A national recursive simulation and linear programming model of some major crops in U.S. agriculture

Kenneth Harry Baum

Iowa State University

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by

Kenneth Harry Baum

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CHAPTER I. INTRODUCTION

Over the last few decades, the agricultural industry in the United States has experienced significant and profound transformations in the spatial configuration of production activities. These changes have occurred at the farm, regional and national levels. For a fuller understanding of how, where, why and when these changes have occurred, ten interdependent research areas must be thoroughly considered:

1. The interdependence of outputs using common inputs
2. Technological change
3. Planned or programmed policy actions
4. Changes in both acreage and yield components in field crop production
5. Uncertainty
6. Demand, supply and price interactions
7. Adjustment over time
8. The aggregate supply of production inputs
9. Rates of investment in factors fixed in the short turn, and
10. Regional specialization and competition [40, p. 108].

A comprehensive research paradigm, or theoretical and analytical framework, used for understanding and explaining the economic behavior of the U.S. agricultural industry should include an explicit quantitative research technique in which changes or transitions in inter-regional crop and livestock activities occur through time in response to and in anticipation of economic and behavioral phenomena. In response to the need for quantitatively estimating the economic behavior of the agricultural sector for policy and planning reasons,
and to test various economic hypotheses, many empirical analytical techniques have been developed to study one or more of the ten research areas listed above [87, 143]. Unfortunately, methodological techniques utilized to study certain economic aspects of agricultural response behavior are often quite inadequate to explain other research problems. In other words, each methodology becomes rather specific in its applicability to study particular economic problems. For this reason, each analytical modeling framework can only imperfectly represent the larger research paradigm of economic behavior in the agricultural industry. Therefore, a serious problem occurs when accurate information is needed for planning and policy decisions, and other economic analyses.

The construction and methodological development of a quantitative economic research framework that would be capable of including explicit consideration of the ten previously listed categories of economic phenomena is a complicated research task. It is obvious that such an analytical technique if developed could be an extremely useful research tool for the economic modeling of U.S. agriculture for many different reasons. This research study has been undertaken as a first generation process to develop such a quantitative analytical technique. This first generation modeling technique interfaces a national simulation model and a recursive programming model in a new methodological framework referred to as Recursive Interactive Programming.
Problems and Transformations in U.S. Agriculture

The problems and related transformations in the technological and spatial structure of U.S. agriculture can be attributed to changes in the ten different, but related categories of economic conditions and stimuli mentioned earlier. These categories may be categorized into three areas: the intertemporal processes of economic growth; the historical involvement of government programs in agriculture; and the interdependence of U.S. agriculture with unstable world markets.

The economic growth of the U.S. economy has had a tremendous impact on its agricultural sector, primarily by affecting the relative input prices faced by farmers making production decisions. As the relative price of capital and capital intensive inputs has fallen relative to the price of labor and labor intensive inputs, the on-farm use of production inputs has shifted toward expanded purchases of larger machinery, fertilizers and other agricultural chemicals [10, 12]. Consequently, economies of farm scale through input substitution have become dramatically more important to producers trying to minimize their average costs per acre [81], and as a result, farm numbers and farm workers have fallen substantially while individual farm acreages and the price of land have increased sharply [9]. Additionally, these economies of scale combined with the recent introduction of hybrid seeds and intensive input use have increased food and fiber supply, and supply potential rapidly, resulting in low
product prices and large crop surpluses until recently [77, 82, 88]. Despite the fact that the U.S. agricultural sector has had chronic surplus problems, questions still arise as to the real surplus capacity under conditions of differential changes in technology, exports and farm sizes [18, 20, 94], and new regional specializations and competition [49].

The second major area of economic impact on U.S. agriculture has been a historical sequence of varied agricultural programs and policies enacted at the federal level and administered by the Department of Agriculture [2]. National agricultural programs and policies have been directed toward maintenance of farm incomes, and the disposal of large commodity surpluses [82], and secondarily to relieve the problems created by the mass migration of people from rural to urban areas [111]. Generally, these programs and policies were designed and created to ease the burdens of farmers of the technological transitions within agriculture [77].

Primarily, these national government programs and policies have consisted of supply control techniques utilizing acreage diversion programs or allotments and price supports utilizing crop loans and support payments for acreage diversions. At times, marketing quotas and marketing certificates have also been used to control the supply of particular commodities. Many of these supply control programs contained gross inefficiencies in terms of resource allocation and technological innovation as well as high costs to the public treasury.
Because land left idle has no economic productivity, and capital inputs were mobile to be used on remaining land in an intensified manner, a major part of the land diversion and supply reduction programs were nullified and land was used inefficiently. Heady [83], Heady, Mayer and Madsen [92], and others [17, 210] have discussed these points in detail. Nevertheless, the major problems associated with the regional transitions of underutilized or misallocated resources into and out of agriculture were hardly addressed by these government programs and may have even been aggravated by them.

On the other hand, along with the supply control programs, the government instituted income maintenance programs. These income maintenance programs were usually in the form of price supports mentioned earlier. These programs were ostensibly developed to support farm incomes, especially those of small acreage farmers when large commodity surpluses and low market prices resulted. These price supports guaranteed the farmer a unit price for his output, thereby removing uncertainty about the minimum level of unit prices when commodity surplus situations occurred, especially over the previous decades. During the 1950's and 1960's the Commodity Credit Corporation (CCC) assumed control over huge surpluses reduced only in part by the P.L. 480 program of food aid to underdeveloped countries [198]. But while these programs undoubtedly helped larger producers because of their lower per unit costs and their larger per acre output, it is not clear that small acreage farmers were able to take full advantage of these
programs [9].

While the debate over the effects of the government programs can never be successfully brought to a final conclusion, it can be expected that government programs will continue to play an important part in technological and regional adjustments in agriculture. Both the supply control programs and the income maintenance programs have had an important effect on the spatial distribution of agricultural activities and input use. In order to understand the impact of national policies on regions or smaller areas, regional interdependencies between crops and livestock activities must be understood in a dynamic setting. Regional or local changes in agricultural activities also have searchable implications for national programs and policies that take into account economic processes of adjustment through time. The question remains whether certain areas have received preferential treatment or benefits unknowingly as a result of government policies directed at the national level.

The third major area of consequence to agriculture has been the intertemporal instability of export demand changes by our trading partners and the resulting income effects on U.S. agriculture [110, 206]. Economic theory suggests that regional land use and the spatial distribution of cropping activities will change as exports of commodities vary over time [108]. Exports can change radically from year to year due to weather disruptions of cropping activities over the rest of
the world or changes in political decisions involving agricultural policies either here or in foreign countries. For example, in 1973 the U.S. exported 17.7 billion dollars worth of agricultural commodities, almost twice the value of exports in 1972 [198]. In 1971 the U.S. exported 27.1 tons of feedgrains, while 43.1 tons were exported in 1972 [56]. Future exports can be expected to increase as long as income levels grow in the developing nations and a preference for a high protein diet persists [59]. But future exports, while trending higher in the long run, can still be expected to fluctuate appreciably around the trend levels over time as conditions which determine foreign countries' import needs change.

Much economic research has been devoted to the problem of exports and its effects on the agricultural sector. For example, Mitchell [134] has explored the problem of estimating variations in export demands by major world areas for U.S. food supplies using econometric methods. Dvoskin and Heady [49], Nicol, et al. [147], and Fedeler, et al. [63] have studied the spatial effects on production activities under different commodity export levels with static, national linear programming models and posing hypothetical different future economic environments. Heady, Reynolds, and Mitchell [94] have used simulation techniques within the context of different farm sizes and production efficiencies to analyze the effect of different levels of exports on commodity prices and farm incomes. There can be little doubt the level of export demands and their probability distributions,
their effects on the spatial distribution of agricultural production activities, market prices and farm incomes will continue to be important areas of economic research.

Simulation and Mathematical Programming Models

Although many analytical techniques are available for national and regional agricultural production, policy, and planning analysis, two different research models are typically used. The first modeling procedure involves the use of mathematical programming transportation models discussed earlier. The second modeling procedure involves the use of sequential econometric equations in a recursive simulation framework [160, 164, 196]. While each model and its accompanying methodology is competent to handle particular aspects of agricultural policy analysis, the role of each is limited by its own methodological structure, and static or dynamic properties.

Static and Dynamic Economic Analysis

Neoclassical economic theories contain both static analyses and/or dynamic analyses [173], but applied economic research has usually fit into one category or the other. Static analysis generally refers to description of economic variables at a given point in time. In terms of neoclassical theory, static analysis occurs when the economic decision making process is subjugate to the allocation of scarce resources at a point in time. Hicks refers to this particular use of statics as the analysis of temporary equilibriums [102, p. 115-117]. As the constraints on the system change over time, a new temporary
equilibrium is reached.

Recent literature in neoclassical theory has placed an increasing emphasis on understanding economic processes and the adjustment mechanisms in economic dynamics. "Economic dynamics may be defined as the study of economic phenomena in relation to preceding and succeeding events" [13, p. 2]. This point of view does not refer to the qualities or character ascribed to the system being studied, but instead changes the position from which the observer may draw conclusions. Samuelson has classified the study of dynamic systems into six specific areas:

1. Static and Stationary
2. Static and Historical
3. Dynamic and Causal
4. Dynamical and Historical
5. Stochastical and Nonhistorical
6. Stochastical and Historical [170, pp. 313-317].

Baumol generalized these classifications into three broader categories which are more useful for the particular research undertaken here:

1. Magnificent dynamics . . . (or) the deduction from fairly broad generalizations (using) alleged psychological or technological laws
2. Statics involving time
3. Process (or sequence) analysis . . . (using) pedestrian relationships between . . . economic phenomena [13, p. 6].

"This study of solutions of dynamic models under alternative policy assumptions might be called comparative dynamics" [36, p. 443], as opposed to static comparisons of equilibrium solutions of static equilibrium models given a long run, hypothesized set of economic events. In comparative dynamics it becomes just as important to know not only
the final equilibrium solution within a given time framework, but also the speed of the system being modeled. In one sense, the key questions in comparative dynamics are those of stability and adjustment processes.

Interregional competition models

Agricultural regional interdependence studies have made great strides in understanding the spatial and competitive relationships between and among many economic variables. National linear or non-linear programming analysis techniques have been extremely useful to predict or select a particular solution of optimal regional or area production activities at a point in time, when given a particular matrix of technical coefficients. These models are also well-adapted for explicit descriptions of the optimizing decision process of producers, the regionalization of production activities and the underlying technical structure of production. As theoretical understandings of modeling techniques and mathematical algorithms have progressed, more problems of policy and analysis relating to agriculture have been studied in greater detail. The economic literature in this area published during the previous two decades is overwhelming and will not be reviewed in this study. However, certain studies highly related to this thesis study will be reviewed in Chapter II.

Nevertheless, most interregional studies, for all their complexity, have failed to incorporate two major related aspects of economic theory affecting economic structure. These are the time element or dynamics,
and the relationships between interregional supplies and demands over time.

The first of these (modeling incorporation problems) is intertemporal structure, or, in short dynamics. The second is the interconnectedness of production . . ., transportation and demand. It is now time to launch a major attack on these twin citadels. Without it we shall have neither an adequate understanding of interregional competition nor an adequate foundation for policy analysis and appraisal [36, p. 442].

Using Baumol's [13, p. 6] categories of analysis, interregional competition studies can be seen as belonging within the second category, or comparative statics analysis involving time. In most cases for these particular studies, the time involved has been limited to two periods, the initial solution period and the optimal or final solution period. However, the use of static models as tools of economic analysis is insufficient to explain economic events as phenomena involving economic processes and changes in temporal structure. Due to this limitation, interregional competition models providing static, long run normative solutions information are extremely difficult to verify either subjectively or quantitatively. Additionally, if "normative" is defined as what ought to be and if "positive" is defined as what actually occurs [67, 138], then Day asserts that from

. . . the dynamic point of view, the distinction between normative and positive economics becomes blurred. If a so-called normative result is not capable of being reached through time, then it can hardly provide a norm for policy [36, p. 443].

This position is highly significant for those economists who provide policy analyses with "normative" programming models because the
policymaker must consider the "positive" aspect of his analysis, or what is likely to happen if a particular policy is effected. The problem for the economist thus becomes one of can the economic system get from here to there; and if so, what policies or circumstances must occur for it to do so?

The second major problem in interregional competition models has been one of matching supplies with demands at a point in time via a transportation system, e.g., the incorporation of a market sector. Many interregional competition models have been formulated as transportation models with minimum fixed regional demands determined a priori by the researcher [61, 73, 86]. Assuming the transportation system in the model reflects real world constraints and costs, then the model does in part reflect the real world marketing structure because supplies are efficiently distributed.

Even so, regional demands and supplies change over time due to price and other variable fluctuations. If an additional assumption is made that current production activities take place due to decisions made in the past, then current supplies can be taken as coming into the market independent of current demands at the national or regional level. Both of the above situations create problems for programming models. The former situation creates a less serious problem for the quadratic programming model because demand quantities are allowed to vary with price changes. In both interregional programming models, current demands for commodities act to simultaneously determine both the temporary equilibrium
prices and supplies. This is due to the fact that in transportation models, supplies must equal demands for commodities. In this particular type of model, supplies are not independent of demands because storage decisions are made a priori to the model's solution. Thus, the transportation model is not adequate by itself to describe the reality of an interregional marketing structure because such models can only describe a temporary equilibrium of commodity supplies and demands. A more realistic modeling framework would contain a marketing sector which would allow consumers not only to change current demands but also allow producers to inventory commodities for the following marketing year based on prices, price expectations and other variables.

Simulation models

Recursive econometric simulation models of U.S. agriculture have been extremely useful for accurately predicting and forecasting an average or aggregate land and resource use, and supply response of various agricultural products under different economic conditions [35, 159, 160, 164, 196]. In these models, the levels of many of these economic variables are calculated endogenously in a recursive format with regression equations estimated with historical and cross sectional data series over short or long run time periods. Other economic variables, such as export levels, input prices, and those related to various government price support and land diversion programs, are typically given to the model at exogenously specified
levels. Consequently, simulation models are similar to interregional programming models in that only part of the agricultural sector is represented in the model.

Simulation models have two important properties not contained in interregional programming models. First, simulation models are able to specify and completely combine the complicated market systems and inventory decisions that are only incorporated into linear and quadratic interregional models in a simplistic manner. Second, these models can be constructed with an explicit dynamic methodological framework which is extremely difficult to incorporate into programming models. Baumol would categorize simulation models as using process or period analysis, his third classification. The dynamic property allows the simulation model to be easily cycled recursively for a few or many production periods, depending upon the needs of the researcher. Thus, the "post-vistic" supply decisions and market and demand interactions of the agricultural sector can be empirically estimated to test economic hypotheses and generate information for policy and planning decisions. In this respect, simulation models derive a large advantage when compared to single period interregional programming models.

Although simulation models have other advantages when compared to programming models, they also have a number of disadvantages which can severely limit their use and applicability for studying certain economic problems. First, recursive simulation models have been primarily used for national or large, regional aggregate analysis because of the statistical difficulties when estimating disaggregated regional or local
supply response, demand, input use, and market equations. Therefore, because these are aggregative models, disaggregative information on supply response, other production and market behavior is very difficult to estimate. Typically, computer routines using fixed weighting schemes based on historical patterns must be utilized to disaggregate the aggregative variable into its component geographic subareas. If the spatial production pattern should vary over time due to structural or technological changes, then the fixed weighting schemes become invalid disaggregation techniques. Interregional programming models which are already disaggregated, obviously do not have this problem.

Second, technical structure of production is implicitly, rather than explicitly, estimated by the simulation model's regression equations. Thus, interregional competition for market shares, and resources, within region competition for resources, the effect of input restrictions, and the optimization or production decision process are also implicitly estimated within the simulation model. As a consequence, much of the production process information available from interregional models is unavailable when the simulation modeling framework is used.

Third, the technical coefficients or parameters in the various simulation equations are estimated with historical or cross sectional data series. Compared with the interregional programming models, incorporating either technical or structural changes into the crucial variable coefficients to reflect changes in agricultural industry operations is extremely difficult. Consequently, simulation models can
become relatively inadequate analytical frameworks for forecasting supply behavior in the production sector or demand behavior in the market sector if the future economic environment of the agricultural industry changes greatly from historical conditions.

Therefore, in order to more adequately explain the dynamics, competitive interactions and spatial distribution of U.S. agriculture than is possible with a "static" linear programming model, or an aggregative and recursive econometric simulation model, it is proposed that a new, and different model and modeling methodology using elements of both the previously mentioned techniques should be developed.

Recursive Interactive Programming

This new model and modeling technique will interface a national linear programming model of agricultural production activities into and with a national econometric market simulation model to create a recursive interactive programming (RIP) model. This model will be far better able to delineate in detail the intertemporal, regional shifts in the spatial distribution of agricultural activities due to price, technological, resource, yield or cost changes and other hypothetical parameter changes, perhaps in the level of exports than either a static national programming model or a national aggregative production and market sector simulation model would be able to do separately. An additional comparative advantage of the recursive interactive programming model will lie within the recursive action characteristics of prices being determined by supplies and demands, neither of which are
fixed from year to year, within the simulation sector. As both national linear programming and econometric production and market sector simulation models have already been built by other researchers for use in other research projects, these initial studies are easily available for this new modeling research format. The linear programming sector of the RIP model would determine the acreage and supplies of commodities based on the market information fed to it by the econometric simulation sector. The linear programming sector of the RIP model presented in this research study will have 99 production areas capable of corn, oats, barley, sorghum, cotton, wheat, and soybean production, where such activities are feasible. Eventually, different land classes, cropping techniques, and resource constraints could be added to the basic linear programming sector. Additionally, respecification of technical parameters in the programming sector to reflect changes in efficiency caused by locational shifts in production could be quantified to better approximate real world conditions.

The simulation sector of the RIP model will include equations to provide estimates of national pre-input and input demands, a market section including variables such as prices, inventories, and income, for the feedgrain, cotton, wheat, soybean, and livestock sectors, a section to revise the linear programming sector problem from period to period, and a section to summarize the acreage and production solution data in the programming sector. To minimize the complexity of the linear programming sector, livestock production will be estimated at national aggregative levels in the simulation sector model.
Naturally, the reliability of the recursive interactive programming model will depend to a great extent on the data transmission within the model of prices, acreages and production, and the respecification from year to year of technical parameters and exogenous variables, within each sector. Nevertheless, the full development of the RIP model should greatly enhance detailed agricultural policy analysis and create new important data applications of past and future agricultural research.

In conclusion, a national dynamic simulation model with a programming sector of U.S. agricultural land resource use patterns and commodity supply responses could be used primarily for simulation analysis of many important agricultural policies, and secondarily, to fuse a great deal of agricultural research, past, present, and future. Agricultural policies could be examined for their immediate and long term effect on the spatial distribution of agricultural activities, the supply response and the capacity to produce food. Possible policy analyses might include different levels of exports, flexibility coefficients used in the supply responses of the programming matrix, technological changes, changes in technical efficiencies and farm sizes, soil loss restrictions, pesticide use restrictions, petrochemical or fertilizer availability, sales taxes or taxes in kind, price supports and land set-asides. Thus, a dynamic national simulation and programming model of U.S. agriculture could be used as a highly flexible tool for detailed analysis of regional and national impacts of different agricultural policies enacted at the national or regional level.
The Objective of This Study

The general objective of this research study is to create a national recursive simulation model with a national linear programming sector to assist in explaining and predicting differential land and supply response from year to year of some major crops in U.S. agriculture. More specifically, the objectives of this study are as follows:

A. Modeling Using Both Recursive Programming and Simulation Techniques
   1. To develop a methodological technique for linking a simulation model and a linear programming model within a recursive cycling format. The new technique and synthesized model will be referred to as Recursive Interactive Programming.
   2. To build successfully a Recursive Interactive Programming model for some major crops in the U.S. agricultural sector.

B. Explanation and Verification of Model
   3. To track and simulate accurately the regional and national U.S. production acreages for barley, oats, corn, sorghum, wheat, cotton and soybeans using historical data series for the period 1969 to 1973 in the following manner:
      a. By individual years
      b. For the five year period as a whole.
   4. To predict the acreages and locus of production of the above crops from 1974 to 1980 under the conditions of a "free market" with trend exports from 1977 to 1980, and actual exports from

Organization of Study

The following four chapters will contain a review and discussions of the economic, theoretical and statistical premises upon which this study is based and a discussion and presentation of the quantitative results of the RIP model. The new interfacing techniques used to link the econometric simulation and linear programming models in this study will also be included.

Chapter II will contain an analysis of the supply response literature including regression analysis, mathematical programming, simulation and recursive programming. These production response techniques and related literature will be evaluated in terms of their appropriateness, virtues and limitations for the estimation of supply response of agricultural activities.

The specification and formulation of the complete simulation and linear programming model will be contained in Chapter III. A discussion of the estimation of flexibility coefficients equations used in this study, and also the methodological problems involved with transferring information for the programming sector to the simulation sector, and the subsequent updating of the programming model will be contained in the first section in Chapter III.

A presentation and discussion of appropriate statistical methods of summary analysis and predictive tests for this model will be presented in the first section of Chapter IV. The second section in Chapter IV will
contain a presentation and discussion of the empirical results of the five historical time period (1969-73) simulation runs. The third section will then present and discuss the empirical results of the predictive period (1974-80) simulation run. The results and conclusions of this study will be presented in Chapter V. The implications and limitations of the particular type of model and modeling technique as applied here and for future research will also be discussed in Chapter V.
CHAPTER II. PRODUCTION AND SUPPLY RESPONSE

The mathematical characterization of an economic model attempting to specify and analyze the supply response of agricultural crops in different economic environments can follow several and varied approaches. Historically, two different methodologies for the estimation of production response have been used. Each methodology has its own economically relevant variables and relationships depending upon the level of aggregation, time framework, and detail deemed appropriate for the particular research study. These are

"First, those in which conclusions about the responsiveness of supply are based upon investigations into the underlying conditions of production; and second those in which the conclusions are based directly on analyses of past experience with respect to prices paid and the response actually associated with them" [28, p. 381].

The appropriate estimation methodology used in the first case has been usually specified within the format of mathematical programming models. In particular, these have been in the form of single and polyperiod farm and interregional competition programming models. The estimation procedures used in the second case have been specified or associated with analysis of variance statistical theory and econometrics. These procedures appear most frequently in various types of static regression analysis models, either as a single equation or as a polyperiod and multi-equation system, sometimes referred to as a simulation model [154, Part II]. A newer methodology has attempted to synthesize parts of both of these methodologies into
a two period modeling design called recursive programming. In this approach, a linear programming model is combined with a set of activity flexibility restraint equations econometrically estimated with time series data for the estimation of production responses. Recursive programming can be distinguished from the technique of dynamic programming through its use of a sequence of optimizing decisions for economic planning, rather than using a single optimizing decision [39, p. vii, viii].

