for calves per cow and milk production are based on 50 year linear time trends on state data.

No increase in the output is projected for the beef feeding activities as no consistent trend has been developed which would indicate any change in the weight of the carcass from fed beef animals. The lower feed requirements are in part cancelled against the heavier feeders entering the feedlot as the beef cow operations wean calves at a heavier weight. No change in output coefficients for hogs is apparent so the dressing percentage, 61.1 percent as assumed by Eyvindson [101], is used to convert the liveweight production into carcass weight as expressed in the demands.

Determination of the livestock rations

A modified system of ration determination is used for this analysis. Rather than allow for nutrient transfers from the commodities to the livestock rations as has been done in previous models [101, 116, 117]. This model defines alternative rations for the livestock categories which draw directly from the commodity balance rows. Under the nutrient transfer system balanced rations are determined endogenous to the model, but it is possible to have rations which, because of

Table 3.13. Factors for changes in calves per cow and milk per cow by state.[a]

State	Calves Per Cows	Milk Per Cows
Maine	1.01	1.59
N.H.	1.01	1.62
Vt.	1.01	1.61
Mass.	1.01	1.72
R.I.	1.08	1.80
Conn.	1.04	1.71
N.Y.	1.03	1.70
N.H.	1.06	1.78
Pa.	1.03	1.66
Ohio	1.10	1.63
Ind.	1.10	1.61
Ill.	1.01	1.62
Mich.	1.08	1.67
Wis.	1.02	1.70
Minn.	1.02	1.66
Iowa	1.02	1.59
Mo.	1.02	1.50
N. Dak.	1.02	1.46
S. Dak.	1.12	1.50
Nebr.	1.08	1.51
Kans.	1.03	1.51
Del.	1.08	1.58
Md.	1.10	1.62
Va.	1.10	1.48

Table 3.13. (continued)

State	Calves Per Cows	Milk Per Cows
W. Va.	1.10	1.40
N.C.	1.10	1.48
S.C.	1.15	1.41
Ga.	1.18	1.45
Fla.	1.10	1.52
Ky.	1.03	1.41
Tenn.	1.07	1.38
Ala.	1.24	1.33
Miss.	1.08	1.24
Ark.	1.23	1.39
La.	1.19	1.23
Okla.	1.04	1.49
Texas	1.07	1.48
Mont.	1.13	1.53
Idaho	1.07	1.69
Wyo.	1.13	1.55
Colo.	1.11	1.55
N. Mex.	1.07	1.50
Ariz.	1.03	1.76
Utah	1.19	1.75
Nev.	1.08	1.70
Wash.	1.01	1.75
Oreg.	1.13	1.64
Calif.	1.11	1.86

[a] Calculated as projected output in 2000/output in 1964.

the commodities included, are not palatable to the livestock unit. An example is to provide the energy component of a beef feeding ration from wheat which under normal management systems is not a feasible alternative. All rations provided for each of the livestock groups are balanced in separate mathematical formulations based on the nutrient requirements specified by the National Academy of Sciences[165, 166, 167]. The rations are formulated to provide alternative levels of substitution between grains, between roughages and grains, and between the roughages given a grain component. These rations reflect research based recommendations which approximate an optimal level of feeding efficiency. In order to account for the "inefficiency" of actual production, the rations are adjusted to set the level of total digestible nutrient consumption at the level of projected TDN consumption as described above to give the regional rations. By providing alternative rations at the outer edges of the substitution possiblity, a linear combination of these rations will provide the system with a larger number of possible rations.

In the rations the oilmeal requirements are based on the total demand for soybean meal equivalent high protein supplements. Part of this requirement is satisfied by high protein grain by-products or from animal slaughter by-products. The historic consumption patterns of animal and grian protein are related to slaughter and milling, respectively. The consumption level per unit of processing determined is assumed to hold to the year 2000. Livestock production has its high protein demands reduced by the expected production resulting from the slaughter of each type of livestock and the milling production of grain protein is accounted for by adjusting the per capita consumption of the commodities determined.

The rations for the exogenous livestock, Table 3.14, are used in conjunction with the projected level of the exogenous livestock group to creat a predetermined demand for the commodities.

Livestock water requirements

State data were used to develop the livestock water use coefficients [31, 164, 251]. The livestock diversion is assumed equal to consumption. Where production areas cross state lines, the water coefficients are determined by setting the county water coefficient equal to the coefficient of the state in which it is located, Table 3.15, and weighting the assigned county coefficients proportionate to the number of the relevant animal units in the county as determined from the 1964 Census of Agriculture [265].

Livestock production of nitrogenous wastes

Livestock wastes historically have served as a local source of plant nutrients. With the advance of technology and the resulting concentration of large numbers of livestock in localized feeding facilities, the disposal of the waste products has become of concern to the operators of the facilities and the community. All livestock activities considered in the model produce a quantity of nitrogen wastes which may be utilized in the cropping sector as a fertilizer nitrogen

Table 3.14. Rations for the exogenous livestock activities.

Livestock	Corn bu.	Sorghum bu.	Barley bu.	Oats bu.	Wheat bu.	Oilmeals cwt.	Pasture tons	Units
Sheep	1.04	0.25	0.32	0.17	0.01	1.01	1.01	cwt carc
Broilers	27.01	1.89	0.67	0.15	0.14	12.29	0.0	1000 lb rcw
Turkeys	44.45	7.94	0.0	1.33	2.70	14.43	0.01	1000 lb rcw
Eggs	36.86	9.77	11.16	2.60	3.69	12.36	0.0	1000 doz
Other	9.99	2.84	0.15	0.65	0.43	0.96	0.16	index = 1000

Table 3.15. Water consumption by livestock activity units by state.

	Hogs	Turkeys	Chicken	Broilers	Sheep & Lambs	Dairy	Beef	Feeder	Horses
	a.f. per cwt car.	a.f. per cwt ready-to-cook	a.f. per (000) dozen	a.f. per cwt ready-to-cook	a.f. per cwt of carcass	a.f. per cow eq.	a.f. per cow eq.	a.f. per head	a.f. per head
Arizona	-	-	-	-	-	.0409	-	-	-
Arkansas	.00092	.00029	.00306	.00054	-	.0409	.0197	-	.0168
California	-	-	-	-	-	.0341	.0197	-	.0168
Colorado	.00060	.00066	.00550	.00097	-	.0204	.0144	-	-
Missouri	-	.00029	-	-	-	.0409	.0263	-	-
Nevada	-	-	-	-	-	-	.0079	-	-
New Mexico	.00092	-	.00306	.00054	-	.0341	-	-	-
South Dakota	.00230	.00055	.00611	.00108	-	.0477	.0197	-	.0134
Wyoming	.00184	-	.00367	.00065	.00668	.0409	.0157	-	-
Other states	.00138	.00022	.00244	.00043	.00668	.0273	.0131	.0094	.0112

SOURCES: Clark [5]; Murray [41]; U.S. Dept. Agr. [95].

source. Data expressing the daily production of nitrogen wastes for the different classes of livestock [151, 173] are adjusted for the efficiency of the handling system and for the feeding time and pattern of the activity [300]. The calculated per unit production of nitrogen, Table 3.16, is used as the activities coefficient for interacting with the nitrogen sector.

Table 3.16. Nitrogen fertilzier equivalent wastes from livestock.

Type	Unit	Lbs. of N per unit
Beef cows	Head per year	58.0
Beef feeding (1.5) [a]	Head per day	.102
Beef feeding (2.25)[a]	Head per day	.103
Beef feeding (3.0) [a]	Head per day	.105
Dairy	Head per day	142.0
Hogs	Cwt. liveweight	2.8
Eggs	1,000 dozen	20.5
Poultry [b]	1,000 lbs. ready to cook weight	28.0
Sheep	Cwt. carcass weight	2.17

[a] Rates are expected daily gain of the feeders while in the lot.

[b] Poultry represents the production of broilers or turkeys.

The quantity of nitrogen equivalent wastes produced by broilers is determined and a comparable production of nitrogen waste is calculated for the other poultry classes based on feed consumption and commodity production relative to broilers. Sheep and lamb wastes are calculated from the coefficients of the endogenous ruminants based on the waste production per unit of output.

The Demand Sector

Restraints are defined in the programming model to require production of the commodities at a level consistent with domestic food and fiber, export, and intermediate feed requirements. The endogenous uses are as intermediate inputs (feed) for the livestock sectors and are discussed in the livestock sections of this report. The exogenous requirements for domestic and export uses are outlined below.

Per capita commodity demands

The per capita direct demands for corn, sorghum, barley, oats, wheat, and sugar beets are based on the average 1967 to 1969 use of each. The corn and sorghum demand is based on their uses for milling, brewing and cereals. Similar uses are considered when calculating the demand for barley, oats, and wheat. The per capita consumption level of cotton is calculated using the consumption levels over the past 30 years and projecting to 2000 on this basis. The average sugar beet production per capita over the 1967 to 1969 period is used as a proxy for the demand for sugar. This procedure is used since a large proportion of the sugar consumed in the nation is imported from countries producing sugar cane and to assume some increase in the proportion of total sugar from sugar beets is not warranted when compared to past trends in the sugar market.

Per capita consumption levels of beef, pork, and broilers are determined from the price-quantity equations developed by Waugh [301]. These equations were developed in a price dependent form and for quantity determination were inverted to give:

$$Q_B = 43.7809 - 0.7697P_B + 0.1076P_{Br} - 0.0386Y \qquad (3.18)$$

$$Q_P = 90.1111 - 0.2786P_B - 0.9612P_P + 0.0728P_{Br} + 0.0032Y \qquad (3.20)$$

$$Q_{Br} = 32.0623 + 0.1076P_B + 0.0728P_P - 0.4485P_{Br} + 0.0023Y \qquad (3.20)$$

where:

Q_B is the beef consumed in pounds per capita in 2000 on a carcass weight basis;
Q_P is the pork consumed in pounds per capita in 2000 on a carcass weight basis;
Q_{Br} is the broilers consumed in pounds per capita in 2000 on a ready-to-cook basis;
P_B is the expected price of beef in 2000;[19]
P_P is the expected price of pork in 2000;[19]
P_{Br} is the expected price of broilers in 2000;[19]

Y is the projected per capita disposable income in 2000.[20]

Using the prices assumed to prevail in 2000 and the appropriate level of disposable income the equations are solved for the per capita consumption levels for the respective quantities, Table 3.17.

The per capita consumptions of turkeys, milk, eggs, and lamb and mutton are calculated from the following equations, respectively:

$$Q_T = e^{2.40871} P_T^{-043835} P_B^{0.19729} t^{0.21801} \qquad (3.21)$$

$$Q_M = e^{6.6301 - 0.019t} \qquad (3.22)$$

$$Q_E = e^{6.00183 - 0.1264t} \qquad (3.23)$$

$$Q_L = e^{5.56087} P_L^{-1.9916} P_B^{0.57397} Y^{0.36813} t^{-.13775} \qquad (3.24)$$

where:

Q_T is the turkey consumed in pounds per capita in 2000 on a ready-to-cook basis;

Q_M is the dairy products consumed in pounds per capita in 2000 on a whole milk equivalent basis;

Q_E is the number of eggs consumed per capita in 2000;

Table 3.17. Projected per capita consumption levels for the commodities in the year 2000.