While this thesis topic is similar in certain respects to the design and structure of recursive programming models and simulation models, important differences exist in its conceptual framework. The similarities and differences will be discussed in Chapter III. This subject modeling research is an initial attempt toward linking and interfacing a simulation model with a recursive programming model. From one point of view, this new methodology and technique referred to as recursive interactive programming (RIP), is a recursive programming model with a market sector. From another point of view, it is a simulation model with a linear programming production subsector. In reality, it is both at the same time.

For a clear understanding of the components and advantages of the new methodology for modeling real world behavior of economic systems and disaggregated subsectors, a brief review of relevant economic theory and literature will be undertaken. This chapter is divided into seven sections. A review of the economic theory of the firm in agriculture is
presented in the first section. The second section will contain the development of the static supply function for the firm and industry. The other factors affecting agricultural supply response; risk and uncertainty, expectation models and technological changes are briefly discussed in the third section. A brief organizational review of the different methodologies used for the estimation of static and intertemporal micro and macro supply response functions in agriculture is given in the fourth section. A more detailed review of micro methods of aggregate supply response analysis will be presented in the fifth section. The macro methods of aggregate supply response analysis are discussed in the sixth section of this chapter. Finally, a brief overall summary of the economic theory and literature in relation to recursive interactive programming is developed in the fifth section.

Economic Theory of the Firm

Agriculture is an industry in which the traditional neoclassical economic theory of the firm can be used as a basis for explaining the aggregate behavior of agricultural supply responses. Although production activities are assumed to occur within a Walrasian general equilibrium modeling framework, the usual (and often implicit) assumption is to use the partial equilibrium approach for the economic analysis as suggested by Marshall [123].

The use of a partial equilibrium framework for economic market analysis assumes that supply, demand and price of a commodity are determined simultaneously from the intersection of the commodity's
demand and supply curves. Each commodity market is examined as if it were relatively well-separated from the rest of the markets in the economy. Closely related commodity prices or market variables are sometimes included in the separated commodity market. Most importantly, the innumerable interrelationships among commodities are reduced to manageable proportions by making use of partial equilibrium analysis.

Many of the assumptions necessary for the derivation of the traditional theory of the firm within a competitive market structure are readily apparent in U.S. agriculture. Most importantly, producers act within a competitive market structure with many sellers and many buyers, each of which is comparatively small relative to the size of the market. Thus, each seller or producer must take the price he is offered for the particular commodity he is marketing. He may have a choice of marketing strategies available if he can inventory some or all of his crop for a specified time period. But his decision to withhold supplies from the market has little if any influence on price. Finally, since producers face given output and input prices, they must plan their level of output presumably using inputs in some technological relationship reflecting input characteristics and their corresponding outputs. This technological relationship linking all the inputs to all the outputs is referred to as the production function.

Typically, the economic problem for the firm lies in choosing an optimal mix of outputs while at the same time choosing an optimal set of inputs needed to produce the outputs [64, 101] that will maximize profits [14]. Profits are defined here as the difference between costs and
revenues, and not as the return on risk or uncertainty as Knight has suggested [118]. In addition to the assumptions that the firm operates in a competitive market and that its only objective is to maximize profit, the following additional general assumptions are also needed for the standard neoclassical analysis as follows:

a. the production function allows perfect substitution between inputs;

b. inputs and outputs are infinitely divisible;

c. factor mobility costs are minimal; and

d. the cost of information is zero; risk and uncertainty do not exist.

Given the above assumptions, the input and output decision problem for the firm can be formulated in mathematical notation and solved with differential calculus. The only remaining obstacle for the entrepreneur is the choice of a particular form of production function.

The conceptual apparatus of the "production function" is extremely important in the understanding and estimation of supply response for a number of reasons. First, by making varied assumptions about the technological relationships of inputs and outputs, input characteristics, and input and output markets, a supply function for the firm and industry can be derived. Secondly, the choice of functional forms of the production function directly affects the empirical methodology used to estimate the supply function. A choice of explicit or fixed coefficient production function, i.e., input use proportions are fixed, leads toward estimating the supply function with mathematical pro-
gramming techniques. On the other hand, the choice of an implicit or variable coefficient functional form production function estimates the supply function using econometric regression analysis. Once the latter is estimated the input proportions are still variable although the variable parameters are now fixed.

A production function for a multiproduct firm can be represented in implicit function form as

\[ G(Y;X) = 0 \]  \hspace{1cm} (2.1) \]

where

- \( Y \) = a vector of \( n \) products; \( Y_1, Y_2, \ldots, Y_n \)
- \( X \) = a vector of \( m \) inputs used in the production process; \( X_1, X_2, \ldots, X_m \)

Output levels are positive and input levels are negative. A production function for a single output, \( Y \), can be expressed in explicit functional form using equation (2.1) as

\[ Y = f(X_1, X_2, \ldots, X_n) \]  \hspace{1cm} (2.2) \]

These explicit functional relationships can assume many different mathematical forms. Heady and Dillon suggested and discussed appropriate uses for the Cobb-Douglas, linear, Spillman, quadratic, cubic, square root and resistance production functions [89].

For the firm, the profit function in mathematical notation would be
\[ \pi = \sum_{g=1}^{n} P_g Y_g - \sum_{k=1}^{m} R_k X_k - A \]  

(2.3)

where

\[ P_g = \text{output prices; } g = 1, \ldots, n \]
\[ R_k = \text{input prices; } k = 1, \ldots, m \]
\[ A = \text{fixed costs} \]
\[ \pi = \text{profit of the firm} \]
\[ X \text{ and } Y \text{ defined earlier and are dependent upon the technological relationship embodied in the production functions (2.1).} \]

The profit function must be constrained by the production function to ensure that the levels of inputs and outputs in the production process are technologically feasible. For this purpose, a Lagrangean function is used to mathematically represent the constrained maximization problem as

\[ L = \pi - \lambda G \]  

(2.4)

where \( \pi \) and \( G \) have been defined in (2.3) and (2.1), \( L \) is the solution value of the constrained profit maximization, and \( \lambda \neq 0 \) is an undetermined Lagrange multiplier. To find the most profitable equilibrium position of the firm in terms of input use and output produced, the Lagrangean function is now differentiated with respect to \( L \). \(^1\) To assure a maximum point on the production surface the partial

\(^1\)For ease of explanation, the production function (2.1), can at this point be explicitly defined as a strictly convex set in order to use differential calculus [101; see chapter 5, section 4], but may be redefined as a quasi-convex or feasible point set [101; see chapter 9, section 2], for mathematical programming analysis.
derivatives, or first order conditions are set equal to zero:

\[
\frac{\partial L}{\partial g} = p + \lambda \frac{\partial g}{\partial g} = 0 \quad g = 1, \ldots, n
\]

\[
\frac{\partial L}{\partial X_k} = R_k + \lambda \frac{\partial g}{\partial X_k} = 0 \quad k = 1, \ldots, m
\]

\[
\frac{\partial L}{\partial \lambda} = g(X_1, X_2, \ldots, X_n) = 0
\]  

(2.5)

Additionally, the second order conditions for the firm's profit maximization requires that the relevant bordered Hessian determinants alternate in sign [29], or that profit is decreasing with further use of any input.

At the firm's profit maximization equilibrium, four economic relationships can be derived from the first order conditions in (2.5) [29, 101]. First, the ratio of any two product prices must equal the rate of product transformation or substitution of those products for each other. For the ith and jth products, the first order conditions can be rewritten as

\[
\frac{\partial L}{\partial Y_i} = p_i - \lambda \frac{\partial g}{\partial Y_i} = 0 = p_j - \lambda \frac{\partial g}{\partial Y_j} = \frac{\partial L}{\partial Y_j}
\]

(i, j = 1, \ldots, n)  

(2.6a)

and then by using simple algebra and rearranging terms, it can be seen that

\[
\frac{p_i}{p_j} = \frac{g_i}{g_j}
\]  

(2.6b)
where $g_i$ and $g_j$ are the partial derivatives of the implicit production function with respect of output i and j.

Second, the input price ratio for any two inputs, i and j, must equal the rate of input transformation and substitution in the production process. By substituting input prices and partial derivatives for the ith and jth inputs from (2.5) into (2.6a), then we have

$$\frac{R_i}{R_j} = \frac{g_i'}{g_j'}$$

(2.7)

where $g_i'$ and $g_j'$ are the partial derivatives of the implicit production function with respect to input i or j. Thus the ratio of the marginal products for any two inputs will be equal to the ratio of their prices in equilibrium.

Third, the ratio of the marginal product of any input to the marginal output of any product will equal their price ratio in equilibrium. Taking conditions (2.6) and (2.7),

$$\frac{\partial L}{\partial y_{k}} = p_{k} - \lambda \frac{\partial g}{\partial y_{k}} = 0 = R_{k} - \lambda \frac{\partial g}{\partial x_{k}}

(g = 1, \ldots, n; k = 1, \ldots, m)$$

(2.8a)

and

$$\frac{P_{k}}{P_{i}} = \frac{g_{i}'}{g_{j}'}$$

(2.8b)

Further, using (2.8b), it can again be shown with simple algebra and rearrangement of terms that the price of the kth input used to pro-
duce output $i$ must equal the value of the marginal product of the $k$th input in the production of product $i$, 

$$R_k = P_i \frac{g_k'}{g_k} \quad (2.9)$$

The fourth relationship is developed from equation (2.9) and shows that the firm under equilibrium conditions, will adjust the quantity of an output to equate the marginal cost of its production to its price. Since the total marginal costs of producing any particular product $g'$, $c$, must be equal to the sum of the marginal input costs of its production, we may write

$$\frac{\partial c}{\partial Y_j} = \sum_{k=1}^{m} \frac{\partial X_k}{\partial Y_j} \quad (2.10)$$

Now by substituting from (2.3), we find that

$$\frac{\partial c}{\partial Y_j} = \sum_{k=1}^{m} R_k \frac{P_j}{R_k} = P_j \quad (2.11)$$

In summary, economic theory indicates under certain theoretical conditions, the firm optimizes its production and input use behavior when constrained by the technological relationships between inputs, between outputs and between inputs and outputs, by adjusting the use of inputs and the quantity of outputs to reflect their respective marginal value products and prices. Any additional constraints forced by the firm may be added to the Lagrangean functional form in the manner demonstrated above. Usually these constraints where used reflect or
demonstrate the theoretical effects of capital or land limitations, Nevertheless, the resulting first order conditions will continue to show that in order for profit maximization to occur, the limiting resource will be allocated among production of outputs so that its marginal productive valuation will equally affect all other input usage and product output. The static economic theory of the firm also relates input demands to output production via the technical parameters of the production function. Changes in marginal productivities of inputs for outputs or the substitutability of inputs for other inputs will increase or decrease input demands. Changes in relative input prices or a change in output prices will also affect input use and output production. Thus a successful entrepreneur must have information available describing not only the production technologies available to him, but also on resource availability and relative prices of outputs and inputs. Therefore, the applied research economist must also be able to acquire and examine simultaneously the information upon which entrepreneurial production decisions are based for useful and relevant research inquiries.

The simple, theoretical model of the firm presented above has been often criticized for its inapplicability to real world firm problems because of its simplicity. While the theoretical and mathematical treatment of the theory of the firm can be greatly complicated from the abbreviated model so far presented, two assumptions have been most often criticized when application of the economic
model of the firm has been used to explain real world economic behavior. First, the assumption of perfect competition among firms in many industries, including agriculture, with regard to resource availability and input and output prices might be seriously questioned. Federal agricultural supply control programs, the steel industry, and Xerox are three examples of imperfect market competition where prices received or charged may vary by output level, resource accessibility is restricted and technology is unavailable. The second objection is directed at the assumption that the only objective of the firm is to maximize profits. In reality, entrepreneurs who make the decisions upon which firms operate, may utilize other decision criteria different than profit maximization. Entrepreneurs may wish to maximize total output to increase a market share, total revenue, investment, leisure time or other nonmonetary goals [14], all of which change the nature of the firm's objective function. Thus, the research economist must employ and specify the appropriate production goals for the particular research inquiry in which he is engaged, and be prepared to change modeling goals and assumptions as conditions change.
The Static Supply Function of the Firm

The static supply function for the firm can be derived from a production function both conceptually and explicitly for the firm in a perfectly competitive market. Both the explicit and implicit functional forms of the production function have been introduced earlier in (2.1) and (2.2) as technological relationships associating input use with the production of various outputs. The use of a production function in a particular algebraic form, or in a generalized explicit form to derive a supply response function has been demonstrated in many mathematical micro-economic textbooks [29, 64, 89, 101, 184]. The methodological technique used for the derivation of the firm's supply function is greatly simplified when the seven competitive equilibrium assumptions mentioned earlier are also extended to this analysis. Finally, a specific form of the Cobb-Douglas (C-D) production function has been chosen to illustrate the methodology involved.

The C-D production function is a very easy mathematical function to manipulate. It is a production function in which a single product, \( Y \), is an exponential function of a number of different inputs, \( X_i \), where \( i = 1, \ldots, n \). The explicit algebraic form of a two input C-D production function can be expressed as

\[
Y = A X_1^{b_1} X_2^{b_2} X_n^{b_n}
\]

(2.12)

where \( A, b_1, b_2 \) are constants. The C-D function can be utilized to reflect either increasing, decreasing or constant returns to scale
depending upon whether $b_1 + b_2$ is $>$, $<$, or $= 1$. Despite its many advantages, the C-D function also has many limitations in its application to various production processes. These disadvantages include the mathematical assumptions of constant elasticity of production with regard to inputs used, constant marginal input productivity, an undefined maximum product and finally, that an input becomes limitational at low levels of use [89, p. 75-76].

The Cobb-Douglas production function specified in (2.12) may be modified to reflect a short run, one variable input production function where the other input variables are fixed, so that

$$Y = A X_1^{b_1}$$

(2.13)

where

$$X = X_2^{-b_2} X_3^{-b_3} \ldots X_n^{-b_n} \text{ for } 2, \ldots, n \text{ other inputs}$$

$$X_1 = \text{a fixed level of input } i; i = 2, \ldots, n$$

From (2.13), the amount of $X_1$ needed to produce a given amount of output, $Y$, can be derived with simple algebra

$$X_1 = \left(\frac{A}{Y}\right)^{\frac{1}{b_1}}$$

(2.14)

The short run total cost function in terms of the variable and fixed input can be expressed as

$$C = P_i X_1 + h$$

(2.15)

where

$C = \text{total costs of production}$

$P_i = \text{price of input } i; i = 1, \ldots, n$

$h = \sum_{i=2}^{n} P_i \bar{X}_i; \text{ the total fixed costs of production}$
Relationships (2.14) and (2.15) can now be used to derive the short run supply function. We begin by substituting equation (2.14) into equation (2.15) to obtain the total short run cost function in terms of output, Y,

\[ C = p^1 (AK)^{-1} Y^{b_1} + h \]  

(2.16)

By using the C-D production function, we have implicitly assumed for the general analysis that the input use demand equation is a smooth and twice differentiable function. Therefore the first derivative of the cost function (2.16) with respect to Y is the marginal cost function,

\[ \frac{\partial C}{\partial Y} = b_1 Y^{b_1 - 1} p^1 (AK)^{-1} = MC \]  

(2.17)

where MC is the marginal cost of producing one unit of Y.

The supply function of the firm is now derived from the above first order condition and the assumption of profit maximization behavior by the firm. It was demonstrated earlier in equation (2.11), that the firm will maximize profits when its marginal cost of production is equal to the marginal return or price it receives for the product. In a competitive market, the firm is a price taker and the output price, \( P_y \), is fixed. Therefore, by substituting this relationship into equation (2.17) we find that marginal cost of production will equal the price of the output in equilibrium,

\[ \frac{\partial C}{\partial Y} = MC = P_y \]  

(2.18)
Finally, we assume the second order mathematical conditions expressed as,

\[ \frac{\partial^2 C}{\partial Y^2} > 0 \quad \text{and} \quad \frac{\partial^2 \pi}{\partial Y^2} < 0 \]  

(2.19)

These conditions require the firm's marginal production costs to be increasing at the profit maximizing equilibrium level, and also that profits are falling with increased output. These two conditions are necessary supplementary conditions to the first order conditions for a global profit maximization point.

Using equations (2.17) and (2.18) and appropriately substituting, we find that

\[ \frac{1}{b_1} P \left( \frac{b_1}{1-b_1} \right) = P_Y \]  

(2.20)

which can be expressed in terms of \( Y \), the short run supply function,

\[ Y = b_1 \left( \frac{b_1}{1-b_1} \right) P_Y / P_1 \]  

(2.21)

The short run supply function can also be expressed as a function of input \( X_2 \) when \( X_2 \) is held fixed, or any combination of \( X_i \) held fixed by resubstituting for \( K \), where

\[ K = \overline{X}_2 b_{2-3}^{2} \overline{X}_3^{3}, \ldots, \overline{X}_n^{n} \]

Thus, output is shown to be a function of all inputs used,

\[ Y = \left( b_1 A \left( \frac{b_1}{1-b_1} \right) \right) \frac{1}{P_Y / P_1} \]  

(2.22)
Equation (2.22) shows the output, Y, that would be forthcoming from
the firm for each level of variable input price, P_, and output price
Py, holding the plant, or other factors of production fixed at some
level. Output also obviously depends on the fixed production param-
eters A, and b, . . . , b in the production function.

The firm's long run supply function can be derived using the
above methodology. The firm's long run cost function, where all costs
are variable, is specified as

$$TC = \sum_{i=1}^{m} P_i X_i$$

(2.23)

where TC is total long run cost and other variables as defined earlier.
Similarly, the firm's long run one output production function, where
all inputs are variable, would be

$$Y = AX_1^{b_1} X_2^{b_2} \ldots X_n^{b_n}$$

(2.24)

where these variables have also been specified earlier. To simplify
the derivation, it will be assumed that the total cost and production
functions contain only two inputs, X_1 and X_2. Earlier, in the short run
production function, "X_2" was fixed at a predetermined level. Thus,
total cost for the long-run two input cost function is presented as
\[ TC = P_1X_1 + P_2X_2 \]  \hspace{1cm} (2.25)

and its related C-D production function would be

\[ Y = A X_1^{b_1} X_2^{b_2} \]  \hspace{1cm} (2.26)

From the firm's profit maximizing equilibrium position described earlier and equation (2.6) we can express \( X_1 \) as a function of \( X_2 \).

First, it is remembered that in equilibrium, the firm maximizes its profits by equalizing the ratio of the marginal productivities of the factors with the ratio of their prices,

\[ \frac{\partial Y}{\partial X_1} = \frac{P_1}{P_2} \] \hspace{1cm} (2.27a)

Substituting for the marginal products of \( X_1 \) and \( X_2 \) derived from the following relationships are obtained,

\[ \frac{P_1}{P_2} = \frac{b_1 Y/X_1}{b_2 Y/X_2} = \frac{b_1 X_1}{b_2 X_2} \] \hspace{1cm} (2.27b)
By reorganizing (2.27b) and solving for $X_1$ in terms of $X_2$, the following function is obtained

$$X_1 = \frac{b_1 P_2}{b_2 P_1} X_2$$  \hspace{1cm} (2.28)

This relationship is now used to derive the long run cost and production functions in terms, $X_2$. Thus,

$$TC = P_1 \frac{b_1 P_2}{b_2 P_1} X_2 + P_2 X_2 = \left( \frac{b_1 P_2}{b_2} + P_2 \right) X_2$$  \hspace{1cm} (2.29)

and

$$Y = A \left( \frac{b_1 P_2}{b_2 P_1} \right)^{b_1} X_2^{b_1 + b_2}$$  \hspace{1cm} (2.30)

Now, using equation (2.30) to express $X_2$ as a function of $Y$, the following equation is derived after some algebraic manipulations,

$$X_2 = \left[ A^{-1} \left( \frac{b_2 P_1}{b_1 P_2} \right)^{b_1} Y \right] \frac{1}{b_1 + b_2}$$  \hspace{1cm} (2.31)
Next, equation (2.31) is substituted for $X_2$ in the total long run cost function (2.29), so that costs are expressed in terms of only output, prices and the exogenous production function parameters:

$$TC = \left( \frac{b_1^2}{b_2^2} + P_2 \right) \left[ A^{-1} \left( \frac{b_1^2}{b_2^2} \right) b_1 \right] \frac{1}{b_1 + b_2}$$  \hspace{1cm} (2.32)

Taking the first derivative of this function with respect to $Y$ results in the following marginal cost equation

$$\frac{\partial TC}{\partial Y} = \frac{1}{b_1 + b_2} \left( \frac{b_1^2}{b_2^2} + P_2 \right) \left[ A^{-1} \left( \frac{b_1^2}{b_2^2} \right) b_1 \right] \frac{1}{b_1 + b_2} \frac{1-b_1-b_2}{b_1+b_2} \hspace{1cm} (2.33)$$

Given that the second order conditions for profit maximization are satisfied, the long run supply function can be derived from the above equation by equating marginal cost to the price of output $Y$, $P_y$ as was done earlier. Once this is done, output, $Y$, can be easily determined for any given set of input and output prices and once the parameters $A$, $b_1$ and $b_2$ have been specified. Thus, the long run supply function of the firm derived from (2.33) can be presented below as

$$Y = \left[ A \left( \frac{b_1}{P_1} \right) \frac{b_1}{P_2} \frac{1}{b_1 + b_2} \right] \frac{1-b_1-b_2}{b_1+b_2} \hspace{1cm} (2.34)$$

The aggregate supply function

The competitive industry or aggregate supply function is the horizontal sum of the supply functions for each individual firm in the industry. If each firm has the same costs and production function, this task is simple. But if, for example, changes in industry input demands
cause changes in input prices, and interindustry competitive assumptions are not valid then the actual industry supply curve will become more inelastic than the horizontal summation of the individual firm supply functions. If the above situation occurs, then the aggregate industry supply function must be estimated using other methods. Also, if the industry is characterized by a very large number of nonhomogeneous firms, a method of stratifying firms into relevant homogeneous groups may be used. Assuming the costs of estimating group supply functions from production functions are not prohibitive, the aggregate industry supply function may then be found by appropriately weighting and summing the various stratified firm supply functions.

Other Factors Affecting Supply Response

The real world supply response of firms or an industry occurs within a nonstatic context. Time plays an important part in the production process and the allocation of scarce resources. Time introduces three different problems for the entrepreneur. First is the concept of risk and uncertainty. For the farmer, the element of time in the production process means that weather conditions, prices, and livestock production characteristics cannot be known with certainty a priori to commitment to the production process. Secondly, technological changes occur affecting the structure of the production process itself and therefore the estimated parameters in the production function. Thirdly, as the entrepreneur changes his time horizon for production and policy changes, the "fixed" factors of production can change. As
the "fixed" factors of production change, not only the amount of output shifts but the composition of output is altered also. Thus, the problem of infusing static supply functions with dynamic response flexibility for real world dynamic supply response analysis research is extremely important.

Risk and uncertainty

Risk and uncertainty are concepts that have long posed roadblocks to complete understanding of economic phenomena. Knight, in a classic treatise, was one of the first to recognize the interrelated effects of these concepts on economic behavior when he stated

It is this true uncertainty which by preventing the theoretically perfect outworking of the tendencies of competition gives the characteristic form of 'enterprise' to economic organization as a whole and accounts for the peculiar income of the entrepreneur [118, p. 232].

He distinguished between risk and the true uncertainty mentioned above.

The practical difference between the two categories, risk and uncertainty, is that in the former, the distribution of the outcome in a group of instances is known (either through calculation a priori or from statistics of past experience), while in the case of uncertainty this is not true . . . because the situation dealt with is in a high degree unique [118, p. 233].

Rational economic behavior can then be defined in this framework as an attempt to minimize uncertainty [118, p. 238]. Knight believed that people do not wish to eliminate all uncertainty and trade off uncertainty against risk. These differences with which people perceive and act with regard to uncertainty forms the basis of the competi-
tive market and enterprise system. Essentially, Knight argued that profit was the unexpected income left to the entrepreneur after all inputs are paid their marginal value product. Thus, for Knight, profit is defined as the return to uncertainty, or the unknowable expectations of what future economic events will really occur.

Risk and uncertainty phenomena are especially crucial in agriculture for production decision making by the farmer [43]. This is primarily due to the time delay from when decisions and input use occur to when the production process concludes. Thus farmers must make production and resource allocation decisions based upon expectations of future market and weather conditions, their present production constraints and possible changes in those constraints during the production process. A great deal of agricultural economic research in production response analysis, therefore, has been oriented toward determining how expectations are formed, and production decisions made under risk and uncertainty conditions [41, 140].

Kaldor and Heady's early empirical study of Iowa farmers' corn and hog price expectations using 1948 and 1949 data is one of the few actual attempts to estimate future price expectations [114]. Unfortunately, follow-up studies have not occurred to continue the process of learning how producers formulate expected prices and whether farmers can accurately predict product prices. Among their most important findings were that differences in price expectations and consistency of forecasting errors varied among farmers, and that among
products, the degree of uncertainty over prices was large enough to be important in production planning and resource allocation and finally that no single procedure was used by any farmer to predict prices. These subject areas of capital planning and price expectation models were further theoretically developed by Heady [80, chapter 16 and 17].

Weather and yield uncertainty has also been discussed as a production and planning problem for farmers in the context of game theory using linear programming methods [78]. This approach assumes that the farmer or producer competes against his lack of knowledge of the future, represented as nature. Given a choice of strategies, with different payoffs or returns, the farmer attempts to maximize his well-being or benefit at the end of the production period. Some strategies suggested have been Wald's maxi-min criterion, Laplace's principle of insufficient reason, Hurwicz's optimism-pessimism criterion and finally Savage's regret minimization criterion [1, chapter 6 and 7].

Quadratic programming techniques have also been used to a limited extent for selecting optimum empirical farm plans under risk conditions. This methodology is theoretically applicable for this purpose because it can include both the income variances and covariances of the activity combinations available to the producer. It can also be used to describe an income-variance efficient frontier. Despite these theoretical advantages, Scott and Baker note that
"... the quadratic programming model contains a 'risk aversion coefficient'. But no one has been able to quantify a correspondence between the risk aversion coefficient and a decision maker's utility function. So, this model has thus far had little empirical use." [174, p. 657]

To deal with this problem, they have suggested a general approach for using a quadratic programming model to select an optimal farm plan under risk based on the farmer's own self-assessed income risk preference function.

The above lines of research have primarily attempted to formulate some modeling techniques for replacing uncertain prices and output with numbers known with certainty. Hopefully, once accomplished production and planning decisions can then be undertaken with more efficient resource allocation. Three different mathematical expectation models have been suggested for this purpose.

The simplest price expectations model is known as the static expectations model,

\[ P^e_t = P_{t-1} \]  \hspace{1cm} (2.35)

where \( P^e_t \) = expected price in year \( t \)
\( P_{t-1} \) = actual price in year \( t-1 \)

Here the entrepreneur believes that current year price will be the same as last year's price. No notice of past price changes affect his expectation of the current price. This formulation leads to the classic Cobweb model of agricultural production and price behavior studied by Ezekiel [62], and then extended by Goodwin [71] and Waugh
[208] among others. Of primary interest to economic theoreticians have been the conditions for static and dynamic stability of such economic systems of behavior.

The second price expectations formulation is a little more sophisticated in terms of information needed by the user and is known as the extrapolative expectations model,

\[ P^e_t = P_{t-1} + \alpha (P_{t-1} - P_{t-2}) \]

(2.36)

where

\[ P_{t-2} = \text{actual price in year } t-2 \]

\[ \alpha = \text{proportion of change in price from the } t-2 \text{th year to year } t-1 \text{ influencing the price in year } t. \]

This model is a more sophisticated price expectation formulation because the expected current year price is not only a function of the previous year's price but also is a function of the change in last year's price over its preceding year's price. As \( \alpha \) is greater than or less than unity, the change in price is assumed to be accelerating or decelerating. A negative \( \alpha \) would suggest a cyclical component to price changes around some mean price. Thus, if last year's price fell, the entrepreneur would expect this year's price to rise.

This model has been criticized because only two price observations are used, \( \alpha \) does not change as the price difference changes, and other relevant economic information is absent for the entrepreneurial decision.
The third expectation model was introduced by Cagan [23], as the adaptive model of price expectations. In discrete form, the difference equation may be written as follows:

\[ p_t^e = p_{t-1}^e + \beta(p_{t-1} - p_{t-1}^e) \quad \text{for} \quad 0 < \beta < 1 \] (2.37)

where

\[ p_{t-1}^e = \text{the expected price in year } t-1 \]
\[ \beta = \text{coefficient expectations} \]

In this model, the current year's expected price is a function of last year's expected price plus some coefficient of expectations, \( \beta \), of last year's actual and expected prices. For some, this model has a greater sophistication because errors in expectations are now built into the model. If \( p_{t-1}^e \) is viewed as a function for the same expected and real variables for \( t-2 \), and so forth to year \( t-n \) then the expected current price becomes a function of all past prices, with the most recent prices receiving the largest impacts or weights. This can be easily seen by rewriting equation (2.37) as

\[ p_t^e = \beta p_{t-1} + (1-\beta)p_{t-1}^e \] (2.38)

If \( \beta \) were equal to unity, the adaptive model becomes the static model. If \( \beta \) were equal to zero, then expectations would be fixed and never revised according to past price changes and prediction errors. As \( \beta \) approaches unity, more and more weight is placed on recent price expectation experience and less on more past experiences.
It is also possible to develop the adaptive expectations model into a distributed lag model. This distributed lag model can then be used for price, output or input response adjustments as Nerlove has suggested [140, 141]. Demonstration of this technique for price expectations can begin by writing a relevant distributed lag model [153]

$$P_t^e = \lambda P_{t-1} + \lambda(1-\lambda)P_{t-2} + \lambda(1-\lambda)^2P_{t-3} + \ldots$$

$$+ \lambda(1-\lambda)^nP_{t-n-1} \quad (2.39)$$

and similarly

$$P_{t-1}^e = \lambda P_{t-2} + \lambda(1-\lambda)P_{t-3} + \lambda(1-\lambda)^2P_{t-4} + \ldots$$

$$+ \lambda(1-\lambda)^nP_{t-n-1} \quad (2.40)$$

Now, if equation (2.40) is multiplied by (1-\lambda) and then subtracted from equation (2.39), the resulting equation is

$$P_t^e = P_{t-1}^e + \lambda(P_{t-1} - P_{t-1}^e) \quad (2.41)$$

where

$$\lambda = \beta$$ or the coefficient of adjustment or equation (2.37)

If \( P_{t-1} \) can be written as a linear function of other economic variables, say output, \( Y_t \) or inventory \( I_t \) in year \( t \) then equation (2.41) can be rewritten as
\[ P_t^e = a_0 \lambda Y_t + a_1 \lambda I_t + (1-\lambda)P_{t-1}^e \quad (2.42) \]

The above formulation has wide applicability for the estimation of factor or output supply adjustment equations. For example, as Ray [160, p. 29] demonstrates this equation can easily be reformulated as a fertilizer adjustment response equation,

\[ F_t = a_0 + a_1 F_{t-1} + a_2 R_t + (1-\lambda)F_{t-1}^* + \lambda u_t^* \quad (2.43) \]

where

- \( P_Ft \) = the price of fertilizer in year \( t \)
- \( F_t \) = the amount of fertilizer used in year \( t \)
- \( F_{t-1} \) = the amount of fertilizer used in year \( t-1 \)
- \( P_Rt \) = the price received for another crop in year \( t \)
- \( u_t^* \) = the error term accounting for fertilizer demand not explained by variables in the equation

In this case, the optimum amount of fertilizer in year \( t \), \( F_t^* \), has been specified as a long run linear supply function based on static price expectations

\[ F_t^* = a_0 + a_1 P_Ft + a_2 P_Rt + u_t^* \quad (2.44) \]

Since long run and short run firm or industry response differences have customarily been made using the criteria of availability of inputs, the amount of time producers need to adjust to changing economic conditions vary. Nerlove approached this problem in terms
of estimating the long and short run supply elasticities with a
dynamic estimation model [140]. He reasoned that measurement of these
elasticities could be accomplished by using a distributed lag model
with static expectations thus accounting for the varying availability
of relatively fixed factors of production. This approach, theoret­
ically, would lead to a more suitable model of dynamic producer be­
behavior reflecting time lags, risk and uncertainty. Nerlove and
Addison [142], then proceeded to estimate supply and demand elastic­
ities using a distributed lag model based on adaptive expectations.
If the assumption is made that output is a linear function of expected
price, $P^e_t$, and time, $t$, then

$$ Y_t = a_0 + a_1 P^e_t + a_2 t + u_t \tag{2.45} $$

Now, by substituting equation (2.37) for $P^e_t$ in the above equation

$$ Y_t = a_0 + a_1 \beta P_{t-1} + a_2 t + a_1 (1-\beta) P^e_{t-1} \tag{2.46} $$

By lagging equation (2.45) by one period and solving for $P^e_{t-1}$, equa­
tion (2.46) may be rewritten as

$$ Y_t = a_0 \lambda + a_1 P_{t-1} + a_2 \lambda t + (1-\lambda) Y_{t-1} + u_t \tag{2.47} $$

where

- $Y_t$ = acreage in year $t$
- $Y_{t-1}$ = lagged acreage
- $t$ = a time or trend variable
\( \lambda \) is equal to \( \beta \) but is now called the coefficient of adjustment

For the demand equation, Nerlove and Addison used an income variable to replace \( t \), and quantity, \( q_t \), and lagged quantity, \( q_{t-1} \) to replace \( y_t \) and \( y_{t-1} \). Their results for both sets of elasticities were very promising. The goodness of fit, \( R^2 \), for most equations were above .9 and larger than static explanatory models. Secondly, the estimated coefficients were reasonable and coefficient signs were mostly correct. But Nerlove and Addison felt their most significant finding was the almost uniform lack of serial correlation among the error terms for each of the estimated equations. They postulated that if the error term is serially correlated with the lagged dependent variable equation (2.46) could be rewritten as

\[
\begin{align*}
\text{u}_t^* &= (1-\lambda)y_{t-1} + u_t \\
&= u_t
\end{align*}
\]

(2.48)

Thus, the addition of \((1-\lambda)y_{t-1}\) as a variable in the response equation would theoretically eliminate the serial correlation found in earlier static supply studies. Depending upon whether relationship (2.48) is true or not, estimating an equation using lagged dependent variables may or may not exhibit serial correlation with a Durbin-Watson autocorrelation statistic [116]. Serial correlation and the resulting estimation biases will be discussed later in this chapter.

Many serious problems occur when simple regression expectation models are used in long run and short run production response studies.
Cassels had earlier suggested that investigations of this nature were beset with two interconnected problems of practical real world production behavior; the time lag of response and the specialization of input. He first discussed and developed the theoretical issue of accurately estimating long run response curves when time lags in the production process occur.

"The more sudden and violent the increase in demand the more difficult it will be for supply to keep pace with it. Time is required for the organization of extra shifts, for the renovation of old machinery, for the augmentation of the labor force and for the assembling of additional supplies of the input elements. More time is required for new producers to come into the field and still more for efficiency to be introduced into all the new arrangements. The longer the period allowed for adjustments to be made, the more successfully can the tendency to transitional decreasing returns be overcome and the more advantage can be taken of the economies of the large-scale production. Thus, there is no [supply] curve which can be regarded as the one-and-only supply curve for any particular commodity" [28, p. 382].

Cassels suggests that because of the time lags involved in the firm's changing the input organizational structure due to shifts in demand and technology, the entrance of new firms in search of profits and entrepreneurial uncertainty of real long run demands and prices, long run equilibrium would never be observed. Since equilibrium cannot be observed, it cannot be estimated.

In essence, Cassels' arguments contain some of the same elements Day developed in his discussion of the use of partial equilibrium analysis and the effort to hold other things constant for the estimation of commodity supply elasticities.
"... what has long been said in theory seems substantiated in practice, producers respond not to prices but to profits, and the latter are functions of many variables and influence production within the interdependencies of numerous structural relations. Nowhere in the attempt to construct a model that simulates these interdependencies nor in its application have I found a use for the concept of elasticity. The geometric advance of soybeans continued though soybean prices both increased and decreased. It occurred not because its 'price elasticity of supply' was some specific number, but because its relative profit position among the alternatives to cotton production continued to be superior.

The empirical conditions that existed in the Delta could not justify the applications of concepts based on the partial derivative. 'All other things' just weren't 'constant'. And I suspect they have seldom been constant in other regions and at other times. 'Elasticity' is a kind of fools gold to the economic prospector. Excavation in the layers of economic structure will help him recognize it as such" [39, p. 145].

Similar theoretical arguments could also be presented when discussing the estimation of short run supply functions and elasticities. But in this case, Cassels additionally argues that the relative use inflexibility of many inputs into the production process produces an asymmetry in the increases or decreases in supply responses to changes in prices and demands. He thus suggests that the supply function in the short run may be somewhat irreversible in the real world.

Capital once fixed in a specialized form cannot quickly be withdrawn, and entrepreneurs committed to a particular line of production will commonly continue to produce even when the price they receive does little more than cover the direct costs of operation. If producers have alternative products to which they can turn, . . ., the supply will be more sensitive to price declines but even in these circumstances there is no reason to suppose that the process of contraction will be an exact rever-
sal of the process of expansion. It seems to be, therefore, that each supply curve must be regarded as relating to an established level of output and should be recognized to have two distinct parts, one representing expansion beyond that output and the other representing contraction below it" [28, p. 384].

The postulated irreversibility of supply response suggests commodity supplies may not always follow the direction of price and demand changes. Day's earlier discussion also recognized this problem and suggested that relative profit and input restrictions determine supply response although neither variable is easily quantifiable for time series equations.

Tweeten and Quance [194] explored this area of contention and performed their own analysis of the supply response irreversibilities of the aggregate agricultural sector, and the crop and livestock subsectors. They first stratified their time series observations into two groups using the criteria of positive and negative price changes. They then estimated the supply elasticities separately for each group and found significant differences between the supply elasticities of these two data series. It remains for a comparable analysis to be done for individual crops either at the state or national level to see if similar results are forthcoming.

Finally, despite statistical success in using the Nerlove or adaptive expectation models to estimate behavioral response changes, this model has been criticized as being inadequate to study supply or demand response changes over time for two additional statistical
reasons. The first criticism is drawn from the statistical impossi­
bility of identifying the coefficient of adjustment, $\lambda$, from the
coefficient of price expectation, $\beta$, in distributed lag models. The
second criticism is a theoretical position taken by many economists who
feel this model is incapable of explaining dynamic agricultural pro-
duction response because it is based on a supply adjustment equation
which is too simple to represent complex production decisions made
by farmers. In other words, the equation makes inadequate assumptions
concerning the changing structural and interactive conditions of crop
and livestock production activities by using a simple, fixed coeffi-
cient of adjustment, $\lambda$. If, in reality, the maximum changes in pro-
duction plans farmers would be likely to make in period $t+1$ is in-
fluenced not only by the level of production in period $t$ but also by
changes in economic and noneconomic conditions, then the coefficient of
adjustment is not fixed, but varies from period to period. Thus it
would seem more reasonable that the coefficient of adjustment could
be an estimated parameter and could change from time period to time
period. In functional form, the coefficient of adjustment, $\lambda$, could
be specified as

$$
\lambda_t = f\left( X_1, X_2, \ldots, X_n, \frac{y_t^P - y_{t-1}^P}{y_{t-1}^P - y_{t-1}^P} \right)
$$

(2.49)

where

$X_1, X_2, \ldots, X_n$ are relevant economic, and noneconomic
variables $Y_t^p, Y_{t-1}^p, Y_{t-1}^p$ as defined earlier.

But since planned, long run equilibrium output in time period $t$ is unobservable in the real world, the real coefficient of adjustment is also unobservable. Therefore, equation (2.49) cannot be estimated unless the last variable is dropped, and actual production changes are used as the dependent variable.

**Technological change**

Another cause of agricultural supply response changes is the adoption of technological innovations by farmers. Technological change occurs gradually over time. Whether technological change causes uncertainty in producers' expectations, or whether technological innovations are adopted partly to cope with uncertainty is difficult to accurately assess [22]. Undoubtedly time, uncertainty, and technological change are all interrelated, in a complex feedback disturbance system.

One of the assumptions underlying the derivation of the static supply curve is that technology is held constant. If technology changes over time, then the technical parameters in the supply response function change over time also. Thus, research studies using estimated supply response functions that shift over time encounter serious difficulties. This situation has pointed out the need for theoretical and methodological inquiry into the dynamic character of technological transition as it affects production and supply relationships. Empirical research on
technological change can be broken out into two separate areas, the rate of technological innovation and technological effects on output.

A minimum amount of empirical economic research has been undertaken to study the rates of adoptions of technological innovations in agriculture, by types of users, locations, and applicable circumstances. Among the few published studies, Griliches' [72] study of hybrid corn adoption and how it affected the corn production and supply functions is a classic. On the other hand, much more work has been published examining the technological effects on aggregate commodity supply curves either using changes in resource use or by using a time "trend" variable. Heady and Auer [85], in a notable study, used a Cobb-Douglas production function with time series data to measure and isolate changes in state and U.S. crop yields due to fertilizer, crop varieties grown, weather, and crop acreage data in the form of indexes and technology in the form of a time trend variable. Use of the Cobb-Douglas production function places all the above variables in the form of large aggregate input categories. For example, the technological trend variable includes management, labor and capital changes. Although most of the production functions were estimated fairly precisely, multicolinearity among variables presented estimation problems for finding reliable regression coefficients. Ray [160] also had difficulties with technological changes occurring from 1929 to 1968 in the commodity production functions used in his simulation model. He decided to estimate the production function for four ten-year
periods rather than using one production function for the entire time period. This approach, while moving toward the ideal of having a different commodity production function for each different time period reflecting technological, resource input and managerial changes, still has two problems. First, the relevant time periods using a common technology must be identified. Secondly, enough data observations must exist to estimate the given production function. Most often though, a simple time trend variable will be used for technological changes

\[ Y_t = a_0 + a_T + u_t \]  \hspace{1cm} (2.50)

where

- \( Y_t \) = output in time \( t \)
- \( T \) = a time variable with some \( t-n=1 \), and \( t-n+1=2 \), etc.
- \( u_t \) = the error term explaining all other output variations

This approach has been often used for trend yield estimation projections [94], and can be modified to reflect resource use changes [93].

The estimation approach presented above has been criticized in two ways. First, regression analysis uses aggregate time series data to estimate parameters in a predetermined form of production function. Concomitantly, assumptions concerning the independent variables and error terms are made which may not be entirely correct which results in biased parameter estimation. Additionally, the aggregate supply function is estimated indirectly without knowing the real underlying
production function. Thus, the organization of input use, behavioral and institutional constraints, and managerial decisions are all estimated implicitly. The second criticism stems from the use of a time variable as a "catch-all" for other technological change occurring in the production function. Use of a time variable assumes that technological progress or trend occurs at a uniform rate over time. This assumption can be seriously questioned. Given a long enough time period, and a large enough regression coefficient, estimated output could become either infinite or negative. Also, changes in technological trends from year to year or turning points remain unexplained with a constant, given parameter in a simple time trend equation.

Estimation of the Firm and Industry Supply Function

A number of different methods have been used to estimate firm and aggregate commodity and livestock supply functions [84]. These methods can be classified in a two way box diagram for illustrative purposes (see Figure 2.1). Horizontally, the particular methodologies may be static or dynamic and vertically may be micro or macro in nature. Dynamic methodologies involve the explicit use of time while static methodologies do not. Macro methodologies can be characterized as being multifirm, aggregative supply functions. Depending upon the particular research question posed by the agricultural economist, any or all of these methodologies may prove to be useful tools of analysis.
Figure 2.1. Analytical Techniques for Estimating the Aggregate Supply Response of Agricultural Products
Static, micro methods of aggregative supply analysis include farm surveys, farm budgeting, and linear programming. These three approaches are primarily micro methods of studying a firm's supply response occurring within one time period. For a polyperiod firm supply response, dynamic programming techniques are usually applied. Once the firm's supply response is estimated, and if necessary aggregation assumptions are fulfilled, an aggregate supply response is obtained by summing firms within the industry. Macro approaches to aggregative supply response can also be static or dynamic, but the analysis is derived from industry response, rather than from firm response data. Static macro methodologies include input-output studies and regression or econometric analysis of time series and cross-sectional data. Linear programming has also been used extensively as a method of static-macro supply response analysis. Recursive programming and simulation analysis are classified as multiperiod or dynamic macro oriented methodologies. Simulation analysis uses econometric equations in a recursive format with the time period specified by the research. Recursive programming uses both linear programming and econometrics but it has so far been used only in a two-period analytical framework and has therefore been quite limited in its use and applicability. Despite their micro or macro orientations each of these alternative techniques uses the theory of the firm and the firm's static supply function as developed in the previous sections as the starting point for supply analysis. Each method
also enjoys certain empirical advantages and disadvantages in its use, transformation, and output of data for economic analysis which will now be presented and discussed in limited detail. First, micro methods of supply analysis will be examined, followed by a section in which macro methods of supply estimation will be examined.