Commodity	Consumption	Commodity	Consumption
Corn	1.20 bushels	Fed beef	108 lbs. carc. wt.
Sorghum	0.05 bushels	Nonfed beef	51 lbs. carc. wt.
Wheat-total	2.58 bushels	Dairy products	4.04 cwt. milk eq.
Wheat-spring	0.52 bushels	Pork	68 lbs. carc. wt.
Oats	0.22 bushels	Broilers[b]	40 lbs. ready-to-cook
Barley	0.58 bushels	Turkey[b]	9 lbs. ready-to-cook
Oilmeals[a]	0.09 cwt.	Lamb and mutton[b]	3 lbs. carc. wt.
Lint cotton	12.0 pounds	Eggs[b]	207.5 eggs
Sugar beets	0.11 tons		

[a] Oilmeal requirement reflects an adjustment for the high protein grain by-products provided from the milling of the per capita equivalent of the other grains.

[b] Not used directly in the population-industry activities but used in conjunction with the population to determine the level of commodity demand and the resource use by class of livestock in the exogenous livestock sector.

Q_L is the lamb and mutton consumed in pounds per capita in 2000 on a carcass weight basis;

e is the base of the natural logarithm;

P_T is the expected price of turkeys in 2000;[21]

P_B is the expected price of beef in 2000;[21]

t is time in years after 1947;

P_L is the expected price of lamb and mutton in 2000;[22]

Y is the projected per capita income in 2000.[23]

The per capita consumption levels of turkeys, broilers, lamb and mutton, sugar beets, and eggs, Table 3.17, are multiplied by the projected population and adjusted for foreign trade to give the lower bounds on the national production activities for the respective commodities. The per capita demands for beef, pork, and milk are used in the producing area population activities to creat a demand in the consuming region equal to the sum of all the producing areas' population times per capita consumption for the commodity in each consuming region.

International trade

Activities are included in the programming model to represent alternative levels of agricultural commodity exports. The base export levels used for all commodities are 1969-71 average volumes, Table 3.18. The export levels for the exogenous commodities is handled in the programming model by adjustments in per capita requirements for a given commodity. A net import decreases the production requirements of the commodity.

Table 3.18. Base level net exports of commodities for the year 2000.

Commodity	Import (000)	Export (000)
Corn		626,333 bu.
Sorghum		126,666 bu.
Barley		48,666 bu.
Oats		16,179 bu.
Wheat		658,719 bu.
Oilmeals[a]		276,407 cwt.
Cotton		3,306 bales
Beef	22,453 cwt.	
Pork	3,349 cwt.	
Dairy products[b]	4,661 cwt.	
Broilers		295,416 cwt.
Turkeys		44,162 cwt.
Eggs		68,699 doz.
Sheep and lamb	1,647 cwt.	

[a] Oilmeals are expressed as soybean oilmeal equivalent of soybean oilmeal, cottonseed oilmeal, cottonseed and soybeans.

[b] Dairy products are expressed as cwt. of milk equivalents.

Exports of corn grain, sorghum grain, barley, oats, wheat, and oilmeals are allocated to the consuming regions proportional to the average exports of each commodity from the major ports over the 1967-69 period [36, 37, 38, 39].

The Transportation Sector

The availability of and demands for commodities are defined by consuming region. This implies that there is no spatial differentiation among commodities produced or demanded in various producing areas within a consuming region. However, among consuming regions, the cost of transporting commodities is specified.

Consuming regions are defined using dual criteria: first, the central city is a major metropolitan area and second, the central city is a transportation center. Fox [103] defined 24 such regions which are modified such that 30 consuming regions are defined. The precise boundaries of the consuming regions are determined by the boundaries of the producing regions included.

Transportation routes

Transportation routes are defined between each pair of contiguous consuming regions. The model is basically one of partial trans-shipment. However, some heavily used long haul routes between noncontiguous regions also exist, and transportation routes are defined to represent the long haul routes if the route reduced the mileage by ten percent over the accumulated short haul routes.

Over each route two activities are defined for each commodity--one activity for shipment in each direction.

Transportation activity costs

A uniform rate is applied to each commodity over all routes. Ton-mile rates as functions of distance for various commodities are determined by least-squares regression from data given in the 1966 Carload Waybill Statistics [135]. Table 3.19 shows the equations used.

Similar data on milk shipments are not available. However, over-the-road costs of fluid milk transportation have been estimated by Moede [161]. The costs are calculated as:

$$\begin{aligned} C &= 4.434 + .058D \text{ when } D < 225, \\ C &= 6.293 + .058D \text{ when } 225 \leq D < 450, \\ C &= 8.878 + 0.58D \text{ when } 450 \leq D < 675, \\ C &= 8.444 + 0.59D \text{ when } 675 \leq D, \end{aligned} \tag{3.32}$$

where:

C is cost in cents/ton-mile and
D is distance in miles.

In calculating the costs for the transportation activities, these rates are held constant. The carcass rate is used for both beef and pork. The cost for each activity is the distance of the route multiplied by the appropriate rate, converted into the units of the commodity restraint row.

Table 3.19. Calculation of rail freight rates.

Commodity	Equation[a]	
Carcasses	$C = e^{4.0935-0.4478D}$	(3.25)
Oilmeals	$C = e^{2.35975-0.318496D}$	(3.26)
Feeders	$C = e^{3.269555-0.337677D}$	(3.27)
Wheat	$C = e^{3.723356-0.538235D}$	(3.28)
Sorghum	$C = e^{3.513613-0.518981D}$	(3.29)
Corn	$C = e^{3.332431-0.537088D}$	(3.30)
Barley	$C = e^{2.544014-0.310044D}$	(3.31)

[a] C is the cost in cents/ton-mile; D is distance in miles.

Chapter Four

Results Available from the Model

AN OPTIMAL solution obtained by the model for the set of equations defined in Chapter II provides the base regional activity levels which minimize the total costs of meeting the specified demand levels subject to the given restraints. This set of base activities can be combined with the support data to allow for presentation and interpretation of the results. This section initially will cover the interpretations of the solution variables and will follow with a discussion and sample of the possible complete output of the production variables in the model. The programming solution procedures include three routines which provide separate interpretations of the system of equations solved. These include the solution, indicating the levels of the activities and the associated limits, costs, and use of the activity or resource; a range analysis, indicating the amount of change which can occur in each of the variables before the basic solution is altered; and an analysis of the change that will occur in the basic solution if a specified nonbasic activity is included.

Interpreting the Solution

Included in a solution of the programming procedure is an analysis of the restraints (rows) and the analysis of the activities (columns). In most of the commercially available packages, these sections are handled individually in the solution prints. The restraint or rows' section of the solution indicates the level of use, the range of possible use, and the implied value of the restraint.

The level of use of a restraint is determined as the sum of all activity levels multiplied by their interaction coefficient for the given restraint or:

$$RL_j = \underset{i}{X_i}\ a_{ij} \qquad (4.1)$$

$i = 1,2,\ldots,$ for all activities,
$j = 1,2,\ldots,$ for all restraints,

where:

RL_j is the level of use of resource j;
X_i is the level of incorporation of activity i; and
a_{ij} is the interaction coefficient between activity i and resource j.

The value of RL_j will be confined by the lower and upper limits of incorporation specified for the resource. These values are listed to the right of the activity level on the solution print. The slack activity listed represents the difference between the defined restraint for the row and the activity level reported. If the row is designated as a "less than or equal to" restraint, the slack is calculated using the upper limit as the restraint even if a lower limit is also defined. Similarly, if the row is designated as a "greater than or equal to" restraint the slack is calculated using the lower limit as the restraint even if an upper limit is also defined. Thus, slack activity levels for the "greater than or equal to" rows will be negative and on the "less than or equal to" rows will be positive.

The implied value of the resource is indicated as the dual activity of the row in the model. The dual activity is often referred to as the shadow price and represents the marginal value product of the resource. The value of the dual activity is zero unless the restraint is at a limit in the given solution. The dual activity or marginal value product represents the amount by which the total cost (objective function value) of the program will be reduced if the limit on the supply of the resource is reduced by one unit. In other words, it represents the marginal value product of the last unit of the resource. On the restraints that simulate markets, the dual activity represents the marginal cost of the last unit of the commodity and would reflect the market price if all input's costs are considered in the model. These marginal costs reflect both the production and transportation costs of satisfying the demand.

Being consistent with the definition, restraints at the upper level will have a positive dual activity as a limit of one less would remove from use the last unit and would reduce the value of the solution by the indicated amount. Similarly, restraints at the lower limit will have a negative dual activity, and those at nonrestrained levels will have a dual activity value of zero. Within the model, as developed, dual activities or shadow prices are determined at the producing area level for nitrogen fertilizer, pasture in hay-equivalent value, and land by the nine land classes. Shadow prices are determined at the water supply region level for water and at the market region for all the commodities except sugar beets, cotton, and spring wheat which have national markets and thus national shadow prices.

The final section of the solution is the columns' or activities' section. This section of the solution lists the activities, their status in the solution--either at a limit, in the basis, or not in the active solution--the level of incorporation in the solution, the input cost for the activity, and the reduced cost or shadow price for the activity. The activity level represents the actual number of units of the activity incorporated into the solution to minimize the value of the objective function (cost function) subject to the resource availabilities defined. The input cost is obtained from the objective function coefficient for the activity and represents its associated nonendogenously determined costs of use. The lower and upper limits are as the titles indicate--the imposed lower and upper limits on the activity as set in the bounds' section of the programming procedures. The normal or default values for all activities are a lower limit greater than zero and no upper limit. The reduced cost or activity shadow price represents the amount by which the objective function (the model cost) will be reduced if the activity level was reduced by one unit.

Thus, activities with no upper bound have no reduced cost or shadow price as their only cost is associated with resource availability and not with limits on their use. Activities at a lower bound (generally demand-creating activities) will have a positive shadow price, and activities at the upper limit will have negative shadow prices. All activities not included in the basis have zero activity levels and are at the lower limit of zero and reflect a shadow price equivalent to the change in the cost function if one unit of the activity was incorporated--in other words, the penalty which would be experienced from introducing use of the activity.

The solution provides the basis for determining the variations in the results. When combined with the secondary input data sets, it provides the total of the comparisons which can be made between two alternative solutions to the model. These data comparisons for the present model are outlined in the upcoming section. However, prior to this comparison, an outline will be given of two other output techniques which can provide supplementary data to analyze the significance and the sensitivity of the results obtained.

Additional Output Data

These two additional outputs from the programming analysis include a range analysis and an analysis of the impact on the basic solution of changing one activity level within the model.

Range analysis is a post-optimal procedure which undertakes an analysis of the model in terms of its present basic solution.

The range analysis provides three types of information. They are:

1. An indication of the effect of a cost (objective function value) change on the optimum activity levels.
2. The cost of changing a column activity from the optimal level and the activity range over which this cost will prevail. This gives an indication of the range over which the reduced cost or shadow price of an activity will hold.
3. The value to the solution of a change in a row activity level and the interval over which it is valid. This gives the range of possible resource level changes over which the dual activity or shadow price will be relevant for the given resource or other restraint.