Micro Methods of Aggregate Supply Analysis

The micro methods of aggregate supply analysis are based on an approach which uses a limited sample of firm supply response data to derive a local aggregate supply function, and then a regional or national supply function from the local supply functions. In particular this estimation work necessitates correct detailed knowledge of firm input-output data or technological production function relationships, costs, prices, and relevant behavioral and institutional restrictions for a thorough analysis. In most cases, the large number of industry, regional or local farms makes sampling the only economically viable method of obtaining data.

Farm budgeting and farm surveys

Farm budgeting and survey techniques were developed to circumvent the twin problems of capital and managerial input allocation among farm activities [109]. Neither of these techniques have been commonly used for aggregate supply analysis. Mighell and Black [129] have summarized many early farm budgeting studies of milk production response. Since then, farm budgeting and survey studies have been superseded by
linear programming analyses that can do approximately the same task. Nevertheless, the use of farm budgeting or survey tools to estimate farm supply functions has proven to be a very tedious and exacting procedure because of the tremendous volume of necessary detailed information. Additionally, one encounters three major difficulties:

1) Interfarm differences in managerial input and in technology;
2) Multiple products which are interdependent in production; and
3) Measurement of input levels, particularly capital [143, p. 542].

when using this data to estimate production functions.

The farm budgeting approach assumes that a close working relationship is maintained between the researcher and farm manager and that the researcher is able to use objective personal judgment when evaluating different farm plans. Essentially, this approach asks the manager how inputs would be organized, given a set of prices, and then what output would be under those circumstances. As the investigator varies prices, the manager changes input organization and therefore output response. The problem for the investigator and manager is to distinguish between the "most likely" and "most profitable" input organizations and output responses under each set of given conditions. The "most likely" circumstances are the ones used by the researcher to develop a supply response schedule. The advantage of this approach is the detailed information developed reflecting the behavior of the firm. But the decision process of selecting the "most likely" farm response embodies a great many personal judgments reflecting the rate of adoption of
technical changes, uncertainty, risk, and institutional constraint factors. In a world of imperfect information and insufficient knowledge of the true technological production relationships, the optimal and other production plans will not always be considered by a particular manager. Thus, the investigator is most often selecting farm plans from an incomplete data set. Also, when capital stock or equity restraints are present, each farm firm will have different cost curves. Thus, Nerlove and Bachman's three data accumulation difficulties suggest aggregation bias is almost always present if this particular micro to macro approach is used.

The farm production survey approach has also been used for estimating aggregate supply response analysis. This analysis tool has the same disadvantages and the same primary advantage as the farm budgeting approach, but the approach is slightly different. First, as the word "survey" suggests, this approach accumulates firm output responses to hypothetical price changes by gathering data from many different farms rather than from just a few selected farms. Secondly, the farm production survey is not primarily designed to expose the production function relationships, or input organization changes, by farmers in response to exogenous factors, such as prices. Rather, the information thrust is in the direction of gathering information on the "most likely" supply responses by producers as reactions not only due to price changes but also nonprice factors as well. Some of the nonprice factors include weather expectations, commodity inven-
tories, future export expectations and expansion plans. But again, the investigator must use his personal judgment in the acceptance or rejection of elicited supply responses.

**Single period linear programming models**

In addition to farm budgeting and farm survey techniques, linear programming is the third technique used to move from micro to aggregate supply analysis. Many books have been written on the use of linear programming techniques in economics [1, 46, 87] and more specifically in farm management [15]. Linear programming is one technique in the general category of mathematical programming. Quadratic, recursive and dynamic programming are three other techniques and will be discussed later in this chapter. Mathematical programming and linear programming in particular is a computational algorithm designed to find the optimal set of activities which maximize some prespecified objective function subject to a limiting set of resources [45]. Typically, many different activities are available to the farm manager, all of which use resources and some of which may be limited or restricted to certain levels due to institutional constraints. But linear programming provides the agricultural economist with a far more flexible tool to study supply response than either the approaches of farm surveys or budgeting because the modeling of the farm firm is a more adequately specified format for empirical research.
The [linear programming] models are more practical because they allow consideration of many variables or activities represented by alternative crops, livestock, technological practices, financial operations, and storage and handling activities. They are also more practical because they allow detailed consideration of resource, financial, tenure, institutional, or risk restraints. These restraints can be detailed by months or seasons of the year, or even by days, if necessary [1, p. 10].

Nevertheless, the data necessary for matrix, objective function and resource restriction construction is usually gathered through farm budgeting and surveys techniques. Thus use of linear programming techniques provides a highly sophisticated analytical framework for research economists.

Linear programming is an approach similar to the Lagrangean technique used earlier to derive the supply response of the firm. But while the Lagrangean technique assumes continuous and twice differentiable functions necessary for calculus derivations, linear programming allows use of discontinuous functional relationships. Linear programming techniques are used whenever the objective is to maximize or minimize some function \( f(X) \) where \( f(X) \) is linear and \( X \) ranges over a convex set [ibid., p. 30]. A maximization problem can be written in matrix form as

\[
\begin{align*}
\text{Max } Z &= c'X \\
\text{subject to } \\
AX &\leq B \\
X &\geq 0
\end{align*}
\] (2.51)
where

\[ A = \text{an } m \times n \text{ matrix of technical (input-output) coefficients} \]

\[ c' = \text{an } 1 \times n \text{ vector of prices, net returns or other weights} \]

for the objective function

\[ X = \text{an } n \times 1 \text{ vector of commodity, livestock, water, financial, etc. activities used in the model} \]

\[ B = \text{an } m \times 1 \text{ vector of resource constraints} \]

\[ Z = \text{the value of the objective function } c'X \]

The algebraic form of the matrix notation could be written as

\[
\text{Max } Z = c_1^T X_1 + c_2^T X_2 + \ldots + c_j^T X_j + \ldots + c_n^T X_n
\]

subject to

\[
a_{11} X_1 + \ldots + a_{1j} X_j + \ldots + a_{1n} X_n \leq b_1
\]

\[
a_{21} X_1 + \ldots + a_{2j} X_j + \ldots + a_{2n} X_n \leq b_2
\]

\[
\vdots
\]

\[
a_{ij} X_1 + \ldots + a_{ij} X_j + \ldots + a_{in} X_n \leq b_i
\]

\[
\vdots
\]

\[
a_{mj} X_1 + \ldots + a_{mj} X_j + \ldots + a_{mn} X_n \leq b_m
\]

\[ X_1 \geq 0, X_2 \geq 0, \ldots, X_n \geq 0 \]
or finally as

$$\max Z = \sum_{j=1}^{n} c_{j}x_{j}$$

subject to

$$\sum_{j=1}^{n} a_{ij}x_{j} \leq b_{i} \quad (2.53)$$

$$x_{j} > 0$$

where

$$i = 1, 2, 3, \ldots, m \text{ and } j = 1, 2, 3, \ldots, n$$

Agrawal and Heady have discussed the seven basic assumptions contained in the conventional linear programming problem presented above.

1. Additivity of resources and activities. . . the sum of resources used by different activities must equal the total quantity of resources used by each activity for all the resources.

2. Linearity of the objective function. [The costs or prices are independent of the level of their respective activity.]

3. Non-negativity of the decision variables.

4. Divisibility of activities and resources. The assumption implies continuity of resources and output. . . .

5. Finiteness of the activities and resource restrictions.

6. Proportionality of activity levels to resources. Proportionality . . . implies constant resource productivity and constant returns to scale . . . [Each process uses resources in fixed proportions.]

7. Single-valued expectations. It means that resource supplies, input-output coefficients, prices of resources and activities, and so forth are known with certainty. This assumption imparts to the model
Naturally, the particular selection of activities, resource constraints, technical input-output coefficients, prices or costs and maximization or minimization of the objective function depends upon the objective of the research inquiry and its time horizon.

For prediction purposes, profit maximizing or cost minimizing solutions are useful for indicating the direction and extent of activity level changes from an initial period within a firm or region and among regions given certain restrictions. The restrictions are responsible for "forcing" the model to approximate a real world solution with real world restraints. In the long run, when all restraints explicitly formulating short run changeover costs, established farm customs, lack of knowledge, capital restrictions and other constraints are removed, linear programming solutions may accurately indicate the real world efficient, long run solution. But linear programming techniques are not especially well-suited to empirically predict short run, year to year activity level changes and adjustments. Usually the actual process of adjustment mechanisms cannot be explicitly formulated in model restrictions, even if actual production practices and input-output coefficients have been specified.

In this respect, the seven assumptions and mathematical format of linear programming models create a problem for the researcher because of its normative approach to farm-firm behavior. Normative is used here in the context of describing how firms should behave given
certain assumptions, relative to some objective while positive would be defined as describing how firms actually do behave given these same conditions [67, 138]. Day has asserted that the controversy over how the optimal solution for a linear programming problem should be interpreted is due to a misconception of what the optimization principle in economic theory really means, and what its use should be for explaining real world economic phenomena [36]. Day reasons that use of the "normative" choice of activity plans by the linear programming algorithm as the optimal choice for the farm manager is a gross misuse of information because the model itself is only as good as the specified data, alternative activities and constraints. Since all alternatives and constraints are seldom perceived much less empirically quantified and placed in the programming matrix, the programming model itself will be underidentified as a real world planning model. Therefore,

... because the choice of variables are optimal in this logical sense does not mean that they are "the best" or "normative". In fact, they need not be thought of as determining what "ought" to be done at all but more realistically the best that can be done under the circumstances of the existing decision environment.

Mathematical programming models are based on the optimizing principle, but for the reasons described they are not necessarily normative [36, p. 445]

In summation, it is the considered opinion in this brief discussion that the critique of linear programming models on a positivistic basis, i.e., they do not describe how farmers do behave or will behave, can only be formulated on the basis that the structure
and elements of the model are incorrectly specified, and will always be so. Thus, the derivation of a firm's supply function from a mathematical programming formulation is normative in nature, and may be somewhat positivistic given a high degree of real world modeling specification.

Two techniques are typically used to estimate normative firm supply functions from linear programming problems; parametric programming and range analysis. Parametric programming is sometimes referred to as sensitivity analysis and is used to describe the changes in activity levels that occur when coefficients in the A matrix, the resource constraint vector, \( \beta \), and the objective function vector, \( \mathbf{c} \), are varied [87, chapter 8]. Typically, for normative supply function estimation, prices in the \( \mathbf{c} \) vector are varied which changes the slope of the isoprice line. Depending upon the amount of change in the component(s) of the \( \mathbf{c} \) vector, the point of tangency of the isoprice line with the boundary of the feasible region may change, leading to a new optimal activity solution set. The original problem specified in (2.51) may now be represented by

\[
\text{Max } \overline{\mathbf{c}}'\mathbf{X}
\]

subject to

\[
A\mathbf{X} \leq \mathbf{B}, \ \mathbf{X} \geq 0 \tag{2.54}
\]

where

\[
\overline{\mathbf{c}} = (c_1, c_2, \ldots, c_j', \ldots, c_n) \text{ for the new objective function with a change in only one element, } c_j',
\]
where \( c'_j = c_j + D_j \).

Thus by changing a particular \( c'_j \) in discrete intervals, a range of optimum activity plans will be obtained. From each of these solutions, a particular activity level or output level is determined providing the stepped supply curve. (See Figure 2.2.) The supply function is stepped because as discrete changes in price occur, the iso-price line shifts from one corner point to another on the boundary of the feasible set of production points or production frontier. These discrete shifts on the production frontier correspond to changes in the levels and mix of competing activities. Depending upon the level of discrete change in the particular \( c'_j \), the optimal plan may or may not remain stable, thus providing the stepped look supply curve. In neoclassical economic theory the production frontier is continuous rather than discontinuous and price changes considered are extremely small, thus providing a smooth supply curve.

The second type of parametric technique used for the estimation of normative supply curves is range analysis [183, Section 3.3]. This technique tries to avoid the problem of missing the corner point by using the above method of discrete price changes. It approaches the problem from a slightly different viewpoint while still trying to ascertain how much a \( c_j \) coefficient must change in order for a new optimal plan to transpire. Range analysis attempts to ascertain the amount of \( \Delta c_j \) required before a new solution becomes optimal, and the old solution suboptimal. This procedure is then repeated until
Figure 2.2. A Stepped Supply Curve from Linear Programming Analysis [168, p. 29]
a sufficient number of supply points have been discovered to develop a supply curve. The advantage of this method is that the critical prices at which supply changes are obtained directly. The disadvantage of this method is that it is more tedious and expensive than parametric programming.

Typically, the aggregate industry supply function would be a horizontal summation of the individual farm-firm supply curves given the classical economic assumptions of a competitive industry and input conditions. But summing these farm-firm stepped supply functions to form an aggregated local, regional, or national supply response curve usually develops serious aggregation problems aside from their normative production function characteristics. The three assumptions or problems discussed be Nerlove and Bachman and presented earlier, e.g., the nonhomogeneity of firms, will almost always be violated causing serious aggregation bias. Usually the large number of firms precludes modeling each firm due to cost and time considerations. Therefore, a common technique is to use an "average" or "representative" farm for different types or classes of farms within an area and then weight and sum these individual supply curves into an aggregate supply curve by using farm frequency within the given classifications.

A careful appraisal of linear programming as a tool for estimating supply analysis highlights several advantages and disadvantages when this modeling technique is used. These disadvantages and advantages are relative to other supply estimation techniques, the complexity of
the particular linear programming model being constructed and the research objective.

Linear programming models can enjoy several distinct advantages for supply analysis estimation. First, the technical structure of production is made explicit in the input-output coefficients and activity relationship coefficients contained in the model. Second, since most agricultural firms are multiproduct farms, many products and activities compete for the same resources. Programming techniques are able to explicitly demonstrate how, why, and where resources are most effectively used and how resource constraints affect production activities and output. This advantage assumes disaggregated input categories and input-output coefficients can be accurately estimated for different kinds of capital, land, labor, and chemical inputs. Third, technological changes and the resulting changes in supply response can also be fairly easily examined using linear programming models, although this must be accomplished in an implicit manner. Typically, these types of studies are done through the use of explicit and exogenous changes in the input-output matrix coefficients, the resource level availability or changes in the objective function [8].

Linear programming models have also been frequently criticized. First, the "normative" nature of these models has been briefly described earlier in this section. The second disadvantage concerning the aggregation problem and bias has also been previously discussed.
This problem as it relates to macro models will be discussed in a later section in this chapter.

The third major disadvantage of single period linear programming models is that they are only capable of being used to estimate a timeless or a point in time supply response. This disadvantage poses two serious problems for agricultural supply analysis. First, there is no answer to the question of how the system moves from one activity solution set, such as the actual real world solution, to the new "most efficient" solution. In other words, a time path for variables is not generated because the supply response occurs instantaneously. While this criticism is one generally made of all static models, the "feasibility" of being able to attain normative solutions still remains controversial. Second, a problem exists when technological change and the investment process is studied using a static, point-in-time model. Although technological changes and investment can be represented in these single period programming models it is extremely difficult because there are intertemporal phenomena. Therefore, an explicit representation of how technology is adapted and diffused due to the stimulus of ongoing production processes cannot be generated using this modeling framework. Thus, questions concerning capacity constraint changes due to investment as production activity shifts occur, are usually examined in other supply response models.

The fourth disadvantage is that linear programming assumes prices, costs, matrix and constraint coefficients are known with certainty.
The "certainty" assumption is made in all stochastic models. In other words, the effects of uncertainty are always unaccounted for because all coefficients are given a priori to the model's solution. Uncertainty, therefore, is introduced into the model indirectly via various methods of parametric programming discussed earlier.

Finally, linear programming models usually assume the goal and only objective of the farmer or entrepreneur is to maximize short run profit or minimize short run cost subject to certain given constraints. In reality, the farmer's goal or objective may be to maximize total revenue, maximize utility of his expected income against the variance of income, or he may even have a multigoal objective in mind when he makes complicated production decisions. Thus, a simplistic "profit-maximization" approach typically used in mathematical programming to explain actual observed behavior may be far too simplistic in many situations to be realistic methodology.

Dynamic programming models

Dynamic programming is generally used as a micro-oriented tool in agriculture for firm planning. Dynamic programming is a specialized type of mathematical programming that explicitly includes time within the modeling format [1, p. 104-114]. This technique assumes that decision processes are multi-staged in the planning process. Additionally, it is assumed a decision in one period affects decisions made in later periods and that the perceived decisions available in later periods affect the decisions made in prior periods. Thus there is
implicitly assumed in the programming technique some type of linear feedback mechanism.

Dynamic programming techniques have great potential for such problems as equipment replacement, crop rotations or sequences over time, multiple cropping programs within a year, sequencing of water among users of a district or village, the optimal growth path of a farm which has many alternatives in plans for successive years, replacement policy for livestock herds, optimal growth paths for farming regions similarly faced with many alternatives over the future, feed inventory policies, and the optimal linkage of tasks in vegetable harvesting and processing. They have been used widely for decision and solutions of allocation of m missiles to n targets, cargo loading, optimal climb paths to be followed by airplanes in attaining minimum time, minimum cost procurement programs, early warning radar net, and similar complex sequential problems [1, p. 104].

Thus, while both linear and dynamic programming assume proportionality, linearity and additivity in the objective function and input-output coefficient matrix, the constraints in dynamic programming models may be nonlinear. This is due to the mathematical respecification of the linear model into a dynamic model dealing with activity selection changes in different time periods. Mathematically this relationship can be demonstrated by using equation system (2.53). By adding an extra constraint that an activity or process, \( X_{n} \), where \( 1 \leq n \leq j \), must be equal to a given quantity \( X_{n}^{*} \), the system (2.53) becomes

\[
\text{Max } Z = \sum_{j=1}^{n-1} c_{j}X_{j} + c_{n}X_{n}^{*} = Z^{*} = \sum_{j=1}^{n-1} c_{j}X_{j} + c_{n}X_{n}^{*} \tag{2.55}
\]

subject to

\[
\sum_{j=1}^{n-1} a_{ij}X_{j} \leq b_{i} - a_{in}X_{n}^{*} \quad \text{for } i = 1, \ldots, n
\]
where

\[ X_j > 0 \]

Because in a linear programming problem, the problem objective is to allocate scarce resources to minimize cost or maximize profit in one time period or planning stage, the planning process is ignored. Dynamic programming attempts to rectify this problem by breaking out the decision path into component time stages. By so doing, it is designed to formulate an optimum overall activity selection program subject to the interdependence of activity levels and selections in different periods. Thus, the overall solution plan may in some farm problem formulations, be radically different than the solution plan suggested by a particular one-period linear programming model.

Dynamic programming techniques have not been widely applied to agricultural problems concerning farm planning decision-making. Undoubtedly, as this technique becomes more widely known and accepted, empirical research methodologies will develop quickly. The typical approach in matrix design has been to link a set of three or four linear programming models together in a diagonal pattern. By using transfer rows, resources and outputs can be switched from one period to another, given a priori constraints. Loftsgard and Heady's pioneering application of this technique to farm and household planning [122], is especially interesting in its attempt to relate farm resource use to expenditure needs of the farm family and the interactions and con-
straints imposed therein. Another very interesting utilization of dynamic Programming for farm capital and equipment usage and replacement planning has been done by Yaron and Horowitz [214].

Dynamic programming can also be used as a macro supply analysis tool. In particular, an important application of dynamic programming left unexamined by agricultural economists is for planning economic development of rural areas by identifying constraints and economic feasibility of different investment patterns. A pioneering attempt to use dynamic programming for these purposes was a study done in rural south central Kentucky [182]. A similar dynamic modeling attempt to estimate aggregate supply functions for a particular region over time could prove to be extremely useful for two reasons. The first reason is that the extension and development of empirical economic methodology necessary to handle a macro supply estimation problem using this technique would help to identify the activity level adjustment processes producers make from period to period. Second, a great deal of empirical knowledge concerning how the supply behavior of producers will vary due to changes in resource availability over time, especially with regard to national agricultural policies.

Dynamic programming models have many of the same advantages and disadvantages of linear programming models discussed in the previous section when used as tools for supply analysis. The dynamic programming model, though, is even more sensitive to the "certainty" criticism because its objective function is exogenously specified over a number
of time periods, and it is possible that a solution in period t-1 could affect prices and costs in following periods. Even so, dynamic programming models include an explicit time element not contained in linear programming models. This time element allows the explicit recognition of decision processes in the model. Dynamic programming models, therefore, provide a more realistic intertemporal foundation for farm planning and furnish a format for investment process activities to be explicitly rather than implicitly formulated.

Macro Methods of Aggregate Supply Analysis

The macro methods of aggregate supply analysis are based on a methodological approach using aggregate supply response data. If the aggregate supply data is local or regional, either local and regional supply responses are estimated or the actual disaggregated supply response data is summed into the appropriately aggregate level of analysis. Because aggregative information is usually far more easily obtained than the firm data necessary for micro analysis, a great deal of research work has been devoted to studying and explaining macro supply response and economic fluctuations, or business cycles [135]. Although a great deal of technical or micro oriented information is discarded in macro analysis, the stimuli and constraints applying to firm economic behavior are generally used as working hypotheses for industry supply response analysis [21, 152, 212]. Frequently, though, slightly different theoretic approaches are neces-
sary to describe aggregate, industry supply response behavior be-
cause variables and situations are varied to reflect real world
conditions where the theoretic competitive industry equilibrium con-
ditions are violated. In these cases, the expected aggregate or macro
industry economic behavior can be different than that of the individual
firm.

**Single period interregional programming models**

Single time period linear and quadratic programming models have
been used for many aggregative applications to economic policy and
planning decisions involving agriculture [97]. These models have been
developed for studies of interregional competition efficiencies, re-
source use, soil loss, supply potential, land use and other relevant
policy questions involving U.S. agriculture. As data availability
and computer efficiency have increased over the last two decades,
many more relevant activity processes and production areas have been
added to existing models. The simultaneous solution characteristic
of interregional models with regard to both levels and spatial dis-
tribution of production, demand, resource use, and transporation ac-
tivities has made linear and nonlinear modeling approaches extremely
useful, although expensive to solve and develop appropriate data
bases. Although econometric approaches for macro supply analysis
are usually far less expensive and time consuming to solve
compared to macro interregional competition models, the appropriate
and necessary time series and cross-sectional data are often unavailable for valid predictive equation estimations. This situation plus the added difficulty of the nonsimultaneity of econometric equations and its inappropriate format for spatial transportation and resource use estimation has added to the popularity of interregional competition modeling techniques.

Interregional competition linear programming models are typically formulated using the objective function goal of minimizing production and transportation costs among regions and between crops subject to known or given regional or national domestic and export demands. Quadratic programming models on the other hand, use a net return objective criteria. Both techniques use a region as the basic activity unit rather than the farm. Thus, by using these two spatial models, the interregional and implicitly, the interfarm competitive characteristics of the entire agricultural sector may be explicitly formulated through the incorporation of regional commodity and livestock demands with an interregional transportation sector. An excellent specific mathematical formulation and explanation of a linear interregional model can be found in C.A.R.D. Report 40T [91]. The mathematical structure closely resembles equation sets (2.51-2.54) and need not be repeated here.

Interregional linear programming models have undergone many transformations during their historical development. Heady and Srivastova [97] have detailed the variations and changes made in these models at the Center for Agriculture and Rural Development where much of this
activity has taken place. These models have been built to provide information about and to study the effects and costs of different changes in government policies, technology, export capacity, land use and environmental quality variables. One of the earliest models built by Egbert and Heady in 1955 [59], included 104 crop production areas located within the continental U.S. This prototype model was used to supply benchmark studies with optimal regional locations of production patterns of wheat and the feedgrains. Each region reflected land availability and productivity common to that particular area of the country. Only national annual feedgrain and wheat demands were used to determine the least cost, most efficient patterns of production under different scenarios. Later, Whittlesey and Heady [210, chapter 2] developed a larger model with 144 regions to study interregional competition and the surplus agricultural capacity existing in 1965. The major extension of this research consisted of using 31 consuming regions each with its own commodity demands, now including oilmeal (soybeans). Cotton demand was given at a national level. The major advantage of this model formulation using transfer and transportation activities among the 31 consuming regions, was to allow regional production competition among crops in a manner allowing least-cost optimal use of resources with regional demands. This model was later used to analyze the effects of national agricultural policies and their relative costs and merits as supply control programs [210, chapter 3]. In 1968 a further development of this model included a
livestock sector so that livestock and crop production patterns could be analyzed simultaneously [59, chapter 5]. Eyvindson [61] then in a monumental research effort reformulated the interregional livestock and crop model to have three different farm sizes in each region, each with its own labor and capital costs, and constraints and yield coefficients. This model also included three different soil types within each of 190 producing regions. The great detail included in this model necessitated building a 7000 x 42000 activity matrix which resulted in many technical problems in finding an optimal solution with the computer. In 1972, initial work was completed on a new expanded 223 production region, 28 market region national interregional competition model by Heady, et al. [90]. This model shifted the emphasis of research work toward long range agricultural export and capacity policy and planning studies particularly as they related to water use, [91], fertilizer availability [49] and environmental problems such as soil erosion [207]. The assumption of a long run adjustment period precluded the utilization of resource constraints on labor or operating capital. Modifications of the number of land classes, aggregation of the producing areas, water use, and transportation sector, final commodity and livestock demands have occurred as research activities have focused on different economic policy and planning questions concerning U.S. agriculture.

While long range, national interregional models have drawn a great deal of attention for supply analysis studies. Regional linear pro-
gramming models have also been recently built for supply analysis estimation of commodities in California but with a different emphasis [179, 180]. In these studies, Shumway and Talpaz first focus on the problem of assessing

"... the predictive ability of models that assumes a long period of adjustment since neither 'normal' prices nor long run desired output levels are observed in the real world. Consequently there are no real world observations against which to validate long run LP predictions" [180, p. 1].

By manipulating the output predictions of their regional profit maximizing LP model by utilizing parametric programming, supply data were generated and evaluated using actual observed production levels. Both adaptive and partial adjustment model econometric equations were fitted with the long run price parameters which were estimated with the parametrically generated data. Their findings demonstrated "that appropriate short run predictions of supply can be generated for purposes of evaluating the reliability of a long run LP supply model".

Although many of the regressions did not have good fits (high $R^2$) and therefore did not predict well, the Nerlove partial adjustment models coefficients satisfied more of the expected a priori signs and magnitudes than did the adaptive expectation models. Shumway and Chang [179] extended this analysis by comparing the accuracy of using the parametrically produced data for estimating supply relationships to econometric models using time series data. Although the partial adjustment positive supply equation formulation was very simplistic in its choice
of variables and therefore may have altered their results significantly, their findings were quite interesting in that the LP data predictions on average were no less reliable than the positive predictive estimates in 1974 and 1975. Also, combining the LP estimated direct and cross price parameters with the time series data did not reduce or improve the predictive accuracy of the time series equations as the authors had hoped. Not surprisingly, Shumway and Chang conclude that the latter finding was apparently due to a nonrealistic specification of their regional linear programming model. Specifically, they felt that much better results would have been obtained if the linear programming model specification had explicitly included more of agricultural decision environment (e.g., riskiness, nonstatic flexibility constraints, nonperfect competition) facing farmers. The respecifications and additions would provide a more accurate portrayal of real world supply responses to price changes.

It is clear that the great deal of research done with linear interregional models has helped to quantify many answers to policy and planning questions concerning agricultural capacity, export levels, land-use patterns, efficiency and environmental or energy restrictions. But as was noted earlier, the fixed demand assumptions that the cost minimization models often make are often criticized on the basis of classical economic theory, where demand and supply are determined simultaneously [184], or supply is known a priori to demand determination providing the basis for a cobweb model recursive
system [62]. Linear models may only be adapted for simultaneous de-
mand and supply analysis through the operation of time-consuming and
expensive iterative procedures although recent literature indicates more
new cost effective algorithms and modeling designs may be available for
this purpose [126]. Therefore, nonlinear interregional competition
models, and quadratic models in particular, have been utilized for the
simultaneous equilibrium solution of demand and supply of agricultural
commodities [150, 185].

While linear models are usually one period models, these quadratic
programming models are capable of incorporating a time element into the
modeling framework either explicitly or implicitly, depending upon
one's point of view. In linear minimum cost models demands are fixed,
therefore supplies are also fixed and known a priori. Thus, in
linear models an instantaneous demand determined supply equilibrium
adjustment occurs given an optimal solution. Therefore, time is not
used in the supply adjustment process. But in a nonlinear model final
demands are not known a priori, although minimum demands have been
specified. In these models, supply must also adjust with demand
changes. Therefore, if the assumption is made that "time" is necessary
for supply and demand adjustments toward an equilibrium position, then
"time" is explicitly present in nonlinear models even though a "one-
period time" solution has been reached. Nevertheless, it is the posi-
tion of this research effort that "time", if construed to be present in
nonlinear models, is present implicitly in the modeling structure and
also that nonlinear models are not polyperiod modeling structures.

For a better understanding of how this "time" element is embodied within the quadratic model, the mathematical formulation must be fully explained. First, an assumption is made that the economy's J commodity demands may be efficiently and realistically estimated with linear demand functions incorporating price as the only dependent variable,

\[ D^j = D^j(C^j) = G_0^j - H^j C^j \]

(2.56)

where

- \( G_0^j \) is an \( n \) vector of constants (\( j = 1, 2, \ldots, J \))
- \( H^j \) is a positive semidefinite matrix of constants
- \( C^j \) is an \( n \) vector of prices associated with the \( n \) elements of \( X^{ij} \)
- \( D^j \) is a vector of quantities of \( n \) products demanded in the \( j \)th consuming region
- \( X^{ij} \) is a vector of \( n \) output levels in the \( i \)th producing region of the \( j \)th consuming region (\( i = 1, 2, 3, \ldots, I \))

This assumption links the quadratic interregional programming model to economic theory in a less naive manner than do conventional linear transportation models. Linear interregional programming models with stepped demand functions, in effect, function similarly to the quadratic models [48].

Classical economic theory presupposes that the total economy-wide demand for a product is inversely related to price. As the price in-
creases, demand for the produce would fall. Unless the individual producer or production unit is large relative to the size of the market, competitive conditions are assumed to exist. This assumption of competitive market conditions implies that the demand function facing the individual producer is horizontal and linear. While competitive market conditions may be a valid working hypothesis for an individual production unit or area, a downward sloping demand function is a more realistic assumption for large area or national models. Thus, the linearity of price assumption in the objective function becomes tenuous when searching for a competitive, profit maximizing solution.

The problem of finding an efficient solution for the pattern of production and transportation activities to meet a set of \( J \) minimum food and fiber demands in the economy can be expressed in quadratic programming notation as

\[
\begin{align*}
\text{Maximize} & \quad \sum_{j=1}^{J} \left[ (G_j^j - H_j^j C_j^j)^T C_j^j - \left( \sum_{i=1}^{I} R_{i}^{ij} B_{i}^{ij} + \sum_{i=1}^{I} V_{i}^{ij} x_{i}^{ij} \right) \right] \\
& \quad - \sum_{j=k}^{J} Q_{j}^{jk} S_{j}^{jk} \\
& \quad T^{11} \\
\text{subject to} & \\
A_{i}^{ij} x_{ij}^{ij} & \leq B_{i}^{ij} \quad \text{(resource restriction)} \\
\sum_{i=1}^{I} x_{ij}^{ij} + \sum_{j=k}^{J} (Q_{j}^{k} - Q_{j}^{ik}) & \geq D_{j}^{j} \quad \text{(demand constraint)} \quad (2.58)
\end{align*}
\]
\[ c^j - c^k \leq s^{jk} \]
\[ c^k - c^j \leq s^{kj} \]
\[ x^{ij} \geq 0, \quad r^{ij} \geq 0, \quad c^j \geq 0, \quad v^j \geq 0, \quad q^{jk} \geq 0, \quad s^{jk} \geq 0 \]

where

- \( A^{ij} \) is an \( m \times n \) input-output coefficient matrix
- \( B^{ij} \) is a vector of \( m \) available resources in the \( i \)-th producing region of the \( j \)-th consuming region
- \( Q^{jk} \) is a vector of quantities of \( n \) outputs shipped from consuming region \( j \) to consuming region \( k \) (\( j = k, \) and \( k = 1, 2, 3, \ldots, J \)). At \( j = k \), \( Q^{jj} = Q^{kk} = 0 \) because shipment from one region to another is 0 in this case
- \( S^{jk} \) is an \( n \) vector of shipping costs associated with \( Q^{jk} \).
  Further we let \( S^{jk} = S^{kj} \).
- \( v^{ij} \) is an \( n \) vector of variable costs (all costs other than those of \( B^{ij} \)) associated with producing \( x^{ij} \)
- \( R^{ij} \) is an \( m \) vector of costs of \( B^{ij} \)

The objective function is now constructed to reflect a net return maximization criteria for producers, where \( T \) is total returns and is in nonlinear quadratic form, \( T^1 \) are production costs and \( T^{11} \) are the transportation costs. Some inputs or resources may also be transferred between regions for greater allocative efficiency [73, 190]. The constraints assure input use does not exceed supply, that the marginal revenue equals the marginal exogenous plus imputed resource costs.
of any activity and that the supply of commodities for any consuming region is at least as great as its demands. Plessner and Heady [155] have developed and discussed five characteristics of the competitive equilibrium solution of a quadratic model:

1. the value of the objective function equals zero, e.g. net profits are zero; \( \bar{f} = 0 \)
2. if all producing regions face the same equilibrium prices, \( p^j \), then each producing region's net profits are maximized and equal zero
3. if any \( X^{i,j} \) is \( > 0 \), marginal revenue equals its marginal production costs
4. if any \( p^j > 0 \), demand equals supply
5. a trade equilibrium for a commodity will exist if it is traded for a given optimal solution, \( \bar{f} = f(X^{i,j}, p^j, \bar{r}^{i,j}, \bar{s}^{i,j}) \).

It must be noted, though, that these characteristic conditions are constrained in a real sense by the incompleteness of the model. The model is incomplete in that only the agricultural sector is modeled and not the complete economy. Thus only a partial competitive equilibrium optimal solution is generated.

For many reasons, quadratic programming techniques have been applied to many fewer economic problem areas than has the linear programming technique. This is quite interesting because quadratic programming, while an incomplete nonlinear modeling format, offers
a more realistic, real world approach to supply and demand situations. The most commonly cited reasons for its limited use relative to linear programming are those of cost effectiveness, capacity, reliability and flexibility. Despite the availability of several efficient, mathematical algorithms for solving quadratic programming models, a far larger number of iterations is necessary for an optimal solution and it is therefore more expensive to solve than a comparable linear programming model. This situation is exaggerated when the problem becomes very large, as with most interregional models, because of algorithm capacity problems. The reliability of linear programming solutions is that an optimal solution is always generated given proper specification of constraints, etc. When quadratic programming algorithms are used, an optimal, efficient solution may or may not be achieved. If a solution is found, it is not always known if the optimal solution is a global solution [1, p. 117]. Additionally, quadratic programming computer algorithms do not have all the flexible, manipulative routines available for the researcher as do the linear programming algorithms. This latter constraint should be eliminated as new computer techniques are composed.

Three additional difficulties exist with using quadratic programming models when considering different agricultural policy and planning problems. First, if estimated solution prices differ from real world prices, demands may also considerably differ from actual quantities. This problem partially affects the second difficulty, the reliability
of the demand equations. If the estimated prices and quantity demanded differs considerably from data used to estimate the demand equations, the reliability of the demand equations may be questioned. Questions may also be raised with regard to the assumption of constant demand slopes, i.e., constant $\beta$s or the implied constant derived demand elasticities, although this is partly a statistical and empirical problem. Finally, the third difficulty is the question of how to incorporate exports and inventory demands into the demand structure of the model. Two choices are available. First the intercept term, $G^j_0$, can be modified, or secondly the demand equations can be estimated using inventories and exports as demands. But problems exist using these methods. Actually, in the real world inventories are not "demands" in themselves but are the supply left after export and domestic demands have been satisfied at a price. Since in a quadratic model supply equals "demands", inventories, unless prespecified as given demands are not assumed to exist. Secondly export demands are often related to political or social decisions rather than being price related [134]. Thus both inventories and exports are usually included in the intercept term in the minimum given demands. Finally, the modified intercept terms, $G^j_0$, must be acceptable to those using the model for real world decisions and policy composition.

Both linear and quadratic interregional competition models have several advantages and disadvantages already discussed at length in this section. Both types of interregional competition models also
have an additional problem referred to as aggregation bias. "Aggregation bias can be defined as the difference between (1) the aggregate supply function as developed by summing the linear programming solutions of each individual firm in the industry, and (2) the function estimated using an aggregate model" [168, p. 44].

This problem has been discussed at length [28, 66, 133], and has been recently extended in the context of mathematically sufficient conditions [151]. This limitation will be discussed not so much as a shortcoming of these two modeling techniques but as a recognition that the problem exists as a necessary condition when these models are built.

Aggregation bias problems affecting industry supply analysis with programming models exist under any circumstances where only incomplete disaggregated data at the individual farm level is available. Usually, the number of farms is so large and the cost of obtaining data is so great that this approach is only theoretically feasible. Typically, enough financial resources are available to gather supply response and technical information for only several farms. Thus, if the aggregate regional model is constructed from a micro-foundation [177], a limited amount of farm data must be used to infer an aggregate supply response either for a) all farms in the particular geographic area examined or b) similar farms. These two approaches are generally referred to as the farm "stratification" and the farm "proportional heterogeneity" methods of minimizing aggregation bias. As Day had originally proposed, the farm proportional heterogeneity method would not produce aggregation bias if three technical conditions are met.
... under suitable conditions a single linear programming model for the aggregate is equivalent to a direct aggregation of the solutions of a set of individual firm models. Conditions sufficient for this equivalence are proportional variations of resources and behavioral "bounds", proportional variation of net return expectations among all firms in the aggregate; and, finally, common technical coefficients which appear in the constraints on the firm's decision [38, p. 797].

Under these sufficient conditions, each farm's production function need only to be linear transformation of one another. They do not have to be exactly similar. The level of resources available to each farm is not crucial, because it is assumed that any surplus resource on one farm will not be in surplus on any other farm in the region given a set of commodity prices. Thus, the product transformation ratios (input-output coefficients) remain the same for each farm. If these conditions do not occur, then nonproportional heterogeneity exists in the region and the estimated programming supply function will be significantly biased. Finally, Paris and Rausser have demonstrated Day's sufficient conditions are overly restrictive and may be reformulated as more general and less binding conditions for exact aggregate analysis to occur [151] even when nonproportional heterogeneity occurs among a region's farms.

Where large differences occur among a region's farm production functions and nonproportional heterogeneity exists, Day suggested that reliable supply response results would most easily be obtained with the farm stratification approach [38, p. 812]. Under this approach, farm firms are grouped into homogeneous classes based on some pre-
determined critical or important variable or set of variables. These variables can include land type, capital stock size, management ability, resource or output mix. Supply responses are estimated for each type of farm and then weighted into a regional supply response based on the frequency distribution of different type farms.

An alternative stratification methodology has also been frequently used for interregional programming models because aggregate data has been easier to collect and analyze than individual farm data [49, 73, 97, 100, 145, 150, 169, 171, 178, 180, 207]. This approach, for want of a better name, will be referred to here as "regional stratification", or stratifying the agricultural industry by geographic regions based primarily on soil type, farming practices and output characteristics. It combines elements of both the proportional heterogeneity and stratification approaches. Day expressed the theoretical justification for this approach by assuming rational behavior by producers, even though resource and managerial abilities may be heterogeneous.

"... imitation of prominent producers' decisions by surrounding firms may lead to a considerable degree of proportional variation in farm activities, more than the linear programming behavior based on wide technical dissimilarities would predict. The idea is that individual farmers in a given area tend to imitate 'management leaders' or prominent producers, and, as a consequence, behave as if they were much more homogeneous in input-output and resource structure than they really are". [37, p. 673].

Although imperfect, the regional stratification method was chosen as the most appropriate methodology for this thesis study. This
modeling approach

. . . has nothing to say about which production units will change in a given year, but only that specific proportions of the region's resources will be reallocated by a corresponding proportion of the region's producers with the passage of time. Such proportions could be interpreted as probabilities of change for the allocation of individual resource units. The peculiarities of individual decision criteria are subsumed in statistical averages [40, p. 118].

Input-output models

Although the agricultural economy is interdependent with other sectors of the national economy, it is typically implicitly and sometimes explicitly modeled as being independent with the remainder of the economy being held fixed exogenously. Input-output analysis is usually used as a descriptive tool used to explicitly exhibit these supply and demand interrelationships. Input-output models have not been used for prediction purposes with a great deal of success due to their structural limitations [96]. Rather, these models are used for describing the complementary supply and demand relationships among various economic output sectors. For example, input-output models would be most appropriately used to demonstrate how a change in final demand values of various parts of the industrial or service sectors would affect the output of various agricultural sectors [27]. Input-output models are mathematically formulated using disaggregated value of economic output data [32];

\[ X_1 - X_{12} - X_{13} - \cdots - X_{1n} = Y_1 \]
\[ -x_{21} + x_2 - x_{23} - \ldots - x_{2n} = y_2 \]
\[ \ldots \ldots \ldots \ldots \]
\[ -x_{n1} - x_{n2} - x_{n3} - \ldots + x_n = y_n \]  
(2.59)

where

\[ y_i = \text{the value of the final demand for sector } i \]
\[ x_i = \text{the value of the total output of sector } i \]
\[ x_{ij} = \text{the value of the output in sector } i \text{ used in sector } j \]

where

\[ i = 1, 2, \ldots, n \]
\[ j = 1, 2, \ldots, n \]

Now, to obtain the technical input-output coefficients \( (a_{i,j}) \) by dividing through each \( x_{ij} \) by \( x_j \), so that

\[ a_{i,j} = \frac{x_{ij}}{x_j} \text{ and } a_{i,j}x_j = x_{ij} \]  
(2.60)

we can rewrite (2.60) in matrix form as

\[ [X - AX] = Y \]

or

\[ X[I - A] = Y \]  
(2.61)

where

\( A \) is the \( n \times n \) matrix of input-output coefficients

\( Y \) is the \( n \times 1 \) vector of final demands
X is the n x 1 vector of total sector output

I is an n x n identity matrix

Using matrix algebra in equation (2.61), we can now relate output to final demands of other sectors:

\[ X = (I - A)^{-1}Y \]  \hspace{1cm} (2.62)

From the mathematical formulation and specification of the model several severe limitations for supply analysis applications become apparent. First, input-output models are characterized by many of the same limiting assumptions found in mathematical programming models: fixed proportionality, constant returns to scale and homogeneous production patterns within regions and sectors. An additional large disadvantage of input-output models is that resources needed for production are implicitly assumed to be infinite. Production processes do not have any upper and lower bounds due to resource constraints. Rather, production processes and input uses change only as final demands change. These are also static models because they measure historical intersectoral product and value flows at a particular point in time. Because production value coefficients are used to develop the interdependence matrix, physical quantity prediction changes must be based on fixed prices. The assumption of constant prices when demands and supplies change is a tenuous hypothesis. Thus its value as a predictive tool lies mainly in its use for small changes in consumption demands during a short period of time rather than for longer term economic projections. Also, because the input-output relationships
between sectors are fixed, the model is highly unlikely to describe product and input mix changes within and between regions accurately with large changes in final demands. Thus, its ability to predict changes in spatial production patterns occurring through changes in regional technologies, transportation costs and resource allocations is severely limited. Although dynamic input-output programming techniques have attempted in various manners to introduce changes in coefficients into the interdependence matrix, \([I - A]^{-1}\), the input-output structure is not well-adapted for supply response analysis.

Regression analysis and econometrics

For many years, regression analysis and econometrics have been a standard aggregate method of both crop \([16, 19, 70, 95, 103, 105, 106, 117, 121, 132, 141, 165, 166, 167]\), and livestock supply response estimation \([69, 76, 156]\). The regression analysis methodology uses time series data or cross-sectional data within a linear, causal, theoretical modeling framework to estimate supply functions. Nonlinear, event or dummy variables may be introduced to test for or to reflect changes in industry structure, weather conditions, technology changes, input levels or developments in government programs. The availability of relevant data may also allow regional or even local supply functions to be evaluated. Simple regression analysis is often referred to as ordinary least squares (OLS) analysis. A less theoretically restrictive set of assumptions is necessary for generalized least squares (GLS)
regression analysis. Because of the differences in assumptions and statistical problems encountered when these models are used, the OLS and GLS techniques offer their own advantages and disadvantages.

Consider first a simple linear model often adopted by economists:

\[ y = X\beta + u \]

(2.63)

where

- \( y \) = a \( n \times 1 \) vector of \( i = 1, 2, \ldots, n \) observations on the dependent variable, \( y \);
- \( X \) = a \( n \times m \) matrix of \( i = 1, 2, \ldots, n \) observations on \( j = 1, 2, \ldots, m \) independent variables, \( X \);
- \( \beta \) = a \( m \times 1 \) vector of regression coefficients; and
- \( u \) = a \( n \times 1 \) vector of error terms.