This type of analysis gives an indication of when a solution needs to be reestimated because of changes in the costs or availability of the resources or production techniques. The printout gives an indication of the relevant length of the particular linear segment of a demand or supply curve that the solution is presently indicating as the equilibrium sector.

The second type of post-optimal analysis is obtained by premultiplying a given nonbasic vector by the inverse of the basis. This operation gives the impact on the solution caused by introducing a given activity and could represent investigating the possible effects of incorporating a conbasic commodity or technology into the agricultural production sector. The procedure also allows for a print of the current inverse to give the unit interaction coefficients for the basic variables. This provides a requirement's matrix for all the basic variables.

Format of Results

The optimal solution to the programming model, when combined with the second level input data, provides the basis to determine the impacts of the alternative policies being evaluated by the model in greater detail than is available from the solution as an individual source. The results available, on a regional basis, include data on:

1. acres of dryland and irrigated crops by land class;
2. nitrogen utilization and price;
3. an aggregative water-use table;
4. yields of dryland and irrigated crops by land class;
5. value of resource use in crop production;
6. the quantity and value of resource used in livestock production;
7. the quantity and value of the commodities produced;
8. land use, value of land, soil loss, and slack land-by-land class;
9. acreage and soil loss by land class and conservation-tillage practice;
10. acreage and percent of land farmed under rotations of varying length; and
11. water balance by water supply regions for both consumption and withdrawal needs.

The specific format and interpretation of these information items are presented in the following tables with their supplementary term definitions. The tables are presented as produced in the summary routines presently used with the model. Most indicate the national summary but can be obtained at the producing area, market region, or any other predetermined aggregation level desired. The greater the level of aggregation, the lower the level of bias resulting from the linear characteristics of the programming system.

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---------------------------------------------------------------------------------------------------------------------------
            BARLEY  CORN-G  CORN-S  COTTON   HAY-L   HAY-N  FALLOW    OATS           PAST-N  SORG-G  SORG-S  S BEAN  S BEET   WHEAT
---------------------------------------------------------------------------------------------------------------------------
```

Table 4.1.

```
                                        <<<<< DRYLAND CROP ACREAGES >>>>>

LG1-D          358   10987    2084    1746    3069      42       6     434       0       0     149    1108    2890       0    1433
LG1-I            0       0       0     291     378       0       0       0       0       0     279       0       0       0     182
LG2-D          498   25887    4733     947   12371     125     299    3561       0       0    2150    4261   13967       0    6873
LG2-I            0       0       0     855     602       0       0     281       0       0    1347     232       0       0      74
LG3-D          716   35331    2526    4061   11521     285     412    1405       0       0     570    2756    6899     525    8606
LG3-I            0       0       0       4     114     121       0      21       0       0       0       0       0       0      12
LG4-D         4414   10705    2143    2193   12708    1219    1017    2136       0       0    5640    2365    8875     130   11921
LG4-I           98      33       0     335     122       4      72       1       0       0     361      34      33       0     114
LG5-D         2717    8418    1108    2721    7660    1087     164    1049       0       0     331    3296    9872     292    7535
LG5-I           26       6       0       2     149     481       0      16       0       0     123      92       6       0     109
LG6-D          924    2735     566     918    7177     629     975    1143       0       0    2504     827    1878      40    8038
LG6-I           27      17       0      77      72       8      13       1       0       0      23      45      17       0     149
LG7-D         5329    1008     372    1981    7249     215     123     389       0       0     535     373    4928      60    2830
LG7-I           43       0       0       2      75      36      24       3       0       0      32       0       0       0     122
LG8-D            0      28       0       9     118      10       0      15       0       0      15       0      13       0     111
LG8-I            0       0       0       0       0       0       0       0       0       0       0       0       0       0       0
LG9-D            0     348       0       0    2923    1608     674     816       0       0     222      34      56       0    1401
LG9-I            2       0       0       0      15       2      25       3       0       0      34       2       0       0      38
LG10-D           0       0       0       0       0       0       0       0       0  635491       0       0       0       0       0
LG10-I           0       0       0       0       0       0       0       0       0       0       0       0       0       0       0
SUB LG1-5     8827   91365   12594   13155   48694    3364    1970    8904       0       0   10950   14143   42542     948   36859
SUB LG6-9     6326    4136     938    2987   17629    2506    1834    2369       0       0    3364    1281    6893     101   12689
TOTAL        15153   95501   13533   16142   66322    5870    3804   11273       0  635491   14314   15424   49435    1048   49548
```

Table 4.2.

```
                                        <<<<< IRRIGATED CROP ACREAGES >>>>>

LG1              0    1789     498     857     947       0       0     121       0       0     223     472       0      54     104
LG2             17     625     158     159    1213       0       0     119       0       0     478     118     298       2     320
LG3            216     247     312     395    2216       0       0      80       0       0     156     215      90      80     531
LG4            116     227     429      63     785     113       0      29       0       0     153       0      33       1     356
LG5            207     417     328     176    2184       0       0      65       0       0     136       0      12      65     258
LG6              0      21     139       6     284       0       0       6       0       0     136       0      10       1     160
LG7             91       9     178     113     358      22       0      12       0       0       4       0       1      11      49
LG8              0       0       0       0       0       0       0       0       0       0       0       0       0       0       0
LG9             42       0       0       0     103       0       0       0       0       0       0       0       0       3      11
LG10             0       0       0       0       0       0       0       0       0    9504       0       0       0       0       0
SUB LG1-5      556    3305    1725    1650    7345     113       0     415       0       0    1146     805     433     201    1570
SUB LG6-9      133      30     317     119     746      22       0      19       0       0     140       0      12      15     220
TOTAL          689    3335    2042    1769    8091     135       0     434       0    9504    1286     805     444     216    1790
GRAND TOTL   15842   98836   15574   17911   74413    6006    3804   11707       0  644995   15600   16229   49879    1265   51338
```

Table 4.3.

```
                                        <<<<< NITROGEN BALANCE TABLE >>>>>
            ------------------------AVAILABLE---------------------     ----------UTILIZED-------
              PURCHASED      LIVESTOCK      ROTATIONS          TOTAL           USED          SLACK            PRICE
QUANTITY    23161626.32     7200732.41           0.00    30362358.72    30248009.41      114349.32             0.00
VALUE        3232988.98      986015.36           0.00     4219004.34     4219006.43          -2.09             0.14
```

Table 4.4.

```
                                        <<<<< WATER USE TABLE >>>>>
                  CROPS      LIVESTOCK          VALUE          PRICE