In multiple linear regression models, it is assumed that the dependent and random variable, \( Y \), is influenced by the levels of a given set of variables denoted by \( X_1 \ldots X_m \). The average value of possible dependent variable, \( Y \), observations for fixed levels of \( X_1, \ldots X_m \) is assumed to be a linear combination of the levels of the independent variables, \( X \). In algebraic form, (2.63) can be rewritten as

\[ Y_i = \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_j X_{ji} + u_i \]

(2.64)

where

- \( X_{1i} \) can be defined as equal to 1 to get an intercept term if needed.
- \( u_i \) denotes the difference between the \( Y_i \) observation and the expected value of \( Y_i \) given the levels of the \( X \) variables.
From the above explanation, the intuitive appeal of regression tech­niques using linear models is easily ascertained. If the dependent variable is specified as observed and production outputs and the X variables are specified as either hypothesized or observed causal or input elements for the production process, then (2.64) can be used to explain and describe the supply response of agricultural commodi­ties. The error term, u, is added to the theoretical equation model due to misspecification either of variable relationships or variables hypothesized in (2.64). If equation (2.64) is specified only in terms of inputs as independent variables and one output without an error term, it may be referred to as a production function [89]. If other independent variables are included, the relationship may be referred to as a supply or output relationship. The production function provides only part of the information necessary to build supply functions that are based on the theoretical assumption of profit maximization by firms. Prices, costs and constraints are also necessary information for an economist to have in order to determine the most profitable level of output coupled with the most efficient use of resources.

Statistical analysis using multiple linear regression only esti­mates and describes the average relationship between the independent variable and the dependent variable. A specification of the relation­ship between the independent and dependent variable that is exactly correct is usually unknown. Thus as has been noted in many texts [113, 116], the regression parameters, β, are unknown a priori and must be estimated. Even if the independent variables and relationship had
been known and specified in the model with certainty, the estimated \( \beta \) coefficients would result in misspecification because the true \( \beta \) is unknown. Only a limited number, i.e., a sample of observations are ever available for the estimation procedure and the true \( \beta \) can only be estimated when the full population of observations is observed. Consequently, the goal of using regression analysis is to minimize the sum of the error terms which yield the best linear, unbiased estimators (BLUE) for the true \( \beta \).

When working with this particular type of statistical analysis, four critical assumptions are usually made with regard to the data set observations. Johnston [113] expresses these as the following:

1) \( E(u) = 0 \);
2) \( E(uu') = \sigma^2 I_n \);
3) \( x \) and \( y \) are sets of fixed numbers; and
4) \( x \) is of rank \( (m < n) \)

When all four of the above conditions are assumed to hold true for the data set, then OLS analysis can be undertaken. If one or more of the above conditions is inaccurate, then GLS techniques must be initiated. An understanding of these four assumptions is necessary for an understanding of common problems and limitations inherent in supply response regression analysis studies. First, the expected value of the error term, \( u_i \), \( E(u) \) is zero and that errors, if any, are distributed around a mean of zero. Secondly, the expected value
of \( u_i^2 \), \( E(uu') \), where \( u' \) is the transpose of \( u \), is a constant, \( \sigma^2 \), times the identity matrix of size \( n \), \( I_n \). Because the only nonzero elements of \( I_n \) are ones on the main diagonal, the \( E(u_i^2) = \sigma^2 \) for all \( i \) and \( E(u_i u_j) = 0 \) for all \( j \neq i \). Additionally, this indicates that the variance of the errors for different levels of the \( X \) variables is constant. This first assumption is commonly referred to as homoscedasticity. The second assumption says that the errors, \( u_i, u_j \) are pairwise uncorrelated. This assumption is simply interpreted to mean that the independent variables are uncorrelated or independent from each other. The third assumption indicates repeated sampling of observations would result in \( y \) varying only if \( u \) also varied. Finally, the rank assumption is necessary to insure that an inverse matrix of \( x'x \), \( (x'x)^{-1} \) exists. If \( (x'x)^{-1} \) did not exist, the \( x'x \) would be nonsingular and an estimate of \( \beta \) would be impossible \([113, 116]\).

Although linear programming may be used to estimate \( \beta \) coefficients and also minimize the sum of \( u_i \) \([183]\), typically an estimated vector of \( \beta \), \( \hat{\beta} \), is sought that minimizes the sum of squares of the error terms, \( uu' \). Minimizing the \( u'u \) scalar is the least square principle of regression analysis.

Equation (2.63) may be rewritten to illustrate the process of estimating \( \beta \) with the OLS technique,

\[
\hat{u} = y - \hat{x}\hat{\beta} \tag{2.65}
\]

where the notation is the same as in (2.63), but \( \hat{\beta} \) is an \( m \times 1 \) vector of any estimated regression coefficients.
From (2.65) the sum of squared error terms can be written as
\[ u'u = (y - x\tilde{\beta})' (y - x\tilde{\beta}) \]
\[ = y'y - 2\beta'x'y' + \beta'x'x\beta \]
The objective is to change the elements of \( \tilde{\beta} \) so that \( u'u \) is a minimum. By partially differentiating \( u'u \) with respect to each element of \( \tilde{\beta} \), setting these \( k \) derivatives equal to zero and solving, the solution to these equations will estimate the \( \tilde{\beta} \)'s that minimize \( u'u \).

\[
\frac{\partial (u'u)}{\partial \beta} = -2x'y + 2x'x\tilde{\beta} = 0 \tag{2.66}
\]

If \( x'x \) is nonsingular, the solution vector \( \tilde{\beta} \) to the normal equations is
\[
\tilde{\beta} = (x'x)^{-1}x'y \tag{2.67}
\]
and \( \tilde{\beta} \) is called the best, linear, unbiased, least squares estimator for \( \beta \). The proof that \( \tilde{\beta} \) is a linear expression of \( \beta \) follows by first substituting for \( y \) in (2.67) from (2.63) producing
\[
\tilde{\beta} = (x'x)^{-1}x'(x\beta + u)
\]
\[ = (x'x)^{-1}x'x\beta + (x'x)^{-1}x'u \]
\[ = \beta + (x'x)^{-1}x'u \tag{2.68}
\]
To prove \( \tilde{\beta} \) is an unbiased estimator for \( \beta \), we show the expected value of \( \tilde{\beta} \) is \( \beta \),
\[
E(\tilde{\beta}) = E \left[ \beta + (x'x)^{-1}x'u \right]
\]
\[ = E(\beta) + E \left[ (x'x)^{-1}x'u \right] \]
\[ = \beta + (x'x)^{-1}x'E(u) \]
\[ = \beta \tag{2.69}
\]
using hypothesized conditions 3 and 4. The mathematical proof that $\beta$ is BLUE can be found in Draper and Smith [47] or Johnston [113]. While this proof is omitted here, an important segment of this proof and tests of significance for regression coefficients makes use of the variance of $\tilde{\beta}$. The variance of $\tilde{\beta}$ is derived as follows:

\[ V(\tilde{\beta}) = E[(b - \beta)(b - \beta)'] \]
\[ = E[(x'x)^{-1}x'u'u'x(x'x)^{-1}] \]
\[ = (x'x)^{-1}x'E(u'u)x(x'x)^{-1} \]
\[ = (x'x)^{-1}x'\sigma^2 I_n x(x'x)^{-1} \]
\[ = \sigma^2(x'x)^{-1} \]

(2.70)

As previously noted, $\sigma^2$ is assumed to be an unknown constant. It can, however, be estimated by

\[ s^2 = \frac{u'u}{n-m} \]

(2.71)

where $s^2$ is an unbiased estimator of $\sigma^2$. Substituting (2.71) into (2.70), an estimate of the variance of $b$ is then obtained as

\[ V(\tilde{\beta}) = s^2(x'x)^{-1} \]

(2.72)

As mentioned earlier, one or more of the four critical assumptions may be unsatisfied. When this circumstance occurs, modification of the OLS analysis is necessary for the BLUE of $\beta$. This modification of the OLS procedure is typically referred to as generalized least squares (GLS). GLS techniques are used when two problems occur in data that is gathered by economists. The problems are autocorrelated errors and multi-collinearity.
Autocorrelation is a fairly common problem in time-series (serial) data [113, chapter 8; 34]. Often this problem occurs when the hypothesized model fails to include an important but unknown independent variable. The explanatory effect of this variable is therefore included in the error term. If the effect of this variable in one period is correlated with the error term in other periods, the errors may be correlated and critical assumption 2 is violated, i.e.,

$$E(uu') \neq \sigma^2 I_n$$

In this situation, the OLS estimate of $\beta$ will be biased.

Autocorrelation is usually corrected with the following procedure. First, the second assumption is relaxed, or generalized and written as

$$E(uu') = V$$

(2.73)

where

$V$ is assumed to be a known, $n \times n$, symmetric, positive-definite matrix.

Thus, the OLS variance of $\tilde{\beta}$ from (2.70) becomes

$$V(\tilde{\beta}) = (x'x)^{-1}x'Vx(x'x)^{-1}$$

(2.74)

An $n \times n$ transformation matrix, $T$, can be found that

$$E(Tuu'T') = TVT = \sigma^2 I_n$$

(2.75)

If the residual error in the $i$th period is assumed to be only correlated with the error in period $i-1$, i.e., a first-order correlation scheme,
then we may write
\[ u_t = \rho u_{i-1} + e_t \]  
(2.76)

where
\[ u_t = \text{errors of the } i \text{ period}; \]
\[ u_{i-1} = \text{errors of the } i-1 \text{ period}; \]
\[ \rho = \text{correlation between } u_i \text{ and } u_{i-1}; \text{ and} \]
\[ e_i = \text{the true, serially independent errors of the } i \text{ period}. \]

Furthermore, \( \rho \) must satisfy the condition that \(|\rho| < 1\) and \( e_i \) must satisfy the assumptions that
\[ E(e_i) = 0, \]
\[ E(e_i e_j) = \sigma^2_e \text{ for all } i = j, \text{ and} \]
\[ E(e_i e_j) = 0 \text{ for all } i = j. \]

Although \( u_i \) does not satisfy the OLS assumptions previously specified, \( e_i \) does. Now, by expanding (2.73), we have,
\[ E(uu') = V = \sigma^2_u \begin{bmatrix} 1 & \rho & \rho^2 & \ldots & \rho^{n-1} \\ \rho & 1 & \rho & \ldots & \rho^{n-2} \\ \rho^2 & \rho & 1 & \ldots & \rho^{n-3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \rho^{n-1} & \rho^{n-2} & \rho^{n-3} & \ldots & 1 \end{bmatrix} \]  
(2.77)

For this particular structure of \( V \), the \( T \) matrix necessary to satisfy (2.13) is
It is easily verified that this transformation matrix produces
\[
 TVT' = \sigma^2_{e} I_n
\]
(2.79)

thus, satisfying (2.75) and the OLS assumptions concerning the new error terms, e_t'. OLS procedures are then applied to the original data after it is transformed via the T matrix
\[
 Ty = TxB + Tu
\]
(2.80)
to produce an efficient estimate of \( \beta \).

Multicollinearity violates the fourth assumption of OLS. Multicollinearity exists when independent variables are not linearly independent, but rather collinear or can be expressed as linear combinations of the levels of other independent variables. The implication of this situation is the \((x'x)\) would not be of full rank and would be singular. The problem is that the dependent variables can be linearly correlated to an infinite number of degrees. The fourth assumption assumes a degree of zero. In reality, multicollinearity will typically range between intermediate levels of .25 and .75. The intermediate level of multicollinearity has the effect of increasing
the estimated variance of the estimated regression coefficients and thus increasing the difficulty of finding statistically significant estimates of $\beta$.

"The main consequences of multicollinearity are the following:

1. The precision of estimation falls so that it becomes very difficult if not impossible, to disentangle the relative influences of the various $X$ variables. This loss of precision has three aspects: specific estimates may have very large errors; these errors may be highly correlated, one with another; and the sampling variances of the coefficients will be very large.

2. Investigators are sometimes led to drop variables incorrectly from an analysis because their coefficients are not significantly different from zero, but the true situation may be not that a variable has no effect but simply that the set of sample data has not enabled us to pick it up.

3. Estimates of coefficients become very sensitive to particular sets of sample data, and the addition of a few more observations can sometimes produce dramatic shifts in some of the coefficients" [113, p. 160].

Three methods are available to correct for multicollinearity problems. The easiest approaches include acquiring new data to break the collinearity in the $X$ matrix and/or eliminating variables (the $X_j$) until multicollinearity is removed from the $X$ matrix. Neither alternative is usually feasible due to lack of time, lack of new data sources, and the additional costs. Thus, tests for multicollinearity, if made, are done to check poor or unlikely statistical results. Usually, if multicollinearity is found then the nonsignificance of estimated regression coefficients for particular variables are discounted as being masked by multicollinearity. The third alternative
is a data transformation procedure which is theoretically described in Johnston [113, p. 164-169].

Finally, the assumption of the X matrix being nonstochastic, or fixed, is difficult, if not impossible to defend, when most economic data is evaluated. Thus, the values of X are almost always stochastic and not fixed, and the OLS estimators, \( \beta \), are inconsistent. However, if it is assumed the X variables are distributed independently of \( u \), it can be shown the OLS estimators provide the same BLUE of \( \beta \) as was the situation when a fixed X matrix is used [113, p. 274-278]. For this study, the above latter assumption will be hypothesized for the regression estimations performed.

Regression analysis of time-series and cross-sectional data has provided the basis for many agricultural supply response studies as indicated at the beginning of this section. The wide use and the deep familiarity with this technique of model building in the applied economics community is undoubtedly due to this technique's superior advantages with regard to relatively quick and cheap estimation and data collection procedures, especially compared with linear or non-linear programming techniques [117]. Another advantage is that many of the aggregation problems peculiar to the micro methods previously discussed do not pertain to macro-regression models. These econometric techniques directly estimate the various macro variables such as national crop acreage and national price, which are of interest for macro policy and planning discussions. Regression analysis estimates
the average response of large numbers of producers to changes in pre-
determined independent variables. Therefore, it is often argued that
because aggregate production data reflects large numbers of producers
or the larger sample size of all farms, the economist will probably be
able to estimate a "normal" supply response for the region studies if
relevant variables and data are available. Often more relevant variables
and data are available for smaller geographic areas because of crop
or livestock specialization, and regional equations are more easily esti-
mated. However, if regional or local supply response estimating equa-
tions have been calculated, the individual responses will then have to
be summed into a national aggregate supply response assuming each of the
these supply functions is independent of the other regional supply
function.

Econometric regression analysis of macro data can also be an
inappropriate method for the estimation of aggregate supply response
functions [211]. First, regression analysis of time-series or cross-
sectional data, estimates the aggregate supply function with an implicit
allusion to the technical structure of production. The technical pro-
duction structure is estimated implicitly in the regression coefficients.
If the technical structure of production activities should change,
the real $\beta$ would too. Yet hardly enough of the information and particu-
lar independent regressor variables needed to represent the technical
change are ever available to accurately re-estimate the regression co-
efficients. Thus, structural changes are very difficult to represent
in regression models because equations are fitted to data representing a particular production structure [120]. If relative net income coefficients, resource levels, or available production activities change, thereby changing the underlying production structure, the regression equation can become an inaccurate predictor of supply response.

Three additional issues are also related to the "implicit structure" estimation problem. First, agricultural firms are typically multiproduct enterprises with different activities competing for many of the same resources, i.e., managerial labor or tractor time. Regression analysis or production function estimation makes the implicit assumption that production activities are independent and can be estimated as if each commodity was produced on a separate farm. If input use can be disaggregated, this issue is not serious, however, reliable disaggregation of input uses is very difficult to estimate and is not often available. Thus, the supply function estimated for multiproduct forms with regression analysis is usually erroneous. Second, a large number of inputs are generally required for commodity production. Therefore, if only a limited number of observations are available for the analysis individual inputs must be aggregated into larger and less specific input category variables due to an insufficient degree of freedom problem [85, 189, 160]. The aggregated X variables may then cause biased estimates of β, the real regression coefficients. When dummy variables [113, chapter 6] and price variables are introduced into the model, the degrees of freedom prob-
lem is compounded. Third, intercorrelations between input, price and dummy variables are often quite large. The resulting multicollinearity confuses the statistical testing of the estimated production parameters. A related problem is that usually inadequate number of observations to break the multicollinearity is found. Therefore, in summary, the implicit estimation of the technical structure of production makes it difficult to obtain reliable estimates of the supply response parameters necessary for accurate formulation of agricultural commodity supply functions for the following three reasons:

1. substitutability and complementarity among inputs and outputs
2. technical changes resulting in different input use and output combinations
3. lack of adequate historical or cross-sectional information for parameter estimation.

The second major disadvantage of using an aggregate regression analysis technique is that it assumes independent variable levels are known with certainty prior to estimating the dependent variable. Uncertainty, expectations, the flexibility of input factors over time and changing technology must all be studied implicitly with the use of "certainty equivalent" variable models. Nerlove and Bachman's distributed lag or adaptive expectations model, the extrapolative expectations model and the static expectations model "have been developed to relate expectations to observable variables" [143, p. 545]. The mathematical
development, and brief discussion of the theoretical and practical difficulties associated with "certainty equivalent" models have been reviewed earlier.

Finally, as was discussed earlier in this chapter, time and technological change are also difficult to analyze using econometric methods. Because their intertemporal characteristics are difficult to explicitly incorporate into regression analysis. The investment process and rate of adoption of technology under different conditions are usually crudely introduced with one of the above "certainty equivalent" models or via the time trend dummy variable technique. In any case, a static regression analysis framework is an inappropriate methodology for studies concerned with intertemporal phenomena.

**Intertemporal macro models**

Simulation, recursive and dynamic programming models have been formulated to study the complex intertemporal and interrelated supply response behavior of various commodities. Dynamic programming models have been previously discussed as primarily micro intertemporal models. The former two techniques will be discussed following this brief introduction.

As explained earlier, research efforts attempting to quantify the supply response of commodities utilize the neoclassical economic theory of the firm. But the neoclassical theory of the firm is in large part constructed upon a Walrasian general equilibrium framework. The Walrasian modeling framework can be represented as a system of simul-
taneous equations determining prices and quantities of outputs and inputs. The economy, when viewed from this perspective appears as a set of interdependent, causally-linked commodity markets. Therefore, a disturbance in one market affects all other markets. Additionally, if one market is in disequilibrium, then at least one other market must also be in disequilibrium. This general equilibrium and simultaneous equation approach to the understanding of how an economy and its various sectors work has been a rich storehouse for economists conducting theoretical mathematical research. However, applied, agricultural economic research investigations exploring the economic functioning of market structures and behavioral characteristics have found that a modification of the Walrasian theoretical model which explicitly includes time is often necessary for the completion of real world studies. A second modification made in most industry or market studies has been to use a partial equilibrium modeling approach. All of the supply response techniques discussed in this chapter make this latter assumption, often implicitly. Use of the partial equilibrium modeling approach has been necessarily popular because of the resulting reduction in modeling complexity.

The utilization of time, in intertemporal models and therefore an introduction time consuming market adjustment behavior process obviously changes the assumption of a Walrasian, instantaneous, market clearing adjustment process typically used in static economic models. The inclusion of a time consuming market adjustment mechanism allows a
more realistic modeling of gradual supply and demand changes to work through the economic system over a period of time following disturbances of relevant economic or behavioral stimulus variables. The Nerlove distributed lag model is one attempt to directly estimate this market and supply behavior adjustment process [140]. Tyner and Tweeten [196], Day [39], and Ray [160] have concluded the intertemporal and noninstantaneous nature of market phenomena must be reflected in a recursive modeling structure if a real economic system is to be accurately represented. Day defended this position clearly when he asserted

"If prices and other decision variables are continually changing, the participants may continually try to reach equilibrium without ever attaining it. In the real world, disequilibrium rather than equilibrium is the norm. The partial adjustment model allows response to new stimuli to follow a time path. This approach replaces the unrealistic assumption that participants immediately jump from one equilibrium point to another when confronted with price or other changes" [160, p. 34].

Thus, agricultural economic variable levels in the real world may be viewed or assumed to be linked in a series of causal relationships. The acceptance of this hypothesis strongly suggests that a structural and descriptive economic modeling effort would recognize that commodity prices and quantities are sequentially related but not necessarily simultaneously determined.
Simulation models

Although every model utilized in agricultural economic research activities "simulates" some particular aspect of economic behavior, simulation modeling refers to a specific type of econometric model. Simulation modeling is defined here as "numerical manipulation of a symbolic model of a system over time" [5, p. 5]. In addition, a simulation system is defined as a set of interactive and interdependent variables, each of which is linked to other variables via a specific, systematic structure. Typically, the economic system or subsector variable interactions and behavioral responses to an economic environment is specified by using a set or series of sets of functional mathematical or econometric relationships. These relationships are then estimated as regression equations, although some input-output relationships or behavioral relationships may be imposed or placed within equation sets. The complexity of the equation system built by the research scientist obviously depends upon the complexity of the real economic sector being modeled.

Simulation is a system modeling technique particularly suited for investigations involving intersectoral or variable interactions occurring over a sequence of time periods. Since most economic systems operate through time, simulation models formulated to mimic such systems must also operate recursively. The recursiveness property and sequential interaction of variables and sectors within a simulation model allow a great flexibility for applications of expectation
equation models using lagged variables. With a proper computer assisted
equation format, information generated when one equation or set of
equations is solved may be used within that particular time period, or
succeeding time periods for other equation(s) or set(s) of equations.
Obviously, when all the equations have been solved sequentially within
the model, one time period has elapsed. The recursiveness or cycling
property then returns the equation counter in the simulation model to
the initial equation and the equation sequence iterates again for as
many cycles or time periods as the experimenter wishes. The implicit
assumption must be made, though, that the estimated structural economic
behavioral characteristics of the system or sector do not change as
decisions are made. Many times this assumption can be demonstrated
to be quite unrealistic.

The recursive characteristic of simulation modeling is often
referred to as a "feedback loop". Feedback loops can be described as
positive or negative. These words do not refer to good or bad quali­
ties, but rather refer to whether or not the variables or a set of
variables is able to move toward or remain stable with respect to
an equilibrium solution. A negative feedback loop is therefore pre­
ferred if the system is assumed to be stable or self-correcting.
Feedback loops occur when endogenously created information from one
time period is used in at least one successive time period. This
property makes possible and encourages the study of the longer term
primary, secondary, and tertiary effects of different public policies,
stochastic events, technological and behavioral changes. For example, in the agricultural sector,

"... the primary effects of increased price supports for corn would influence not only variables in the feed grain sector but also acreage planted to soybeans and wheat. Secondary impacts might occur as increased income enabled feed grain farmers to purchase additional operating and durable inputs the following year. Four or five years might be needed for the model to work out all the indirect influences" [160, p. 38].