               65150.50        1223.06     1274750.30          19.21
```

Description of the row and column headers in Table 4.1; dryland crop acreages by soil group.

Rows

1. LG1-D is land class I dryland
2. LG1-I is land class I irrigated land used for dryland crops
3. LG2-D is land class IIE dryland
4. LG2-I is land class IIE irrigated land used for dryland crops
5. LG3-D is land classes IIS, IIW, IIC dryland
6. LG3-I is land classes IIS, IIW, IIC irrigated land used for dryland crops
7. LG4-D is land class IIIE dryland
8. LG4-I is land class IIIE irrigated land used for dryland crops
9. LG5-D is land classes IIIS, IIIW, IIIC dryland
10. LG5-I is land classes IIIS, IIIW, IIIC irrigated land used for dryland crops
11. LG6-D is land class IVE dryland
12. LG6-I is land class IVE irrigated land used for dryland crops
13. LG7-D is land classes IVS, IVW, IVC dryland
14. LG7-I is land classes IVS, IVW, IVC irrigated land used for dryland crops
15. LG8-D is land class V dryland
16. LG8-I is land class V irrigated land used for dryland crops
17. LG9-D is land classes VI, VII, VIII dryland
18. LG9-I is land classes VI, VII, VIII irrigated land used for dryland crops
19. LG10-D is total noncultivated hay (including wild hay) and noncultivated pasture dryland
20. LG10-I is total noncultivated hay (including wild hay) and noncultivated pasture irrigated
21. SUB LG1-5 is the summation of rows 1-10
22. SUB LG6-9 is the summation of rows 11-18
23. TOTAL is the summation of rows 1-20

Columns (000 acres)

1. BARLEY is barley for grain
2. CORN-G is corn for grain
3. CORN-S is corn for silage
4. COTTON is cotton for lint (by product is cotton seed oilmeal)

5. HAY-L is legume hay grown in rotation
6. HAY-N is nonlegume hay grown in rotation
7. FALLOW is summer fallow land
8. OATS is oats for grain
9. Empty file
10. PAST-N is permanent pasture and hay not cultivated in rotation
11. SORG-G is sorghum for grain
12. SORG-S is sorghum for silage
13. S BEAN is soybeans for beans
14. S BEET is sugar beets for beets
15. WHEAT is wheat (all wheat) for grain

Description of the row and column headers in Table 4.2; irrigated crop acreages by soil group.

Rows

1. LG1 is land class I irrigated
2. LG2 is land class IIE irrigated
3. LG3 is land classes IIS, IIW, IIC irrigated
4. LG4 is land class IIIE irrigated
5. LG5 is land classes IIIS, IIIW, IIIC irrigated
6. LG6 is land class IVE irrigated
7. LG7 is land class IVS, IVW, IVC irrigated
8. LG8 is land class V irrigated
9. LG9 is land classes VI, VII, VIII irrigated
10. LG10 is total noncultivated hay and noncultivated pasture irrigated
11. SUB LG1-5 is the summation of rows 1-5
12. SUB LG6-9 is the summation of rows 6-9
13. TOTAL is the summation of rows 1-10
14. GRAND TOTAL is the summation of row 23 from Table 4.1 and row 13 from Table 4.2.

Columns

Columns are the same as for Table 4.1.

Description of the row and column headers in Table 4.3; nitrogen balance table.

Rows

1. QUANTITY is the quantity of nitrogen (000 tons)
2. VALUE is the value of nitrogen (000,000 dollars)

Columns

1. PURCHASED is nitrogen purchased
2. LIVESTOCK is nitrogen from livestock wastes
3. ROTATIONS is an empty file
4. TOTAL is the summation of columns 1-2
5. USED is the amount of nitrogen used by endogenous and exogenous crops (over and above nitrogen contributed by legume carry over)
6. SLACK is column 4 minus column 5 (surplus nitrogen from livestock)
7. PRICE is the weighted average shadow price of nitrogen (dollars per pound)

Description of the row and column headers in Table 4.4; water use by endogenous crop and livestock production.

Rows

No rows

Columns

1. CROPS is the quantity of water consumed by endogenous crops (000 acre feet)
2. LIVESTOCK is the quantity of water consumed by endogenous livestock (000 acre feet)
3. VALUE is the total value (price times quantity) of water consumed by endogenous crops and livestock production
4. PRICE is column 3 divided by the summation of columns 1-2 or the average price of water consumed (dollars per acre foot)

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Table 4.5. <<<<< DRYLAND CROP YIELDS >>>>>

	BARLEY	CORN-G	CORN-S	COTTON	HAY-L	HAY-N	FALLOW	OATS		PAST-N	SORG-G	SORG-S	S BEAN	S BEET	WHEAT
LG1	40.0	118.4	15.2	1.4	4.2	2.5	0.0	63.2	0.0	0.0	40.6	25.0	38.7	0.0	39.2
LG2	60.6	104.5	13.6	1.0	3.0	2.3	0.0	60.5	0.0	0.0	38.1	15.9	35.3	0.0	35.8
LG3	42.4	104.3	12.0	1.3	3.0	2.2	0.0	61.4	0.0	0.0	60.9	17.2	34.1	21.4	34.4
LG4	45.0	97.3	10.6	1.0	2.7	1.7	0.0	47.2	0.0	0.0	47.0	17.8	34.5	20.3	33.9
LG5	40.9	79.1	10.9	0.9	2.8	2.0	0.0	57.2	0.0	0.0	21.3	9.3	29.7	19.1	33.4
LG6	39.3	79.8	9.3	0.7	2.6	2.0	0.0	46.2	0.0	0.0	33.4	8.0	32.0	18.9	24.5
LG7	20.1	57.4	8.0	0.9	1.8	1.4	0.0	37.3	0.0	0.0	25.6	6.6	28.6	16.5	17.7
LG8	0.0	48.0	7.5	0.3	2.6	1.7	0.0	42.3	0.0	0.0	19.1	0.0	14.1	0.0	16.0
LG9	22.5	32.0	0.0	0.0	1.8	1.3	0.0	26.9	0.0	0.0	8.6	4.9	7.7	0.0	13.5
LG10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
SUB LG1-5	44.2	102.9	12.8	1.1	3.0	1.9	0.0	57.2	0.0	0.0	43.5	15.6	33.9	20.5	34.5
SUB LG6-9	23.0	70.1	8.8	0.8	2.2	1.5	0.0	38.0	0.0	0.0	30.1	7.5	29.4	17.5	21.6
TOTAL	35.3	101.5	12.5	1.1	2.8	1.7	0.0	53.2	0.0	0.1	40.4	14.9	33.2	20.2	31.2

Table 4.6. <<<<< IRRIGATED CROP YIELDS >>>>>

	BARLEY	CORN-G	CORN-S	COTTON	HAY-L	HAY-N	FALLOW	OATS		PAST-N	SORG-G	SORG-S	S BEAN	S BEET	WHEAT
LG1	0.0	188.9	20.1	2.0	6.0	0.0	0.0	96.1	0.0	0.0	106.6	20.5	0.0	33.2	67.9
LG2	121.2	110.3	16.5	1.4	6.1	0.0	0.0	91.4	0.0	0.0	55.8	18.2	47.5	16.7	74.5
LG3	60.3	110.6	14.9	2.0	6.0	0.0	0.0	76.9	0.0	0.0	81.6	18.6	44.7	20.3	71.3
LG4	57.3	91.0	13.8	1.5	3.9	1.4	0.0	52.9	0.0	0.0	72.4	0.0	35.2	16.1	47.4
LG5	56.2	73.7	11.9	1.3	5.1	0.0	0.0	48.1	0.0	0.0	48.7	0.0	43.2	23.2	49.2
LG6	0.0	73.4	11.7	1.0	3.6	0.0	0.0	37.9	0.0	0.0	57.5	0.0	35.8	14.4	39.2
LG7	39.7	67.6	10.7	1.8	4.1	1.3	0.0	27.9	0.0	0.0	63.3	0.0	31.4	17.3	41.6
LG8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LG9	24.0	0.0	0.0	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	21.8
LG10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0
SUB LG1-5	60.0	146.9	15.7	1.9	5.5	1.4	0.0	80.4	0.0	0.0	70.6	19.7	45.9	24.6	62.7
SUB LG6-9	34.8	71.6	11.2	1.8	4.1	1.3	0.0	31.2	0.0	0.0	57.6	0.0	35.3	14.9	38.8
TOTAL	55.1	146.2	15.0	1.9	5.4	1.4	0.0	78.3	0.0	2.5	69.2	19.7	45.6	23.9	59.7
GRAND TOTL	36.2	103.0	12.9	1.2	3.1	1.7	0.0	54.1	0.0	0.1	42.8	15.2	33.4	20.9	32.2

Table 4.7. <<<<< RESOURCE USE IN CROP PRODUCTION - VALUES >>>>>

	LAND	WATER	LABOR	PEST	FERT-T	FERT-N	FERT-OBJ	MACH	OTHER	SOIL-LOSS	TOTAL
BARLEY	892352	3427	106896	9057	76820	33036	43784	482102	3907	0	1574560
CORN-G	16729799	107839	1233203	774072	2852107	1675485	1176622	5446283	437934	0	27581237
CORN-S	2418691	37326	286139	31997	366714	159286	207429	1080683	68530	0	4290080
COTTON	3246398	108329	623684	318437	275861	114946	160915	1019160	111622	0	5703492
HAY-L	7988464	327923	846666	64960	435791	37709	398082	3096873	305897	0	13066573
HAY-N	538650	680	51685	17998	27666	13169	14497	219471	28669	0	884819
S FALLOW	260684	0	24076	2041	0	0	0	130152	1479	0	418433
OATS	1174027	6490	88727	20191	120809	11698	109111	395537	7524	0	1813304
	0	0	0	0	0	0	0	0	0	0	0
PAST-N	0	0	0	0	0	0	0	0	0	0	0
SORG-G	1650419	88154	119098	14434	145554	76996	68557	586550	12824	0	2617033
SORG-S	2416293	108959	326018	8301	281709	40196	241513	1182639	44862	0	4368782
SOYBEANS	7717786	20844	207501	125028	105550	3237	102313	1252698	45108	0	9474515
SUGAR BEET	172754	1358	30979	3226	21812	3292	18521	26428	4138	0	260695
WHEAT	5523563	40379	249931	77024	460259	178571	281688	1382441	34876	0	7768474
TOTAL	50729880	851708	4194604	1466765	5170652	2347621	2823031	16301016	1107371	0	79821998

Description of the row and column headers in Table 4.5; dryland crop yields by land group and Table 4.6; irrigated crop yields by land group.

Rows

1. LG1 is land class I
2. LG2 is land class IIE.
3. LG3 is land classes IIS, IIW, IIC
4. LG4 is land class IIIE
5. LG5 is land classes IIIS, IIIW, IIIC
6. LG6 is land class IVE
7. LG7 is land classes IVS, IVW, IVC
8. LG8 is land class V
9. LG9 is land classes VI, VII, VIII
10. LG10 is land used for noncultivated hay and noncultivated pasture (permanent)
11. SUB LG1-5 is the summation of rows 1-5 (weighted average)
12. SUB LG6 -LG9 is the summation of rows 6-9 (weighted average)
13. TOTAL is the summation of rows 1-10 (weighted average)
14. GRAND TOTAL (Table 4.6 only) is the summation of row 13 from Table 4.5 and row 13 from Table 4.6 (weighted average)

Columns

1. BARLEY is the yield of barley (bushels per acre)
2. CORN-G is the yield of corn for grain (bushels per acre)
3. CORN-S is the yield of corn for silage (wet tons per acre)
4. COTTON is the yield of cotton lint (bales per acre, 480 pound net per bale)
5. HAY-L is the yield of legume hay grown in rotation (dry tons per acre)
6. HAY-N is the yield of nonlegume hay grown in rotation (dry tons per acre)
7. FALLOW is an empty file
8. OATS is the yield of oats (bushels per acre)
9. Empty file.
10. PAST-N is the average yield of nonrotation hay and nonrotation pasture (dry tons per acre of hay equivalent)
11. SORG-G is the yield of sorghum for grain (bushels per acre)
12. SORG-S is the yield of sorghum for silage (wet tons per acre)

13. S BEAN is the yield of soybeans (bushels per acre)

14. S BEET is the yield of sugar beets (tons per acre)

15. WHEAT is the yield of all wheat (bushels per acre)

Description of the row and column headers in Table 4.7; resource use in crop production--values.

Rows

1. BARLEY is barley for grain
2. CORN-G is corn for grain
3. CORN-S is corn for silage
4. COTTON is cotton for lint (by-product is cottonseed oilmeal)
5. HAY-L is legume hay grown in rotation
6. HAY-N is nonlegume hay grown in rotation
7. S FALLOW is summer fallow land
8. OATS is oats for grain
9. Empty file
10. PAST-N is an empty file
11. SORG-G is sorghum for grain
12. SORG-S is sorghum for silage
13. SOYBEANS is soybeans for beans
14. SUGAR BEET is sugar beets for beets
15. WHEAT is all wheat for grain
16. TOTAL is the summation of rows 1-15

Columns (000,000 dollars)

1. LAND is the value of all land used
2. WATER is the value of water consumed
3. LABOR is the value of total labor (hired and family) used
4. PEST is the value of pesticides used (herbicides and insecticides)
5. FERT-T is the total value of fertilizer used (N,P,K)
6. FERT-N is the value of nitrogen fertilizer used
7. FERT-OBJ is the value of nonnitrogen fertilizer purchased
8. MACH is the value of machinery inputs used (including fuel, oil, repairs, and depreciation)
9. OTHER is the value of other inputs (not including pesticides, fertilizer, labor, machinery, water, and land) used
10. SOIL-LOSS is an empty file
11. TOTAL is the total value of resources used and is the summation of columns 1-5 and columns 8-9

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Table 4.8.

<<<<< RESOURCE USE IN LIVESTOCK PRODUCTION - QUANTITY >>>>>

	# UNITS	SPACE	WATER	CORN	SORG	BARLEY	OATS	WHEAT	OIL M	HAY-L	HAY-N	SILAGE	PASTURE	-N-	CALVES
BEEF COWS	62396	0	682	0	0	0	257328	0	47444	200878	89515	108593	0	3619400	-42227
BEEF FEED	46231	0	307	52447	111732	90384	0	0	113933	1090	5304	307510	0	1348428	46231
DAIRY	11052	0	76	1377971	0	29978	68333	2701	54453	23866	3677	30638	0	1503063	-4004
HOGS	260658	0	108	1894574	0	200	946	160	156803	1993	0	0	0	729841	0
BROILERS	9578	0	1	307267	21566	7688	1739	1592	139814	0	0	0	0	268197	0
TURKEYS	1664	0	0	87847	15685	0	2627	5334	24004	0	26	0	0	46578	0
SHEEP	2898	0	43	2643	643	823	427	222	2565	0	3416	0	0	6289	0
EGGS	4991	0	5	218461	57931	66123	15379	21849	53974	0	605	0	0	102211	0
OTHER	30000	0	0	299682	85116	4539	19533	12798	28707	0	6900	0	0	0	0
TOTAL	429467	0	1223	4240892	292674	199734	366312	44655	621697	227828	109444	446741	0	7624007	0

Table 4.9

<<<<< RESOURCE USE IN LIVESTOCK PRODUCTION - VALUES >>>>>

	SPACE	WATER	FEED	INPUTS	LABOR	OTHER	NITROGEN	CALVES
BEEF COWS	0	18876	21057986	3702770	1143803	2558967	491281	-19472081
BEEF FEED	0	10107	8462439	1630878	142314	1488564	161999	21403797
DAIRY	0	1389	7515161	4641446	1384260	3257186	226013	-1853084
HOGS	0	967	7583272	3230316	567458	2662858	106723	0
BROILERS	0	15	3007104	0	0	0	43448	0
TURKEYS	0	3	673760	0	0	0	6746	0
SHEEP	0	775	271213	0	0	0	851	0
EGGS	0	53	2041639	0	0	0	15169	0
OTHER	0	0	2217443	0	0	0	0	0
TOTAL	0	32186	52830017	13205410	3237835	9967575	1052229	78632

Table 4.10.

<<<<< COMMODITY ACCOUNTS >>>>>

	QUANTITY				VALUE						
	PRODUCED	INTER	CONS	NET EX	PROD	INTER	CONS	NET EX	TOTAL P	BOUND P	SHADOW P
CORN	10178126	4240892	291088	5617485	28710773	11962840	821110	15845977	2.82	0.02	2.80
SORGHUM	667027	292674	11779	357639	2393475	1050193	42267	1283305	3.59	0.37	3.22
BARLEY	573336	199734	140478	231704	1467514	511241	359570	593070	2.56	0.00	2.56
OATS	633274	366312	53007	212643	844158	488296	70658	283455	1.33	0.00	1.33
WHEAT	1653174	44655	626239	980674	6934638	187316	2626912	4113675	4.19	0.45	3.74
OIL MEALS	848207	623158	-21159	234671	10239460	7522696	-255429	2832917	12.07	0.48	11.60
HAY-L	227828	227828	0	0	13847429	13847417	0	0	60.78	0.00	60.78
HAY-N	114911	109444	0	0	7231089	6887063	0	0	62.93	0.00	62.93
SILAGE	446741	446741	0	0	8574701	8574695	0	0	19.19	0.00	19.19
PASTURE	0	0	0	0	0	0	0	0	0.00	0.00	0.00
COTTON	20833	0	8078	12755	5628662	0	2182562	3446100	270.18	1.38	268.80
SUGAR	26394	0	26394	0	290168	0	290168	0	10.99	0.00	10.99
PORK	159262	0	158584	-2400	10594897	0	10549786	-159660	66.53	1.54	64.99
MILK	1167314	0	1170654	-3340	8492388	0	8516689	-24299	7.28	1.06	6.22
FEEDERS	46231	46231	0	-0	21953262	21953264	0	-0	474.86	13.59	461.28
FED BEEF	274911	49444	181051	-14481	32122382	5777395	21155225	-1692054	116.85	2.20	114.65
--SOY	0	0	0	0	0	0	0	0	0.00	0.00	0.00
N FED BEEF	57044	0	81679	-1609	6545029	0	9371532	-184610	114.74	0.00	114.74
--SOY	0	0	0	0	0	0	0	0	0.00	0.00	0.00
--FED	49444	0	0	0	0	0	0	0	0.00	0.00	0.00
TOTAL	0	0	0	0	165870024	78762417	55731049	26337874	0.00	0.00	0.00

Table 4.11.

<<<<< POPULATION DATA >>>>>

POPULATION	COST/CAP
242371.51	239.14

Description of the row and column headers in Table 4.8; resource use in livestock production--quantities.

Rows

1. BEEF COWS is beef cows for feeder calf production
2. BEEF FEED is fed beef production
3. DAIRY is dairy cows for milk production
4. HOGS is pork production
5. BROILERS is broiler production
6. TURKEYS is turkey production
7. SHEEP is lamb and mutton production
8. EGGS is egg production
9. OTHER is other animals including horses and mules, zoo animals, and other livestock
10. TOTAL is the summation of rows 1-9

Columns

1. # UNITS is the units of livestock produced: (a) beef cows (000 head), (b) beef feeding (000 head), (c) dairy cows (000 head), (d) hogs (000 cwt live weight), (e) broilers (000,000 of pounds of ready-to-cook weight), (f) turkeys (000,000 of pounds of ready-to-cook weight), (g) eggs (000,000 of dozens), and (h) other livestock (000 units)
2. SPACE is an empty file
3. WATER is the quantity of water consumed (000 acre feet)
4. CORN is the quantity of corn grain used for feed (000 bushels)
5. SORG is the quantity of sorghum grain used for feed (000 bushels)
6. BARLEY is the quantity of barley used for feed (000 bushels)
7. OATS is the quantity of oats used for feed (000 bushels)
8. WHEAT is the quantity of wheat used for feed (000 bushels)
9. OIL M is the quantity of oilmeals used for feed (000 cwt. soybean oilmeal equivalent)
10. HAY-L is the quantity of legume hay used for feed (000 dry tons)
11. HAY-N is the quantity of nonlegume hay used for feed (000 dry tons)
12. SILAGE is the quantity of corn and sorghum silage used for feed (000 wet tons)
13. PASTURE is an empty file
14. -N- is the quantity of nitrogen produced from livestock wastes (000 tons)
15. CALVES is the quantity of calves (000 head)

Description of the row and column headers in Table 4.9: resource use in livestock production--values.

Rows

Same as Table 4.8.

Columns (000,000 dollars)

1. SPACE is an empty file
2. WATER is the value of water consumed
3. FEED is the value of feed fed
4. INPUTS is the value of inputs used not including feed and water
5. LABOR is the value of labor used
6. OTHER is column 4 minus column 5
7. NITROGEN is the value of nitrogen produced from livestock wastes
8. CALVES is the value of calves

Description of the row and column headers in Table 4.10: commodity accounts.

Rows

1. CORN is corn for grain
2. SORGHUM is sorghum for grain
3. BARLEY is barley for grain
4. OATS is oats for grain
5. WHEAT is wheat (all wheat) for grain
6. OIL MEALS is oilmeals in soybean oilmeal equivalent
7. HAY-L is legume hay
8. HAY-N is nonlegume hay
9. SILAGE is corn and sorghum silage
10. PASTURE is an empty file
11. COTTON is cotton lint
12. SUGAR is sugar beets
13. PORK is pork from hogs
14. MILK is fluid milk from dairy cows
15. FEEDERS is 450 pound feeders from beef cows

16. FED BEEF is beef from fed beef

17. -- SOY is fed beef equivalent from soy protein meats

18. N FED BEEF is nonfed beef

19. -- SOY is nonfed beef equivalent from soy portion meats

20. -- FED is nonfed beef from fed beef

21. TOTAL is the totals for columns 5-8 only

Columns

1. PRODUCED is the quantity produced in the following units: corn grain (000 bushels), sorghum grain (000 bushels), barley (000 bushels), oats (000 bushels), wheat (000 bushels), oilmeals (000 cwt.), legume hay (000 dry tons), nonlegume hay (000 dry tons), silage (000 wet tons), cotton (000 bales), sugar beets (000 tons), pork (cwt. carcass), milk (cwt. fluid milk equivalent), feeders (000 head), fed beef (cwt. carcass), fed beef soy (cwt. carcass equivalent), nonfed beef (cwt. carcass), nonfed beef soy (cwt. carcass equivalent) and nonfed beef from fed beef (cwt. carcass)
2. INTER is the quantity used as an intermediate product (see units for column 1)
3. CONS is the quantity used for final domestic demand (see units for column 1)
4. NET EX is the quantity of net exports (see units for column 1)
5. PROD is the value of production (000,000 dollars)
6. INTER is the value used for intermediate product (000,000 dollars)
7. CONS is the value used for final demand (000,000 dollars)
8. NET EX is the value of net export (000,000 dollars)
9. TOTAL P is the total price or the summation of columns 10-11 (dollars per unit)
10. BOUND P is the bound price generated by the minimum production requirement, if any (dollars permit)
11. SHADOW P is the shadow price of the commodity (dollars per unit)

Description of the row and column headers in Table 4.11; population data.

Rows

No rows

Columns

1. POPULATION is the number of people in the United States (48 states; 000)
2. COST/CAP is a "cost of living proxy" (dollars per capita)

Description of the row and column headers in Table 4.12; land use and soil loss.

Rows

Rows are the same as Table 4.1.

Columns

1. AVAIL is total available land (000 acres)
2. USED-D is land used for dryland crop production (000 acres)
3. USED-R is land used for irrigated crop production (000 acres)
4. USED-T is the summation of columns 2-3 (000 acres)
5. VALUE is the value of land used (000,000 dollars)
6. PRICE is the land rent (dollars per acre)
7. SLACK is column 1 minus column 4 (000 acres)
8. S. LOSS is soil erosion (000 tons)

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Table 4.12.

<<<<< LAND USE AND SOIL LOSS >>>>>

	AVAIL	USED-D	USED-R	USED-T	VALUE	PRICE	SLACK	S. LOSS
LG1-D	24307	24307	0	24307	5161847	212.36	0	128435
LG1-I	6399	1130	5065	6196	1675241	270.39	203	17952
LG2-D	75673	75673	0	75673	11370596	150.26	0	403507
LG2-I	6898	3391	3507	6898	922087	133.68	0	33703
LG3-D	75613	75613	0	75613	11930112	157.78	0	343743
LG3-I	4810	271	4539	4810	960206	199.64	0	7087
LG4-D	65466	65466	0	65466	7768398	118.66	0	365322
LG4-I	3551	1206	2305	3510	435216	123.98	41	16679
LG5-D	46257	46251	0	46251	5387519	116.49	7	209850
LG5-I	4985	1009	3848	4857	667239	137.39	129	11016
LG6-D	28515	28354	0	28354	2510771	88.55	162	152756
LG6-I	1217	449	763	1213	123210	101.60	5	3676
LG7-D	15136	25391	0	15123	1338458	52.71	13	75161
LG7-I	1272	337	848	1186	143723	121.20	86	2040
LG8-D	319	319	0	319	21203	66.49	0	796
LG8-I	10	0	0	0	0	0.00	10	0
LG9-D	8824	8082	0	8082	284374	35.19	742	53562
LG9-I	296	121	160	281	29683	105.80	15	760
LG10-D	0	0	0	0	0	0.00	0	0
LG10-I	0	0	0	0	0	0.00	0	0
SUB LG1-5	313958	294316	19263	313579	46278459	147.58	379	1537294
SUB LG6-9	55589	63053	1772	54557	4451421	68.67	1032	288751
TOTAL	369547	357369	21035	368136	50729880	134.06	1411	1826044

Table 4.13.

>>ACREAGE BY LG AND CON-TILL<<

	STRAIGHT ROW			CONTOUR FARMING			STRIPCROPPING			TERRACES		
	CON-R	CON-L	MIN-TIL	CON-R	CON-L	MIN-TIL	CON-R	CON-L	MIN-TIL	CON-R	CON-L	MIN-TIL
LG1	7194	15250	5168	1297	1487	0	0	106	0	0	0	0
LG2	9129	27838	18074	4148	6088	7240	7598	2155	0	18	283	0
LG3	13033	54330	5948	3646	2940	0	0	175	0	66	285	0
LG4	9969	16378	4686	3285	5407	7989	3198	3363	11174	1010	2516	0
LG5	11843	24572	6284	481	753	166	151	199	0	0	6658	0
LG6	5001	8795	1243	0	451	1791	1409	5175	2968	762	1971	0
LG7	14394	4671	708	115	204	597	0	5771	73	45	0	0
LG8	7	269	17	0	26	0	0	0	0	0	0	0
LG9	1621	2955	876	906	1360	645	0	0	0	0	0	0
TOTAL	72190	155057	43003	13878	18717	18428	12357	16944	14215	1902	11713	0

Table 4.14.

>>SOIL LOSS BY LG AND CON-TILL<<

	STRAIGHT ROW			CONTOUR FARMING			STRIPCROPPIN			TERRACES		
	CON-R	CON-L	MIN-TIL	CON-R	CON-L	MIN-TIL	CON-R	CON-L	MIN-TIL	CON-R	CON-L	MIN-TIL
LG1	33110	74925	21461	9466	7154	0	0	272	0	0	0	0
LG2	36253	106655	109082	33075	50609	41913	47990	11072	0	12	548	0
LG3	44674	233338	25539	25806	20439	0	0	736	0	69	228	0
LG4	42738	51119	32076	26703	42419	71500	8796	20545	80574	1701	3828	0
LG5	42765	105698	36273	3232	4795	1140	107	713	0	0	26142	0
LG6	20102	34199	9323	0	3600	15145	9181	30523	24862	1675	7821	0
LG7	16787	16364	1572	540	1555	3632	0	36218	404	131	0	0
LG8	1	651	5	0	139	0	0	0	0	0	0	0
LG9	5493	17170	7210	7366	10761	6323	0	0	0	0	0	0
TOTAL	241922	640118	242541	106188	141472	139653	66074	100080	105840	3588	38568	0

Description of the row and column headers in Table 4.13; acreages by land group and conservation--tillage practices and Table 4.14; soil loss by land group and conservation--tillage practice.

Rows

LG1 is land class I

LG2 is land class IIE

LG3 is land classes IIS, IIW. IIC

LG4 is land class IIIE

LG5 is land classes IIIS, IIIW, IIIC

LG6 is land class IVE

LG7 is land classes IVS, IVW, IVC

LG8 is land class V

LG9 is land classes VI, VII, VIII

Columns (000 acres)

1. CON-R is conventional tillage with residue removed with straight row farming
2. CON-L is conventional tillage with residue left with straight row farming
3. MIN-TIL is reduced tillage with straight row farming
4. CON-R is conventional tillage with residue removed with contour farming
5. CON-L is conventional tillage with residue left with contour farming
6. MIN-TIL is reduced tillage with contour farming
7. CON-R is conventional tillage with residue removed with strip crop farming
8. CON-L is conventional tillage with residue left with strip crop farming
9. MIN-TIL is reduced tillage with strip crop farming.
10. CON-R is conventional tillage with residue removed with terrace farming
11. CON-L is conventional tillage with residue left with terrace farming
12. MIN-TIL is reduced tillage with terrace farming

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Table 4.15. << ACRES OF ROW CROPS GROWN IN ROTATIONS >>

ROTATION WEIGHTS

	<.125	.250	.500	.750	1.000	TOTAL
LG1	0	3326	4456	1053	14593	23427
LG2	0	11972	20803	3524	19918	56216
LG3	0	9821	9306	1924	33115	54167
LG4	0	10074	9564	4926	9188	33752
LG5	0	5541	10974	1718	9167	27400
LG6	0	3027	4090	346	2498	9960
LG7	0	3151	1982	3893	582	9608
LG8	0	57	0	8	0	65
LG9	0	407	0	9	283	699
TOTAL	0	47376	61174	17401	89343	215294

PERCENTAGE DISTRIBUTION

Table 4.16.

ROTATION WEIGHTS

	<.125	.250	.500	.750	1.000	TOTAL
LG1	0.00	0.02	0.02	0.00	0.07	0.11
LG2	0.00	0.06	0.10	0.02	0.09	0.26
LG3	0.00	0.05	0.04	0.01	0.15	0.25
LG4	0.00	0.05	0.04	0.02	0.04	0.16
LG5	0.00	0.03	0.05	0.01	0.04	0.13
LG6	0.00	0.01	0.02	0.00	0.01	0.05
LG7	0.00	0.01	0.01	0.02	0.00	0.04
LG8	0.00	0.00	0.00	0.00	0.00	0.00
LG9	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.22	0.28	0.08	0.41	1.00

Description of the row and column headers in Table 4.15: acreage of row crops grown in rotation and Table 4.16: proportion of row crops grown in rotation.

Rows

Rows are the same as Table 4.13.

Columns (000 acres)

1. < .125 is row crops grown in rotations comprised of less than 12.5 percent row crops
2. .250 is row crops grown in rotations comprised of 25 percent row crops (1 in 4 years)
3. .500 is row crops grown in rotations comprised of 50 percent row crops (1 in 2 years)
4. .750 is row crops grown in rotations comprised of 75 percent row crops (3 in 4 years)
5. 1.000 is row crops grown in rotations comprised of 100 percent (continuous) row crops

Table 4.17.

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     ***  MODEL I-C SUMMARY: HIGH EXPORT   ***                                                    SUM1 FOR UNITED STATES

                                                    <<<<< WATER BALANCE TABLE -- CONSUMED >>>>>
          ---------WATER AVAILABLE---------   -------------------WATER UTILIZATION------------------------
 REGION   RUNOFF TRANSFER  DE SALT     TOTAL  EX CROP  EN CROP  EX LVST  EN LVST  ONSITE     M&I  TRANSFER    PRICE    S. LOSS
      0   101097    24537      213    125848    31697    48191       50     1173    2918   17381     24537    20.86    1826044
      1      905        0        0       905       71      478        0        9       0     346         0     3.53        141
      2     6279        0        0      6279     1291     4568        1       32       0     386         0     2.49      30263
      3     1182        0        0      1182      584      527        0        6       0      64         0     2.63       5767
      4     4392        0        0      4392     1119     3186        1       31       0      55         0     1.99       8736
      5     4536        0        0      4536     1232     3221        2       26       0      55         0     2.73      13927
      6     6831        0        0      6831      227      394        0        7     469      90      5643     1.91        379
      7    25937     5643        0     31580     9261    11142        4       51     510    2226      8386     8.49       3752
      8      888        0        0       888      668        0        0       10       7     203         0    30.28        653
      9      494     3407        0      3901      970       56        1        8      14    2852         0    59.96        122
     10      744     4979        0      5723     2722     2767        1       11      79     143         0     8.49        276
     11     1215        0        0      1215      843       15        0       11     390      56         0    71.08        162
     12     2305        0        0      2305      355     1239        2       20     459     229         0    21.86       4424
     13     4188        0        0      4188      730        0        1       13      81     119      3244     1.50        251
     14     3289        0        0      3289      634      143        1        5      22      18      2467    24.83        884
     15     2210        0        0      2210      496      357        1        6      38     148      1164    30.68       2015
     16     1092     5120        0      6212      690     4843        1       19     246     413         0    38.67        287
     17     1789        0        0      1789     1319      305        2       20      45      45        54     3.71       7331
     18     2392        0        0      2392      987     1044        1       17      44     300         0     2.13       8305
     19     3594     1754        0      5348     1124     2143        2       29      51     217      1783    36.57      13747
     20     1948        0        0      1948      192     1339        9      196     124      89         0     2.90      98816
     21      491     1783        0      2274       57     2043        1      102      12      60         0    40.68      36700
     22     3244       54        0      3298       31     2720        5      142     232     167         0     6.63     165024
     23      275        0        0       275        2        0        1       65      96     112         0     4.99      77765
     24     1536        0        0      1536      331      349        1       54       0     800         0   165.64      36483
     25     2955        0        0      2955       76     1767        0       83       0     121       908    53.79      64094
     26       16      857        0       873       24      830        0       10       0       8         0    53.79       9423
     27     1005        0        0      1005       39      888        0       11       0      66         0    11.58      41671
     28      377        0        0       377       11        0        1       50       0     315         0     4.22      26118
     29      351        0        0       351        8        0        0       10       0     333         0    11.58       9521
     30      112        0        0       112       57        0        0        7       0      47         0     6.10       9295
     31     2260        0        0      2260     1053      154        1       11       0     153       889    92.92        519
     32     1806      889      213      2908     2131      459        3       18       0     298         0   100.00       6596
     33      511       51        0       562      312       47        0       20       0     182         0   122.34      41056
     34     3511        0        0      3511     1189     1057        6       42       0    1218         0     8.28      75423
     35     6436        0        0      6436      859      112        0       20       0    5445         0     8.28      17861
```