Because simulation models are built with econometrically estimated regression equations, simulation models are constructed as non-optimization models. As was examined earlier, uncertainty, technological change, and resource restrictions limit the movement of producers toward a hypothesized optimum equilibrium position [41, 72]. Thus, if the real world behavior of the system being modeled can be described as a "disequilibrium equilibrium", e.g., the system is either on the supply or demand curve but not at the intersection, equilibrium point, then

"Simulation provides the social scientist with a 'laboratory'. Experiments that would be too costly or completely impossible to perform on the real economic system can be conducted on a computer model of the system. The model can be used to provide decision makers with information on the probable impact of a policy change on the real system before the change is introduced into the system itself" [160, p. 37-38].

It could be easily hypothesized that the biological lag between production decisions, realized output and output prices in agriculture would greatly interest agricultural economists and commit them toward an increasing use of recursive, system modeling techniques. Tyner
and Tweeten in an early national agricultural simulation modeling article remarked

"Relations between variables in agriculture and between agriculture and the nonfarm sector are complex and dynamic and are not always suited to analysis by conventional optimizing quantitative techniques. Quantitative procedures are needed which can include time lags, non-linearities, and secondary and tertiary effects over a reasonably long period of time. The simulation procedure meets these requirements and allows the recursive aspects of the agricultural process to be most effectively portrayed" [196, p. 67].

There has been a growing need for the utilization and development of agricultural simulation models for long term quantitative forecasts relating different agricultural policies and their effects for national or regional planning decisions.

The economic logic exercised when a simulation or recursive model of the agricultural sector or a particular market sector is constructed is fairly straightforward. The critical assumption made is that a time lag occurs between the initiation of the production activity and when the output is finally ready to be marketed. A simple, yet elegant recursive model is the two-dimensional "cobweb diagram" for a single market system introduced in a classic paper by Ezekiel presented in Figure 2.3 [62].

In this diagram, the usual supply and demand curves used in partial equilibrium analysis have been replaced by an output supply function which is lagged one time period and a price function curve. In this diagram, current output is related to past prices and current
Figure 2.3. Diagram of Simple Cobweb Model
prices are related to current production. If quantity produced in
the first period is \( q^1 \), then current price is \( p^1 \). Given a price of
\( p^1 \), production in period 2 is \( q^2 \). The price and quantity produce a
change in each following period until an equilibrium quantity, \( q^* \),
and price* are reached in the nth period. In Figure 2.3, the cobweb
model converges to equilibrium and a negative feedback mechanism is
implicitly assumed. A positive feedback assumption would result in
the oscillations diverging from \( p^* \) and \( q^* \). A possibility also exists
for a continuous oscillation of a constant magnitude around equilib­
rium. The recursive property of the cobweb model is demonstrated
because it shows how initial market conditions affect market conditions
in later time periods, i.e., \( t + 2, t + 3, t + 4, \ldots, t + n \).

This simple model was generalized by Waugh [208] to discuss multi­
dimensional cobweb models. This generalization allowed the author to
describe simultaneous adjustments in prices and outputs of a number
of commodities, even allowing for time trends. A similar analysis was
developed earlier for multiple market systems containing production
lags by Goodwin [71]. These two articles will serve as background for
a brief mathematical development of recursive systems.

The simplest mathematical representations of the price and lagged
output functions for a single market system is that they are linear,
single dependent variable equations. These functions may be written in
terms of expected price and quantity variables,
$p_t = -aq_t + u_t$ for the price equation, and

$g_{t+1} = bp_t + e_{t+1}$ for the lagged output equation \hspace{1cm} (2.80)

where

$p_t$ is the price deviation in time period $t$ from trend equilibrium value $p^*$

$q_{t+1}$ is the quantity deviation produced in period $t+1$ from trend equilibrium value $q^*$

$u_t$ and $e_{t+1}$ are the errors of estimation.

The equilibrium values for particular equilibrium quantities, $p^*$ and $q^*$, may be moving along a linear or nonlinear trend over time. Thus by expressing $p_t$ and $q_t$ as deviations from their equilibrium trend values, their errors or deviations are not distorted by changes in their respective base values [71, p. 186].

Stability conditions for the single market cobweb model can be easily generated if $e_{t+1}$ and $u_t$ have expected values of zero. By recursively substituting the price equation into the quantity equation in (2.80), it can be shown that after $2k$ periods,

$q_t + 2k = (ab)^{2k}q_t \hspace{1cm} (2.81)$

If the term $(ab)^2$ is less than one, the system can only converge toward an equilibrium price and quantity position and is stable. If $(ab)^2$ is equal to one, the system oscillates continuously and is also considered to be stable. This second possibility assumes the unlikely
supposition that both the price and output curves have equal slopes. If \((ab)^2\) is greater than one, the system diverges into ever increasing price and quantity changes and is unstable. This last hypothetical market behavior possibility is not a common market behavioral occurrence under normal economic conditions.

So far, the simple linear equation cobweb model does not adequately explain the continued real world existence of irregular commodity and periods in particular markets. This problem is partially eliminated under the following two hypothesized conditions. First, actual price and quantity equations or functions may not be linear except within narrow ranges. When government supply control or price support programs are in effect, the available data series may only cover this situation. Ezekiel reasoned that supply elasticities would be large only for small changes. He also reasoned supply elasticities would become increasingly inelastic for larger changes for a number of reasons including biological lags, immobility of inputs, and the frequency distribution of costs. Samuelson discusses the mathematical conditions for convergence and divergence or recursive systems when the supply and price curves are nonlinear [170, p. 390-391].

The graphical example in Figure 2.4 demonstrates the possibility of a neutral continuous oscillation using Waugh's two equation example [208, p. 738]. The equations specified are nonlinear but fixed,

\[
\begin{align*}
    p_t &= -2q_t \\
    q_{t+1} &= 2p_t^{1/3}
\end{align*}
\]  

(2.82)
Figure 2.4. Case Leading to Continuous Oscillation with a Nonlinear Output Curve [208, p. 739]
where $p_t$ and $q_t$ are measured as before. If the initial starting point quantity is either large, $q_1 = 6$, or small, $q_1 = -2$, a continuous equilibrium oscillation represented by the heavily shaded rectangle is reached fairly quickly. If the points on the rectangle are labeled A, B, C, D, then the slopes of the curves at these points are $\Delta q_2/\Delta p_1$, $\Delta p_2/\Delta q_1$, $\Delta q_3/\Delta p_3$, and $\Delta p_2/\Delta q_2$ respectively. Then the change in $q_3$ with a small change in $q_1$ would be

$$\frac{\Delta q_3}{\Delta q_1} = \frac{\Delta p_1}{\Delta q_1} \frac{\Delta q_2}{\Delta p_1} \frac{\Delta p_2}{\Delta q_2} \frac{\Delta q_3}{\Delta p_2}$$

and the system would be stable if $\Delta q_3/\Delta q_1 < 1$.

The problem with the neutral oscillating system as proposed by Waugh, is that nonlinearity of either or both of the curves is not by itself sufficient to describe the irregular period and oscillations of real world commodity markets. In order to start the system at points E or F, the initial market position must be one of disequilibrium. Yet no matter where one starts in this system, an equilibrium oscillating position and stable period is necessarily reached. Therefore, since the real world behavior of many commodity markets exhibit both irregular cycling periods, or price and quantity oscillations, nonlinearity is not sufficient by itself to describe observed market behavior over time.

A second hypothesized condition needed for demonstration of irregular but maintained commodity cycles in an individual market is that the "fixed" supply and price functions now are allowed to shift...
over time. The supply and demand functions may shift due to any number of imagined exogenous shocks to the system. These disturbances can take the form of changes in exports, weather variations, income or random events all following each other at discreet intervals. If a stable market system is assumed, or supply demand function shifts occur, an irregular cycle can be maintained, with the variable oscillations becoming larger or smaller within irregular cycling periods [71, p. 190]. Thus the explanation of real world commodity behavior can be to a large extent, demonstrated with continually shifting supply and price functions which may also be nonlinear. In an unstable system any postulated disturbances will only increase the oscillations and a nonlinear region would be needed for dampening effects toward equilibrium values. Given a nonlinear neutrally stable system, even a

"neutral dynamical equilibrium becomes inadmissible for constantly shifting curves. Each new shift adds to the amplitude of swing and there is no subtraction, so that the amplitude will increase without limit. Since markets are subject to continual change, we are driven to assume at some point or other a damping element" [117, p. 191].

Although, the unilaterally coupled or separated market is an interesting theoretical model for economic analysis, in reality market behavior are interrelated and interactive.

The two dimensional model for a single commodity can be generalized to reflect a multimarket cobweb model, or coupled markets with production lags. For example, agriculture is characterized by an interaction of many livestock and feedstock markets. The interdependence
takes the form of a term in the supply or price function being proportional to a price or quantity in other markets. If equation system (2.80) is reformulated to reflect the interaction between the different commodity and livestock quantities and prices, the single commodity and dependent variable equations can be written in matrix format.

Equation set (2.80) becomes

\[
\begin{align*}
\hat{p}_t &= \hat{A}\hat{q}_t \\
\hat{q}_{t+1} &= \hat{B}\hat{p}_t = \hat{B}\hat{A}\hat{p}_t
\end{align*}
\]

(2.84)

where

\[\hat{p}_t, \hat{q}_t, \text{ and } \hat{q}_{t+1}\] are \(n \times 1\) vectors representing \(n\) market price and quantity deviations from their respective trend equilibrium values.

\(A\) and \(B\) are \(n \times n\) matrices of \(\beta\) coefficients on the above variables.

If the maximum absolute root of \(BA\) is less than one, it can be shown that the system of equations converges to zero. Waugh [208] has developed methods for generating these \(A\) and \(B\) matrices using both statistical data and some logical economic principles concerning symmetry between given coefficients developed earlier by Hicks [102].

Individual market behavior of a given output is affected when related market systems are dynamically coupled. The stability of a market is determined by only its own supply and price functions in the absence of coupling. But when coupling occurs, the stability or degree of
oscillations and period of cycling of a particular market will be affected by the behavior characteristics of other related markets specified in the A and B matrices.

Goodwin has explored the theoretical mathematical relationships between just two dynamically demand coupled markets under three different production lag conditions. In the first case, only the first market has a production lag. The stability of the first market will likely be decreased from its original condition, and the oscillation in the second market will likely be less than that observed in the first. Additionally, if the two goods are complementary, the market's oscillations will be out of phase with one another. If the two goods are substitutes, the markets will be in phase with each other. Out of or in phase means the price in one market will be high and the other price low or both market prices being high or low together respectively. In the second case, both markets have production lags and have identical $\beta$ coefficients and lags. Goodwin found that the original cycling period needed to reach an equilibrium solution for each market would remain the same even if they were dissimilar as long as each contained identical lags. Secondly, both markets will have two cycling oscillations, one of which is less stable and the other more stable than their original, uncoupled oscillations. He concludes that since the less stable solution tends to predominate, coupling decreases the stability of both systems. If the markets are dissimilar in the $\beta$ coefficients, the stability of the oscillation is less than that of
the oscillation in the least stable market under normal own price responses. Phasing of the markets is similar to the first case presented. The third and final case investigated the coupling of dissimilar markets with differing lags. The second market was given twice the production lag of the first market. The characteristics of this market system turned out to be extremely complicated. First, the cycling period of each market changes and becomes longer depending upon the structural parameters and the uncoupled cycling periods. Additionally and

"Even more remarkable is the fact that it [the cycle] is no longer simply periodic; it does not repeat itself, even with no outside disturbance or natural damping. Except by accident the various periods will not dovetail, because they are not integral multiples of one another, and hence in each cycle they will join in a new way, resulting in an ever-changing wave shape. Although the two markets will contain the same set of periods, their time shape will not be the same... Furthermore most of the periods in the one will be out of phase with those in the other market" [71, p. 201-202].

In summary, when more than one market is allowed to interact, the stability of both markets is decreased by the coupling. Their phase relationships tend to be in or out of phase if they are substitutes or complementary goods, respectively, but may be completely arbitrary. Markets with the same lags will not have their periods altered, but dissimilar lagged markets will have different periods and a complicated, changing wave shape for the oscillatory period.

The cobweb theorem and its recursive methodology developed by Ezekiel, Waugh, Goodwin, and others, has been applied extensively to a wide variety of economic problems relating to supply responses of agri-
cultural outputs. During the last two decades, a large number of simulation techniques have been developed to describe a wide variety of economic systems involving individual markets, a few related markets, or large number of markets in which commodities and livestock are sold by producers. Many of these models are macro oriented, and describe the agricultural sector, or particular markets. A growing minority of these studies describe firm behavior. Lack of space, however, prevents an extensive review of all these studies such as Anderson has done [5]. The analysis of this methodology will be limited to a brief mention of important and related studies and a somewhat longer discussion of simulation modeling formats incorporating both commodity, input and livestock markets. Disaggregated or individual livestock simulation models dominate in the agricultural economic literature for two reasons, although other subsectors may also be modified individually [157]. First, simple, single equation regression models cannot easily be applied to the various livestock sectors and livestock products because gestation or production behavior and formation of price expectations are usually completed over several marketing periods. The relevant marketing periods may be months, quarters, or years. Typically, livestock simulation models are estimated using quarterly or monthly data series.

Second, an especially difficult and integrated problem within livestock models is the development of an adequately explained inventory submodel. The historical evolution of livestock simulation models
could be described in terms of a growing awareness and resulting sophistication in representing livestock supply responses as part of an inventory and time problem. Thus, recursive simulation modeling procedures are highly adaptable for the portrayal of livestock industry marketing behavior.

Many individual livestock sector models have been described and estimated during the last decade. Hartman [75] has constructed a quarterly model of the egg cycle. The cash pork bellies market has also been modeled [65]. Miller and Halter have developed a model of the Venezuelan cattle industry for planning and policy purposes [130]. Martin and Zwart estimated regional supply and inventory equations for hogs and have presented a regionalized simulation model of the North American pork sector [124]. Their model is especially interesting for its use of a quadratic programming model to allocate the predetermined supplies among regions. Often beef and pork markets have been portrayed together as a multi-market system [69, 76]. A more complicated and ambitious beef, pork, chicken, lamb, and turkey model was completed by Rahn, et al. [156].

As noted earlier, the strength of simulation modeling lies in its ability to solve and accurately describe the economic behavior of complex systems over time. In agriculture, as in other major sectors, economic processes and activities involve numerous physical quantities and information flows between and among a multitude of markets. While the purely macro analysis approach generally disregards examination
of these many individual components, the impact of various policy or behavioral alternatives on the particular macro sector being studied is articulated through changes in disaggregated micro variables and resource use levels. This point of view is especially applicable toward modeling the agricultural sector. In agricultural sector modeling, an understanding of the behavior of the micro components and resource use within the sector has long been considered important for an understanding of the behavior of the entire sector [98, 195]. Additionally, an intelligent and perceptive grasp of these more micro element relationships within the larger modeling framework is very useful for policy and planning recommendations in developing countries [79].

Many U.S. agricultural industry simulation models have been constructed under the above considerations. Perhaps the most explicitly developed dichotomized model of macro industry and micro firm behavior was built by Schechter and Heady [172] to analyze the consequences of various alternative government farm policies on both industry and firm behavior. Typically macro agricultural simulation models have consisted of highly aggregated output, input, and demand equations. For example, Cromarty [35], Tyner and Tweeten [196], and recently Rosine and Helmberger [164] have studied the behavior of the U.S. agricultural sector over an historical period of time to gauge the effect of various government programs on aggregate agricultural resource allocation and aggregate output and income. Ray, following earlier national simulation studies, disaggregated the macro agricultural economy into five commodi-
ty groups, feedgrains, wheat, cotton, soybeans and tobacco and aggregated livestock group [160]. Each sector was represented by its own submodel of production, input use, and demand relationships defined by a causally related sequence of equations. Ray's historical model was later extended by Heady, Reynolds and Mitchell [94] and modified [93] for use in long term policy and planning forecasting. Meanwhile, Ray [159] has reformulated his earlier model by explicitly incorporating estimated supply and demand elasticities in each of the commodity and newly disaggregated livestock sectors. Resource use relationships had been subsumed in average per acre cost relationships and are absent from this model, despite his earlier assertion that

Agricultural output is a function of the level and productivity of resources used in agriculture. Output, price, income and resource returns are tied directly or indirectly to resource commitments. Hence, an understanding of the impacts of alternative government and other exogenous variable changes on commodity resource demands is fundamental.

... because commodity price and gross income estimates generated in the current year are instrumental in determining commodity resource demand levels in the following year. Also, if a policy variable which directly concerns one commodity, influences other commodities, we can observe changes in the factor demands for those commodities [160, p. 41-42].

The specific intentional utilization of the model has been for estimating the effects of different agricultural policies for planning and policy evaluation purposes.

Generally, the specification of the above models in a recursive equation and modeling format has followed very similar structural linkages between equations although many variations between models
exist. The similarity in structure is due in large part to the assumed lag between production decisions and realized output. This assumption has clarified the sequencing of equations within the recursive structure. "A model is recursive if its member equations can logically be arranged so each dependent variable is a function of exogenous [pre-specified variables and [endogenous or determined within the system] variables that have been treated as dependent earlier in the model" [160, p. 40]. To reflect system recursiveness, the general equation groupings within the national or various disaggregated submodels are usually broken out into three divisions, "pre-input, input, and output" equations [196, p. 67-68].

The pre-input set of equations for year t always includes crop acreage estimates. Ending calendar year level or value of stock estimates for machinery, commodity, land, and other multiple-year physical assets are also calculated. Typically, the livestock ending year inventory and current year purchases are also calculated in this section. The input section is the second subset of equations. The acreage and stock estimates from the pre-input section are used either directly or indirectly to compute current period variable input expenses. These expenses include fertilizer, seed, fuel, oil, and repairs, labor, and miscellaneous and flow of service input expenses including machinery and land ownership expenses, real estate taxes and interest on crop and livestock inventory expenses [160, chapter 6]. These input levels are then used in the output or third section of the model. Usually,
input levels are used directly in a period specific Cobb-Douglas production function estimated from input factor share data to estimate crop yields or aggregate production levels. They may also be used indirectly to modify exogenously given production data [93] when not used directly in a production function. Total commodity and livestock supplies are then determined by adding imports and carryover inventory to current production. Next, output prices based partly on available supplies and final demands are estimated simultaneously and supplies are allocated among uses. Finally, an estimate of gross income as a function of output, price and government payments when such programs are in effect is made. The livestock output sector, when specified, is handled slightly differently from the above general format in that livestock production and marketings are used to determine livestock price. The values of the above variables are stored in the computer program and then retrieved to become lagged variables in year $t + 1$ to determine levels of related variables in year $t + 1$, according to the causally ordered behavioral relationships specified a priori by the experimenter. The computer then cycles the multi-equation computer program through as many time periods as desired to test economic hypotheses concerning the agricultural sector's behavior under different economic environments.

Although most national agricultural sector simulation models are completely specified in terms of national aggregate input, output, and price variables estimation, regional disaggregation of some of this
data could be important and useful for many policy and planning purposes for obvious reasons. An initial attempt toward at least a partial disaggregation and regionalization of input use data has been developed by Systems Control, Inc. (SCI) within the context of a national simulation model [186, 187, 188, 189]. The available literature does not make clear whether this particular model is able to cycle recursively or is able to generate information one year at a time. Nevertheless, while the model follows the disaggregated pre-input, input, and output commodity and livestock format proposed by others, the input sector formulation has been reorganized with the inclusion of a regional quadratic programming model. The quadratic programming model has eight regions, ten crops and 43 different cropping activities. The 23 feedgrain, wheat, cotton, and soybean activities are located within only six regions. The objective function of the QP is atypical in that the cost of adding additional land past a "normalized" level for a crop within a region is nonlinear, rather than prices being functions of quantity produced. The regional crop optimal input use demands for nonstock inputs are then added into national demands. These optimal demands then interact with the pre-input supplies of these variable inputs and equilibrium prices and final input demand quantities are generated. Thus, the usual assumption made in earlier mentioned models of perfectly elastic input supply functions has been eliminated. These variable input levels and the land and capital stock inputs are then used in Cobb-Douglas production functions that are
both crop and region specific. These production levels are then modified to reflect weather impacts. The following modeling steps followed in the SCI model are similar to those in other national simulation models.

In addition to the general review of national simulation modeling the SCI model may be critiqued for its approach toward the regionalization of aggregate commodity variables. First, the level of regionalization in this model does not justify the inclusion of a quadratic programming model. Regional crop and input demand equations at this large level of regional aggregation are easily and cheaply estimated. A generalized Gauss-Seidel input market equilibrating mechanism could also be easily substituted. Second, the inclusion of the QP model adds additional technical modeling and cycling problems not justified by the additional information generated by the model. Third, the regions are so large that national impacts of regional specific problems or circumstances could be as easily generated using regional acreage and input equations as with the QP model. Finally, the quadratic programming objective function is more defensible when prices are a function of demand rather than costs. This is largely due to the cost estimation problem related to increasing acreages of a crop within a particular region. Thus, although the SCI model is extremely interesting from a conceptual viewpoint, its specification seems to be more complicated and inconvenient than is necessary for national policy analysis.

The general "accuracy" critique of simulation models generally
follows the appraisal of any complex modeling problem which has been quantified and put into a quantitative equation format [154, chapter 10; 68; 112; 158; 176]. The first two areas discussed, verification and validity, are interdependent although nominally separated here for enumeration purposes.

First, a simulation model is constructed so that the sum of the parts (equations) is more than the parts taken individually. Individual macro regression equations suffer from the many limitations discussed earlier in this chapter. Nevertheless, although estimated regression equations utilized in the model may fit historical data with high $R^2$ and low mean square error, many equations when combined into a single model can often perform very poorly because market and variable interactions have been misspecified or ignored, even if unintentionally. Some equations may track well ex-post and others may not track the original data series. Therefore, the question becomes one of how well do the relationships between and among variables in the model reflect real world relationships, and secondly of whether all necessary relationships have been adequately specified within the model. In reality, the researcher is often forced to compromise by using some equations which do not have a good fit to historical data, but which improve the ability of the model to estimate other "more important" variables more accurately.

Secondly, a problem exists in what criteria to use when evaluating different simulation models for validation. For individual equations,
$R^2$, MSE, and t or F statistics are available for the experimenter to make a statistical judgment about the dependent and independent variables relationship specification. But,

... in a multiple-equation model each individual equation may have a very good statistical fit, but the model as a whole may do a very bad job in reproducing the historical data. The converse may also be true, the individual equations of a simulation model may have a very poor statistical fit, but the model when taken as a whole may reproduce the historical time series very closely. An important problem, then, is how to evaluate a simulation model properly [154, p. 309].