Description of the row and column headers in Table 4.17; water consumption balance table.

Rows

Rows designate the water supply region (1-35) and 0 is the U.S. total. These regions represent an aggregation of the 51 water supply regions in the model. Data could be presented for each of the 51 regions.

Columns

1. RUNOFF is the dependable water supply available from surface runoff (000 acre feet)
2. TRANSFER is water transferred in through natural flows, or interbasin transfers (000 acre feet)
3. DE SALT is water from desalting sea water in sea coast regions only (000 acre feet)
4. TOTAL is the total water available or the summation of columns 1-3 (000 acre feet)
5. EX CROP is water consumed by exogenous crops (000 acre feet)
6. EN CROP is water consumed by endogenous crops (000 acre feet)
7. EX LVST is water consumed by exogenous livestock (000 acre feet)
8. EN LVST is water consumed by endogenous livestock (000 acre feet)
9. ONSITE is water consumed by onsite uses (000 acre feet)
10. M & I is water consumed by municipal and industrial uses including recreation, mining, and thermal electric power (000 acre feet)
11. TRANSFER is water transferred out through natural flows, interbasin transfers, and exports (000 acre feet)
12. PRICE is the weighted average shadow price of water for all uses (dollars per acre foot)
13. S. LOSS is total soil erosion (000 tons)

*** MODEL I-C SUMMARY: HIGH EXPORT ***

SUM1 FOR UNITED STATES

Table 4.18.

<<<<< WATER USE TABLE -- WITHDRAWN >>>>>

REGION	EXOG CROPS	ENDOG CROPS	EXOG LVST	ENDOG LVST	ONSITE	M & I
0	45119	48242	50	1173	3616	41962
1	114	478	0	9	0	2245
2	2071	4567	1	32	0	1958
3	955	527	0	6	0	386
4	1651	3190	1	31	0	292
5	1861	3221	2	26	0	228
6	326	394	0	7	473	90
7	12316	11190	4	51	569	2696
8	838	0	0	10	15	227
9	1493	56	1	8	48	3194
10	4097	2766	1	11	107	292
11	1189	15	0	11	373	124
12	472	1242	2	20	804	619
13	965	0	1	13	109	280
14	835	143	1	5	35	44
15	656	357	1	6	45	365
16	1017	4842	1	19	437	1013
17	2048	305	2	20	45	243
18	1532	1047	1	17	44	829
19	1571	2141	2	29	51	886
20	289	1339	9	196	124	608
21	83	2046	1	102	12	245
22	46	2720	5	142	232	1141
23	3	0	1	65	96	1222
24	492	349	1	54	0	308
25	105	1764	0	83	0	310
26	33	830	0	10	0	20
27	58	888	0	11	0	169
28	16	0	1	50	0	3433
29	12	0	0	10	0	3730
30	84	0	0	7	0	515
31	1411	154	1	11	0	353
32	3011	459	3	18	0	731
33	422	47	0	20	0	446
34	1788	1056	6	42	0	2984
35	1260	112	0	20	0	9734

Description of the row and column headers in Table 4.18; water withdrawals.

Rows

Rows designate the water supply region (1-35) and 0 is the U.S. total. Could be reported for the 51 water supply regions in the model.

Columns (000 acre feet)

1. EXOG CROPS is water withdrawn by exogenous crops
2. ENDOG CROPS is water withdrawn by endogenous crops
3. EXOG LVST is water withdrawn by exogenous livestock
4. ENDOG LVST is water withdrawn by endogenous livestock
5. ONSITE is water withdrawn for onsite uses
6. M & I is water withdrawn by municipal and industrial uses including recreation, mining, and thermal electric power

The summary tables previously outlined are usually compiled at the national, market region, and water supply region levels. From this level they can be reported or further aggregated into reporting zones, where all or only specific segments of the data are reported. The interpretation of the alternative solutions to the model and the resulting implications for policy are given for the complete model [45;46]. In other reports only specific portions of the data are analyzed or the model development procedure is outlined [47;48;113].

Footnotes

1. The commodities include barley, corn, silage, cotton, legume hay, nonlegume hay, oats, sorghum, soybeans, sugar beets, wheat, spring wheat, feeders, fed beef, nonfed beef, dairy products, and pork.

2. The endogenous crops include barley, corn, corn silage, cotton, legume hay, nonlegume hay, oats, sorghum, sorghum silage, soybeans, sugar beets, and wheat.

3. Active conservation capacity is water storage available for irrigation, municipal and industrial uses, power, fish and wildlife, or other direct uses. The joint-use capacity includes that storage area of the dam allocated for flood control during part of the year and to active conservation for the remainder of the year.

4. Unpublished data obtained through private communications with D. W. Davies, U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado, March 1971.

5. The data for this equation are developed from tables given by Wischmeier and Smith [116], and from the regional data given for the soil classes in the SCS questionnaire (Appendix A).

6. Professor of Agronomy, Iowa State University, Ames, Iowa.

7. The endogenous crops are barley, corn, corn silage, cotton, legume hay, nonlegume hay, oats, sorghum, sorghum silage, soybeans, and wheat.

8. Increases in labor efficiency as based on historic trends for each of the crop categories are 65 percent for cotton, 45 percent for wheat, 60 percent for feed grains and soybeans, and 35 percent for the silages and hays.

9. Being moisture deficient indicates an excess of potential evapotranspiration over precipitation.

10. A 10-year amortized life for terraces represents a tradeoff with a longer amortization period and inclusion of repair and maintenance costs.

11. The crops include corn, grain, corn silage, grain sorghum, sorghum silage, oats, barley, wheat, soybeans, cotton, sugar beets, alfalfa, clover-timothy, lespedeza, small grains for hay, and other hay.

12. Private communication with Frank Schaller, Department of Agronomy, Iowa State University, August 1971.

13. The 1972 OBERS Report backup materials were obtained through private communication with Dr. Melvin Cotner, Director, NRED, U.S. Department of Agriculture, March 1973.

14. For crops not included in the ERS data, it is assumed that the acreage required in

the year 2000 will be the same as required in 1969 with the production differential being made up by increases in yield per acre.

15. Yields for the crops not included in Dean's study [14] were obtained by extending the 1949-1969 yield trend from the Agriculture Census [96-100] to the year 2000.

16. The *1964 Census of Agriculture* was used for the state-to-county allocation, as not all 1969 state summaries were published at the time of calculation. State data for 1969 were available from the *National Summary* [100].

17. This assumption is used, as time series estimates of the percent of acres receiving fertilizer are not available for the exogenous crops.

18. The weights were determined from the *1964 Census of Agriculture* data for farms by economic farm class [99].

19. Prices were included as an index with 1957 to 1959 = 100.

20. The income used is the disposable per capita income projected by the Office of Business Economics [101] with the additional restraint that no area will have a disposable income greater than 4,000 dollars in 1957 to 1959 dollars (5,400 dollars in 1970 prices).

21. See footnote 19.

22. See footnote 19.

23. See footnote 20.

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Appendix A

SCS Questionaire and Limitations

Assigned Land Resource Areas by Regions and States

Northeast Region	
Ohio	$\underline{114}$, 100, 139, 124
Kentucky	$\overline{120}$, 121, 125
New York	140, 101, 142, 141
Maine	143, 146
New Hampshire	144
Connecticut	145
Pennsylvania	127, 147
West Virginia	126
New Jersey	149
Virginia	$\underline{128}$, 148
South Region	
Oklahoma	78, 80, 84
Texas	77, 81, 82, 83, 85, 86, 87, 150
Arkansas	117, 118, 132, 131, 119
Louisiana	$\underline{133}$, 151
Tennessee	$\overline{122}$, 123
Mississippi	134
Alabama	135, 129, $\underline{133}$
North Carolina	130, $\underline{136}$, $\underline{\overline{133}}$, 153
South Carolina	137, $\overline{153}$
Georgia	$\underline{128}$, $\overline{136}$
Florida	$\overline{138}$, $\overline{152}$, 154, 155, 156
Midwest Region	
North Dakota	53, 54, 55, 56
South Dakota	60, 61, 62, 63, 66, 102
Nebraska	64, 65, 71, $\underline{75}$, 106
Kansas	72, 73, $\underline{75}$, $\overline{76}$, 112, 74, 79
Minnesota	57, 88, $\overline{103}$, 89
Iowa	107, 104
Missouri	109, 115, 116
Wisconsin	90, 91, 93, 95, 105, 92
Illinois	108, 110, 113, $\underline{114}$
Michigan	92, 94, 96, 97, $\overline{98}$, 99
Indiana	$\underline{111}$
West Region	
Washington	1, 3, 9, 7, 6
Oregon	2, 8, 10, 23
California	4, 5, 21, 22, 17, 18, 14, 16, 15, 20, 19, 31, 30
Idaho	11, 12, 13, 25, 43
Montana	44, 46, 52, 58, 59
Wyoming	34, 32, 33
Nevada	24, 27, 26, 29
Utah	28, 47
Colorado	48, 49, 45, 51, 67, 69
Arizona	39, 40, 41, 35, 38
New Mexico	37, 36, 42, 70

No LRA's assigned to Maryland, Massachusetts, Rhode Island, and Vermont.

STATE ______________________

LRA ______________________

U.S. DEPARTMENT OF AGRICULTURE
Soil Conservation Service
Attachment to EVT-2

Form 1. Dominant Soil, L, S, K, and T Factors by Capability

Subclasses

1. Class and Subclass	2. Dominant Soil	3. L-Dom. Slope Length	4. Dom. % Slope	5. K Factor	6. T. Factor
		(ft)	(%)	Tons per acre per year	
I					
IIe					
IIs					
IIw					
IIc					
IIIe					
IIIs					
IIIw					
IIIc					
IVe					
IVs					
IVw					
IVc					
Ve					
Vw					
Vs					
Vc					
VIe					
VIw					
VIs					
VIc					
VIIe					
VIIs					
VIIw					
VIIc					
VIIIe					
VIIIs					
VIIIw					
VIIIc					

Instructions - Data Form 1

This form is to be used for all LRA's in the Midwest, South, and Northeast Regions, and for those LRA's in the Western Region that are east of the Continental Divide and have K and T factors assigned to the sloping soils.

1. Select the capability subclasses that occur in each LRA. The most direct method is reference to the CNI printouts, Table F, that were sent to the states in July 1970. Write N.A. under dominant soil for all subclasses that do not occur in LRA. Do not subdivide any subclasses. Choose dominant soils on the basis of the full extent of the LRA, not just that portion that occurs in the state responsible. Some LRA's are assigned to two or three states. These LRA's are underlined in the list of assignments. For these LRA's choose the dominant soils only on the basis of that portion of the LRA in the assigned state.

2. Designate a dominant soil mapping unit for each subclass selected. This should be done from general knowledge by personnel well acquainted with the soils of the state. Published soil surveys or CNI printouts by soil series may be helpful in selecting a dominant soil if uncertainty exists. Do not choose a series on the basis that it represents the median of erodibility or productivity of the soils in the subclass, unless that series is in fact the dominant series or among the dominant ones.

   Where the dominant soil mapping unit is a complex or association of soil series, list only the dominant series and its dominant phase.

3. Enter the dominant length of slope, in feet, and the dominant slope gradient in per cent for each dominant soil in columns 3 and 4. Do not use ranges in either value. These entries should be estimated by personnel well acquainted with the soils of the area. If percent slope is zero enter N.A. in column 3. For slopes more than 1200 feet long, enter >1200 in column 3.

4. Enter the K and T factors for each dominant soil. Make single entries for T values in column 6 specifically for each dominant soil.

STATE ______________

LRA ______________

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

United States Department of Agriculture--
Soil Conservation
Service
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems				
		(ft)	(%)	Tons per acre per year					
I									
IIe									
IIs									
IIw									
IIc									
IIIe									
IIIs									
IIIw									
IIIc									
IVe									
IVs									
IVw									
IVc									
Ve									
Vw									
Vs									
Vc									
VIe									
VIw									
VIs									
VIc									
VIIe									
VIIs									
VIIw									
VIIc									
VIIIe									
VIIIs									
VIIIw									
VIIIc									

Instructions - Data Form 1W

This form is for use in LRA's in the Western Region west of the Continental Divide where K and T factors have not been developed.

1. Select the capability subclasses that occur in each LRA. The most direct method is reference to the CNI printouts, Table F, that were sent to the states in July 1970. Write N.A. under dominant soil for all subclasses that do not occur in LRA. Do not subdivide any subclasses. Choose dominant soils on the basis of the full extent of the LRA, not just that portion that occurs in the state responsible. Some LRA's are assigned to two or three states. These LRA's are underlined in the list of assignments. For these LRA's choose the dominant soils only on the basis of that portion of the LRA in the assigned state.

2. Designate a dominant soil mapping unit for each subclass selected. This should be done from general knowledge by personnel well acquainted with the soils of the state. Published soil surveys or CNI printouts by soil series may be helpful in selecting a dominant soil if uncertainty exists. Do not choose a series on the basis that it represents the median of erodibility or productivity of the soils in the subclass, unless that series is in fact the dominant series or among the dominant ones.

   Where the dominant soil mapping unit is a complex or association of soil series, list only the dominant series and its dominant phase.

3. Enter the dominant length of slope, in feet, and the dominant slope gradient in percent for each dominant soil in columns 3 and 4. Do not use ranges in either value. These entries should be estimated by personnel well acquainted with the soils of the area. If percent slope is zero enter N.A. in column 3. For slopes more than 1200 feet long, enter > 1200 in column 3.

4. For each dominant soil, assign a T value representing the allowable soil loss due to erosion in tons per acre per year. Consider the thickness of the surface horizon and the relative loss of productivity that would result from erosion of surface horizons. Five tons should be the maximum value.

5. Select the dominant cropping systems and land uses for the LRA and enter in the 6 blank column headings. Where rangeland is a dominant use of land in the LRA, entries might include (a) rangeland, poor cover and (b) rangeland, good cover.

6. Estimate the average annual soil loss in t/ac/yr that is occurring throughout one full cycle of the cropping systems or annually for land uses. These estimates are to be developed for each of the dominant soils, except where it is known that the cropping system or land use does not occur or exist for a given soil. In this case, enter N.A. in the appropriate block. Choose cropping systems that will result in a wide range in soil erosion losses; for example:

	Cropping System	Estimated Soil Losses t/ac/yr
Example A.	Wheat-4 yrs fallow	70
	Wheat-1 yr fallow	20
	Wheat-peas	7
	Wheat-continuous	4
	Rangeland, poor cover	8
	Rangeland, good cover	2

		Estimated Soil Losses		
		Soil A	Soil B	Soil C
Example B.	Irrigated Row Crop	2	N.A.	N.A.
	Irrigated close grown crops	0.5	N.A.	N.A.
	Wheat-1 yr fallow	8	N.A.	12
	Rangeland, poor	6	15	12
	Rangeland, good	2	3	3
	Forest	N.A.	0.1	N.A.

		Estimated Soil Losses
Example C.	Desert shrubs	4
	Rangeland, poor	4

U.S. DEPARTMENT OF AGRICULTURE
Soil Conservation Service
Attachment to EVT-2

STATE ____________

LRA ____________

Form 2. C Factor Table - Cropland

1. Cropping Management System	Conventional Till		4. Minimum Tillage	5. No Till
	2. Residue Removed	3. Residue Left		

Instructions - Form 2

One copy of this form is to be developed for each LRA east of the Continental Divide.

1. Include in column 1 those cropping management systems used most commonly on land in capability classes I-IV in the LRA. Do not abbreviate the name of the crop; indicate corn, soybeans, etc., instead of rowcrop. At least 5 and no more than 10 systems should be listed. Be sure to include a range in cropping systems from the most intensive to the least intensive system commonly used in the LRA for land in classes I-IV.

2. For each system listed, enter a C factor in each column on the form.

3. For columns 2 through 5, to determine the C factor, choose the pounds of residue which is usually left on the surface in the LRA for the cropping management system used.

Note-C factors for kinds of permanent vegetative cover are not needed in data being assembled.

U.S. DEPARTMENT OF AGRICULTURE
Soil Conservation Service
Attachment to EVT-2

STATE____________________

LRA____________________

Form 3. Change in Yield and Farming Time for Conservation Practices and Tillage Methods

1. Operation	2. Change in Farming Time	3. Change in Crop Yield
(A) Practice		
1. Straight-row	100	100
2. Contour farming		
3. Stripcropping		
4. Conventional Terraces		
5. Parallel Terraces		
(B) Tillage		
1. Conventional	100	100
2. Crop Residue Use		
3. Minimum tillage		

Instructions - Form 3

Form 3 is to be completed for all LRA's. In those cases where a given practice cannot be applied in the LRA due to topography or other restraints (for example, parallel terraces on irregular, hummocky relief), enter N.A. in all columns for that practice. For some LRA's, especially in the western states, all entries may be N.A. Form 3 should be completed in all cases, however.

1. Base levels of 100 for A. Practices and B. Tillage are assigned for straight-row practice and conventional tillage, as indicated in the table. Conventional tillage includes both spring and fall plowing.

2. Increases in time or yield from practices or tillage are to be indicated by assigning numbers larger than 100, proportional to the percent increase. Reductions are indicated by assigning numbers less than 100.

Example: If minimum tillage takes 20 percent less time than conventional tillage, the value in column 2 for minimum tillage would be 80. If it is estimated that yields, using minimum tillage, are 5 percent higher than those with conventional tillage, enter 105 in column 3.

Note: The economist may be able to assist in the completion of this form.

U.S. DEPARTMENT OF AGRICULTURE
Soil Conservation Service
Attachment to EVT-2

State ____________________

LRA ____________________

Form 4. Yield Differential by Capability Subclasses

Class and Subclass	Dom. Soil	Row Crops			Close Grown Crop	Hay	Pasture	Range
I		100	100	100				

Instructions - Form 4

This form is to be completed for all LRA's.

1. Include all capability subclasses and dominant soils identified for the LRA on Form 1.

2. Write in the names of two or three dominant row crops from among those indicated in the cropping management systems in Form 2, in the blank column headings under "Row Crops."

3. Set the yield on class I land equal to an index value of 100 for each row crop and for close-grown crops, hay, pasture, and range. In those LRA's with no class I land, set subclass IIe (or the highest ranking subclass) yields at the index value of 100. Where crop is not grown, enter N.A.

4. Use the "Predicted Acre Yield under Defined Management Levels" from the published soil surveys in the LRA, or similar data from other sources where published soil surveys are not available, to set index values for remaining classes and subclasses. (For consistency use high level management.)

Example: If the predicted yield of corn on class I is 110 bushels per acre and the predicted yield on class IIe is 95 bushels, the index value for IIe would be calculated as follows:

$$\text{Index} = \frac{95}{110} \times 100 = 86$$

Instructions - Form 5

This form is to be completed for all LRA's.

1. By class, subclass, and dominant soil shown in Form 1, complete columns 1 and 2 of Form 5.

2. Using slope and terrace spacing compute average acres served per mile of terrace.

3. Estimate the percent of land area that is feasible to terrace, assuming that none has been terraced. Excluded will be those acres that due to topography or other physical reasons are not feasible to terrace.

4. Show average cost per mile of terraces using predominant type of terrace being constructed.

5. Estimate average acres of waterway needed to provide outlets per mile of terrace.

6. Estimate average cost per acre of waterways.

7. Estimate feet of tile outlets required per mile of terrace, where tile outlet terraces are being built.

8. Estimate average cost per foot of tile outlets installed.

9. Estimate percent of terraces with waterway outlets. [24]

10. Estimate percent of terraces with tile outlets. [24]

11. Estimate percent of terraces with no outlets. This is generally applicable to level terraces where no outlets required. [24]

[24] For columns 10, 11, and 12 use percentage based on modern systems presently being installed.

STATE ____________________

LRA ____________________

U.S. DEPARTMENT OF AGRICULTURE
Soil Conservation Service
Attachment to EVT-2

Form 5. Average Cost - Terraces and Outlets

1. Class and Sub-class	2. Dominant Soil	3. Percent Land Feasible to Terrace	4. Acres Per Mile Terrace	5. Cost Per Mile Terrace	6. Acres Waterway Per Mile Terrace	7. Cost Per Acre Waterway	8. Feet Tile Outlets Per Mile Terrace	9. Cost Per Foot Tile Outlet	10. Percent Terraces with Waterway Outlet	11. Percent Terraces with tile Outlets	12. Percent Terraces with no Outlets

Limitations in the Data Assembled by the SCS for the ISU Water Quality Project

1. The data assembled provide no specific information about nutrients, pesticides, dissolved oxygen and biological oxygen demand, water temperature, pathogens, and other pollutants which are important aspects of water quality. Some of these are related to sediments from agricultural land, but no estimates are included on this relationship.

2. No estimates are included of the delivery ratio---that proportion of the sediment resulting from sheet and rill erosion that enters surface water in streams and lakes. The delivery ratio varies substantially in different parts of the country.

3. The dominant soil chosen for each subclass is the most extensive soil. Several other soils will occur in the same subclass in a given LRA. The length of slope, degree of slope, erodibility, yield differentials, and feasibility of terracing will vary among soils in a given subclass. The dominant soil was not chosen to be typical in erodibility or other qualities for the subclass, but merely on the basis that it is the most extensive. Therefore, for subdivisions of the LRA where the soil indicated as dominant does not occur, the data in the forms may not be appropriate.

4. Some of the subclasses in Forms 1 and 1W represent only irrigated land. On forms from the Western Region, an (I) designates such subclasses. The Universal Soil Loss Equation is adapted to irrigated land only during portions of the year when no irrigating is done. K and C factors have not been developed for irrigated land, and the relationship between irrigated land and dryland in terms of these factors is not known. Water added by irrigation will influence the EI of subsequent rainfall. For irrigated subclasses, the K, T, and C factors provided on the forms apply to the dryland equivalents of the dominant soil mapping units.

5. In the states west of the Continental Divide, K and T values have not been assigned to soil series. It was necessary for the states to estimate the erosion losses for each subclass under selected cropping systems or range conditions. These are gross estimates based on little or no measured data for many subclasses and may be substantially in error. The soil losses estimated for irrigated land in the west may represent erosion resulting from irrigation practices in addition to that resulting from the runoff from precipitation.

6. The soil loss equation predicts only sheet and rill erosion. Erosion from road cuts, gullies, streambanks, construction sites specifically for this study, and other sources cannot be predicted from the data assembled by SCS. In some watersheds much of the sediment in streams comes from such sources.

7. Only a limited number of cropping systems, the major ones currently being used, are listed on Form 2 for each LRA. C factors are not the same for a given cropping system in all parts of the country. Thus when models predict shifting of cropping systems into an LRA, where they are not currently used, the data assembled may not provide the proper C factors for the new cropping system.

8. Assumptions made regarding the crop residue on the surface in minimum tillage or no till practices may not be uniform between states. We have not checked with the states to determine the assumptions made. We believe that it is safe to assume that the C factors listed under these practices apply to the prevailing method used in each LRA.

9. The use of diversions to control runoff and erosion is not accounted for in the data assembled. In some LRA's where diversions are used effectively to control runoff and reduce erosion on some land, no entry is made on Forms 3 and 5 for terraces. Only a few states in the northeast are in this category.

10. There is some variation in the use of the yield index of 100. Yield index may be lower for Class I land than for some of the Class II land for some crops. Some states used 100 consistently for Class I land. More productive subclasses were given an index of more than 100. Other states gave the most productive subclass a rating of 100 and gave Class I land a lower rating.

11. A yield index of 100 for a given crop designates a wide variation in actual yield of that crop, depending on the LRA. For example, an index of 100 for corn may be 135 bushels per acre in an LRA in Ohio, but only 70 bushels per acre in an LRA in Kansas. The yield per acre in common units for a yield index of 100 is given on Form 4 for each crop in each LRA.

12. Some states have almost an equal number of terraces of different types currently being installed. Only the dominant one of these was chosen for Table 5. Thus the overall cost of terracing in some LRA's may be more or less than indicated by data in Table 5.

13. No estimates are included for the costs of relocating a crop into an area where it is not now produced, or for bringing into cropland areas not so used now. These costs vary by kinds of soil. They are substantial for some crops on some kinds of soil and should not be disregarded.

14. NA has been used on the forms in many places. It means either not applicable or that the practice is not now being used in the LRA.