Many descriptive measures have been suggested to evaluate the forecasting performance of relevant variables in large-scale models for a wide variety of purposes.

An Outline of Nonparametric Measures

A. Single-variable measures
   (1) Mean forecast error (changes and levels)
   (2) Mean absolute forecast error (changes and levels)
   (3) Mean squared error (changes and levels)
   (4) Any of the above relative to:
      (a) the level of variability of the variable being predicted
      (b) a measure of 'acceptable' forecast error for alternative forecasting needs and horizons

B. Tracking measures
   (1) Number of turning points missed
   (2) Number of turning points falsely predicted
   (3) Number of under- or overpredictions
   (4) Rank correlation of predicted and actual changes (within a subset of 'important' actual movements)
   (5) Various tests of randomness
      (a) of directional predictions
      (b) of predicted turning points
C. Error decompositions
   (1) Comparison with various 'naive' forecasts
   (2) Comparison with "judgmental", 'consensus,' or other noneconometric forecasts
   (3) Comparison with other econometric forecasts

D. Cyclical and dynamic properties
   (1) Impact and dynamic multipliers
   (2) Frequency response characteristics.

The use of any of these measures would depend upon the experimenter's decision as to the particular relevance to his model's predictive ability. Thus, Rausser's comment that perhaps the real questions is "Does the Search for Quantitative Economic Knowledge Remain an Essay in Persuasion?" [158, p. 273] is striking in its insight for two reasons. First, quantitative models are necessarily abstractions of the system they represent and must, therefore, be misspecified representations of real world relationships. Secondly, because the model is misspecified, different model or quantitative specifications may be utilized with each involving a distinctive behavioral explanation structure which uses divergent sets of endogenous or exogenous variables. "For these reasons, it is safer to investigate the 'sufficiency' of models rather than their 'realism', i.e., is the constructed model for the purposes designed, adequately sufficient" [158, p. 274].

Finally, the third criticism of large-scale simulation models is centered around their estimation costs compared with simpler modeling formats of either a single or simultaneous equation model. The general objective is to build the lowest cost model generating the greatest
amount of "reliable" information. In reality, this question is answered \textit{ex ante} by funding allocated by the project, the experimenter's time and model building experience, the availability of data and the purpose of the model. In short, the more complicated model is almost always preferred because of the extra leeway in policy and variable manipulation available to the researcher if the added benefit of improved reliability of forecasts is larger than the extra costs entailed in the added modeling complexity.

\textbf{Recursive programming models} Recursive programming is a relatively new methodological procedure for studying the intertemporal and interdependent levels and locations of the supply responses of various agricultural crops and livestock activities. Although recursive programming models belong within the general class of dynamic models in which

"planning is determined by a single optimizing decision, . . . recursive programming plans are determined by a sequence of optimizing decisions . . . recursive programming systems are . . . multiple phase models in which phase changes are governed by a single rule, the optimizing principle" [39, p. viii].

"A change in the equation which 'govern' the system is called a \textit{phase change} and the period of time during which the same equation hold a \textit{phase}" [40, p. 111].

Sahi defines recursive programming simply as

"a sequence of mathematical programming in which the parameters of a given problem are functionally related to the optimal variables of the preceding problems in the sequence" [168, p. 31].
Recursive programming was introduced and developed in response to production response studies estimating aggregative supply relationships with regression and econometric techniques [100]. Even though the ten interrelated categories of variables and relationships [page 1, chapter 1] have been diligently considered in equation estimation procedures, the production structure, and the optimization and choice mechanisms are implicitly represented. Day has argued that mathematical programming models have been continuously neglected by economists in favor of regression models.

"Ever since these concepts [mathematical programming] have been available econometricians have hesitated to use them for predictive purposes. The explicit use of the optimizing principle seemed to conflict with the long revered fact that motivations, other than pecuniary, influence the behavior of producers. This reluctance, however, never crossed over into its implicit use, that is, for interpreting the results of statistically fitted supply relations" [39, p. 3].

Thus, when estimated variable coefficients have different than expected signs, information or an economic structure exogenous to the specified model must be utilized to justify or explain sign discrepancies. Recursive programming attempts to correct this problem by merging a linear programming model with activity flexibility coefficients and restraints that have been econometrically estimated by using the problem's solution data from the preceding time period. Thus, recursive programming facilitates a simultaneous examination of aggregate supply and production responses of agricultural products with an explicit explanation of both the decision processes included in
activity selection and the interaction and technical structure of activities over a sequence of time periods.

The reasoning and ideas which form the theoretical mathematical foundation have been rigorously explained by Day [39, chapter 3]. While these ideas are simple if taken individually, their mixture leads to the development of complex,

"multiple phase dynamic systems. Such a dynamic system is one whose behavior is determined by distinct regimes or phases which are described by distinct equations or sets of equations . . . [and is] one whose phases are governed by a single rule . . . the optimizing principle of economics" [39, p. 36-37].

and are a more general type of dynamic system than either the closed or complete causally determined dynamic system or the historical dynamic system defined by Samuelson [170, p. 317, 315].

To illustrate both the simplicity and complexity of recursive programming we initially assume that the harvested acreage of a crop is related to its own price in the previous year in a regression equation format,

\[ Y_{i,t} = \beta P_{i,t-1} \]  \hspace{1cm} (2.85)

where

\[ Y_{i,t} \] = harvested acreage of crop i

\[ P_{i,t-1} \] = lagged price of crop i

If the harvested acreage of crop is limited by a government imposed allotment or even more simply by a limited land base then

\[ Y_{i,t} \leq A_t \]  \hspace{1cm} (2.86)
where

\[ A_t \text{ is the imposed upper limit harvested acreage constraint} \]

Thus, a simultaneous system of equations has been specified and is inconsistent if the allotment acreage is less than the predicted acreage, i.e., \( A_t < \beta P_{t-1} \). If the equality in (2.86) is removed, then the system is underdetermined. The constraint equation may also be specified to reflect capacities of available factors of production or other policy variables. The important point to remember is that the behavioral response equation is now subject to a constraint equation.

When two crops are grown on a particular land base, and are allowed to compete with each other for the available land, the above supply equation set is modified into the following equation system

\[
\begin{align*}
Y_{1,t} &= \beta_{11} Y_{1,t-1} + \beta_{12} Y_{2,t-1} \\
Y_{2,t} &= \beta_{21} Y_{1,t-1} + \beta_{22} Y_{2,t-1} \\
\end{align*}
\]

and

\[
Y_{1,t} + Y_{2,t} \leq \bar{Y}
\]

where

\[
\begin{align*}
Y_{2,t} &\text{ is the harvested acreage of the competing crop} \\
P_{2,t-1} &\text{ is the lagged price of the competing crop} \\
\beta_{11}, \beta_{22} &> 0 \text{ a priori expected values based on economic theory [64]} \\
\beta_{12}, \beta_{12} &< 0 \\
\bar{Y} &\text{ is the total available land base}
\end{align*}
\]
If equation (2.88) holds, then the behavioral equation set must also hold. The converse of this statement is not necessarily true because of the above overdetermined equation system. If equations (2.87) are specified as inequalities, then the system is underdetermined and an infinite number of solutions is possible. In the situation where only one of the behavioral equations holds as an equality and where the constraint equation also holds as an inequality, a problem of activity choice selection is generated. Therefore,

"[s]ome kind of mechanism must be added if one is to decide in a meaningful way which of the two supply equations holds whenever the overall land constraint holds. The mechanism which will resolve problems of this kind is the optimizing principle of economics. . . . The important problem is not whether it should be used but rather how it can be used without grossly misrepresenting the simple decision processes [and underlying technical structure of production] governing farm behavior. The attempts to solve this problem leads to a synthesis of time-series analysis and linear programming versions of production theory. It is to such a synthesis that the rest of this paper is devoted. We shall call it recursive programming" [40, p. 112].

Because recursive programming employs linear programming techniques, it is an optimization technique using a linear, net return objective function and linear constraints. At the same time, this methodology adds an innovation referred to as flexibility restraints that changes the conceptual nature of the programming problem. The use of flexibility restraints enables the model to partially resolve one of the important problems in linear and nonlinear programming, the linearity problem. In so doing, the recursive programming model becomes capable of estimating and predicting positive rather than normative supply
response behavior.

The linearity problem is due to the nature of the linear programming algorithm, and the specification of the objective function. More specifically, the algorithm maximizes the objective function which is linear in terms of the coefficients. If a coefficient is positive and is larger than other coefficients, the algorithm will select that activity and increase its solution level until a (resource) constraint is reached. Thus, if a coefficient is negative one year, it may not enter the solution vector at all. If the same activity coefficient is positive the following year, it may enter the activity solution at a very high level. In both these situations, the normative behavior responses of producers are observed.

In the real world, agricultural activities levels change, but not at an extremely high or normative rate of change. Thus, the linearity problem is essentially one of specifying allowable or positive year to year changes in the levels of activities, from the preceding year. These activity programming restraints are usually referred to as flexibility restraints in recursive programming models. Thus, the model solution is optimal, but is optimal in a highly restrained sense approximating a more predictive real world solution based on farmers actual production behavior in the past.

These maximum and minimum activity flexibility restraints in each time period are based on a hypothesized set of economic conditions that influence farmers' production decisions in a particular time
period. The explicit assumption is made that period t's decisions are derived from the production decisions and resultant market behavior in period t-1. The factors acting to restrict producers from normative changes in established production activities other than input availability include price, weather and marketing uncertainty, inadequate technical or managerial knowledge, institutional restrictions, personal preferences and goals other than short run profit maximization. The above factors are usually not directly observable in the real world and must therefore be measured indirectly by the flexibility restraints. The various expectation and adjustment equation models discussed earlier in this chapter also represent the same conglomeration of forces mentioned above, including restrictions on the changes in the availability of production inputs developed by Nerlove [140]. Thus, the flexibility constraints may also be utilized to estimate changes in available inputs. Then the mathematical notation for generalized flexibility restraints using the previous equation notations can be expressed as

\[ Y_{i,t} \leq (1 + \bar{\beta}_i)Y_{i,t-1} \]  

(2.89)

and

\[ Y_{i,t} \geq (1 - \bar{\beta}_i)Y_{i,t-1} \]  

(2.90)

where

\[ \bar{\beta}_i \] is the maximum allowable increase in the level of the ith activity from year t-1 to year t; 0 \leq \bar{\beta}_i \leq \infty
\( \beta_i \) is the minimum allowable decrease in the level of the
ith activity from year t-1 to year t; \( 0 < \beta_i < 1 \)
i = 1, 2, \ldots, n

The first equation is the upper flexibility restraint or bound for
each crop and the second is the lower flexibility restraint or bound
for each crop. The upper bound on the solution acreage of each crop
cannot be larger than its preceding year acreage plus some proportion
of it, \( \bar{\beta}_i \). The minimum lower bound on the solution acreage of each crop
cannot be less than the preceding year acreage minus a proportion of
it, \( \underline{\beta}_i \). These restraints set the upper and lower limits respectively
of the aggregate crop acreage changes farmers can make from year to
year. When an overall land constraint as in (2.88) and other con­
straints are also added to the restraint equations, a system of linear
nonhomogeneous difference equations is formed. This system can only
be resolved by applying the optimizing principle in the form of an
objective function where the expected net returns of each crop activity
are maximized jointly. The recursive programming is thus mathematically
presented in dynamic notation as

Maximize \( Z_t = R_1, t \cdot X_{1,t} + R_2, t \cdot X_{2,t} + \ldots + R_n, t \cdot X_{n,t} \)

subject to

\[ \sum_{j=1}^{n} a_{i,j} \cdot X_{j,t} \leq D_i, t \]

\[ X_{j,t} \leq (1 + \underline{\beta}_{j,t}) X_{j,t-1} \]
\[ Z_t \leq (1 - \beta_j,t)X_{j,t-1} \]
\[ X_{j,t} \geq 0 \]  
(2.91)

where

- \( Z_t \) = the objective function value to be optimized in year \( t \)
- \( X_{j,t} \) = the level of the \( j \)th activity in the \( t \)th year; \( j=1, \ldots, n \) activity
- \( X_{j,t-1} \) = the level of the \( j \)th activity in the \( t-1 \)th year
- \( D_{i,t} \) = the level of the \( i \)th restraint in the \( t \)th year; \( i=1, \ldots, m \) restraints
- \( R_{j,t} \) = the net return per unit of the \( j \)th activity in the \( t \)th year
- \( a_{i,j,t} \) = the amount of the \( i \)th restraint needed per unit of the \( j \)th activity in year \( t \)
- \( \beta_j,t, \bar{\beta}_j,t \) have been defined earlier as the upper and lower coefficients in year \( t \)

This representation of a recursive programming model demonstrates its dynamic properties in the Frisch-Samuelson sense, as well as in the Hicks sense [39, pp. vii-viii]; it is a self-generating recursive model. The optimal solution in the first period is used to generate the flexibility restraints in the second period. The optimal solution in the second period generates the flexibility restraints in the third period, and so on. Over a number of time periods, the recursive properties
of the model, when expressed through the flexibility restraints, act to trace out a distributed interdependent lag response for each of the activities in the model. As relevant policy variables are varied, different polyperiod supply and production responses occur as the flexibility restraint levels change.

Through the use of parametric price programming a "positive" supply function for a given year may be derived (see Figure 2.5). Like the linear programming supply function, the recursive programming function is also stepped indicating optimum quantities over a range of prices. But unlike a linear programming supply function, a different supply function is generated every year because the flexibility constraints shift every year based on the previous year's optimal solution. Thus, not one, but a series of time dependent supply functions are generated by this modeling technique. Furthermore, each particular period's supply function is related to the preceding period's pattern and level of production activities. Therefore the flexibility restraint and optimization formulation of a profit maximizing recursive programming model also suggest important empirical differences with regard to other dynamic and static production response models when predicting short and long run supply behavior over time.

To illustrate these properties, the two crop model introduced in (2.87) and (2.88) is placed in a simple recursive programming format as
Figure 2.5. Stepped Supply Curves from Recursive Programming Analysis [168, p. 35]
Max \( Z = R_1 \cdot x_{1,t} + R_2 \cdot x_{2,t} \)

subject to
\[
\begin{align*}
X_{1,t} + X_{2,t} & \leq L \\
X_{1,t} & \leq (1 + \beta_1)X_{1,t-1} \\
X_{2,t} & \leq (1 + \beta_2)X_{2,t-1} \\
-X_{1,t} & \leq (1 - \beta_1)X_{1,t-1} \\
-X_{2,t} & \leq (1 - \beta_2)X_{1,t-1}
\end{align*}
\]

\( (2.92) \)

and
\[
X_{1,t}, X_{2,t} \geq 0
\]

where
\( R_1, R_2, \beta_1, \beta_2, \beta_1, \) and \( \beta_2 \) are now fixed from year to year exogenously.

\( L \) is the amount of harvestable land within the region.

By using the mathematical properties of linear programming it can be shown that an optimal solution will have the same number of nonzero variables as equality constraints \( [183] \). A recursive programming problem representing a production system would therefore be expected to be determined by exactly as many equations as there are positive basis variables selected by the optimization process. Since both the lower flexibility constraints in equation system \( (2.92) \) are greater than zero both variables must be positive. Additionally, only two of the five constraint equations will govern the system over a sequence of time.
periods because there are only two activities in the system. The relative returns between the two activities and constraint levels act as the decision variables for the choice of which two restraints are finally chosen.

A change in the equations which "govern" the system is called a phase change and the period of time during which the same equations hold a phase. The operation of this system over time will tend, in general, to exhibit multiple phases. . . . During a given phase, simple, first-order difference equations will determine the time paths of acreage [40, p. 112].

For the simple system presented above, the explicit solution for such an equation is

\[ X_i = \lambda^{t-t_0} X_{i,t_0} \tag{2.93} \]

where

\[ X_{i,t_0} \] is the starting acreage level from which the particular activity moves just prior to a phase change.

This is easily demonstrated using equation system (2.92)

To visualize how time paths of acreage might appear suppose that with each new year, the first crop is expected to be the more profitable . . . and that net returns from both crops are positive. Suppose also that the acreage of the first crop is much smaller than that of the second, and that there is some idle land.

The following phases are a possible outcome. [depending upon the flexibility coefficients, net returns and other conditions]

Phase I

\[ X_{1}(t) = (1 + \bar{\lambda}_1)^t X_{1}(0) \quad (t=1, \ldots, t_1) \]
\[ x_2(t) = (1 + \overline{\beta}_2)^t x_2(0) \]  

\text{Phase II}  
\[ x_1(t) = (1 + \overline{\beta}_1)^t x_1(t_1) \quad (t = t_1 + 1, \ldots, t_2) \]  
\[ x_2(t) = \overline{x} - x_1(t) \]

\text{Phase III}  
\[ x_1(t) = \overline{x} - x_2(t_2) \quad (t = t_2 + 1, \ldots) \]  
\[ x_2(t) = (1 - \overline{\beta}_2)^t x_2(t_2) \quad [40, \ p. \ 112] \]

The three phases can also be depicted graphically in Figure 2.6 [40, p. 113].

In phase 1, both activity acreages increase by using the idle arable land. Their increase is limited by the coefficients in the two upper limit restraint equations. In phase 2, not enough idle land is available for both crops to expand at their optimal rates. The first crop expands optimally limited by its upper limit flexibility restraint equation. The second and less profitable crop first expands and then declines using whatever slack land is left from the overall land constraint. In other words, the first crop in this phase expands by first using idle land and then by using the second crop's land. In the third phase, the acreage expansion of the first crop is limited by the overall land constraint and the lower bound restraint equation of the second crop. Thus, acreage of the second crop is released slowly reflecting the unwillingness of farmers to rapidly specialize in a crop even though it is a more profitable activity. This example demonstrates that in Phase 2 and 3
Figure 2.6. A Graph of the Three Expected Crop Acreage Phases [40, p. 113]
neither long or short run normative, optimal solutions occur despite the use of the optimization technique.

The aggregative model can now be "closed" by assuming that the expected net returns of each crop in the current year are dependent on the previous years' production and prices, current expected yields, and their related input costs. But current supplies are independent of current demands because of the lag hypothesis. These expected net returns could be determined with a Nerlove price expectations model or some variant of it. Then as production of the first crop increases relative to its aggregative demand and as the supply of the second crop falls relative to its demand in Phase 2, their net relative return relationship will eventually reverse in Phase 3. As a result Crop 2 will become more profitable to produce than its competitor. Farmers should then begin changing their production patterns based on the change in price or net return expectations to favor the second crop over the first. When this happens, a phase change occurs and the model enters Phase 4. Over a long period of time, the model will then oscillate through a series of phases of changing relative net returns.

The following results seem most important. First, prices and acreages, ergo, net returns, marginal revenues, and outputs undergo multiple phases in which rates of change over time change in each phase. Second, the phases begin to repeat themselves. This is called phase periodicity and the results tend to resemble dampened sine and cosine curves! Third, phases occur in which output of a commodity may increase while its price is falling! [40, p. 115].

These results have several important implications for the empirical
estimations of supply response behavior. First, the supply elasticity concept is not a particularly valid tool for predicting production response over time. The supply elasticity changes as production patterns, relative returns, costs and system restraints vary over time. In other words, "holding everything else constant" is a nonapplicable hypothesis when a dynamic system is modeled. Second, unlike other supply estimation techniques the recursive programming methodological framework will describe a multivariate, polyphase cobweb cycle for agricultural products if relative returns change over time. Finally, a reasonable explanation can be offered of why production of a commodity can fall over time even though its price may be increasing, i.e., a downward sloping supply curve. This result stems from the lag in expectations linked through the reaction of output on demand to a production structure with a finite number of alternatives. In essence, when the Marshallian, positively sloped short run supply curves are derived by continuously varying price to obtain a series of different supply responses, the production sector is divorced from the demand sector. The dichotomization of the supply and demand sectors in the market system is useful for testing artificial hypotheses about the supply sector at a point in time. But production response over time must also include expectations and the dynamic properties of a demand sector in the market system for realistic policy and planning behavior to occur.

Relatively few recursive programming models have been built for
production response studies for a number of reasons. The main reason for its limited use has been the time and cost needed to develop the objective function, matrix, and flexibility restraints and the complexity of the modeling technique. The primary focus of recursive programming models has been to methodologically and empirically develop the flexibility restraint procedure for improved predictions of supply responses. While the technique has been used for farm growth modeling [4, 99], recursive programming has been typically applied to national and regional agricultural response models. The development of these models will be discussed in a historical sequence.

Recursive programming was originally developed by Henderson to predict the 1955-1956 land utilization patterns in the U.S. for a dozen major field crops [100]. His hypothesis was that a recursive programming model that maximized net returns and utilized flexibility restraints on yearly crop acreage changes could be effectively used for prediction. His model of U.S. agriculture was divided into 160 producing areas representing relatively homogeneous soil, climate and farming practice regions each with its own production activities. The objective function consisted of announced support prices being the expected prices, 1954 costs being expected costs and the 1949 to 1953 average yields being the expected yields. Overall producing area land constraints and flexibility restraints, as discussed earlier, completed the model.

The flexibility restraints were estimated by using calculated acreage changes from 1946 to 1954. These proportionate changes were
first stratified by direction of change and then by the level of crop acreage. These final groups of acreage changes were then averaged to estimate the flexibility coefficients actually used in the analysis. The latter stratification showed an inverse relationship between the acreage level as a percentage of the total land base and the proportionate changes. In other words as acreage percentage increased, the proportionate change decreased and vice versa for acreage decreases. The economic rationale Henderson proposed to explain this observed behavior was that when farmers specialize in a crop, they face an increased risk from crop failure. Thus, to minimize risk while still trying to maximize income, farmers will only specialize in crop production to a limited extent.

Although Henderson's model was crude, his predicted crop acreages, on the whole, were more accurate than the Crop Reporting Board of the U.S.D.A. when compared to the actual harvested crop acreages in his 160 region model. Henderson then aggregated his 160 region model into a 55 region model and again tested the summed national crop acreage estimates. He found that the accuracy of the acreage estimates decreased as the model become more aggregated. An important result was that the average error in estimated crop production increased as the number of major crops in a region decreased. A conclusion that can be drawn from his model is that the decisions to plant crops which are in the model are not independent of the planting decisions of other crops not included in the model. Therefore, the procedure of
including only a few major crops acts to seriously bias the predicted results. Thus, predictive land use models should include as many crops and related activities as possible for accurate forecasts.

Day further developed Henderson's ideas mathematically and demonstrated rigorously that recursive programming models were a more general class of programming models [39, Part I]. Then, in an historical analysis from 1940 to 1957, he tested many of the mathematical and economic hypotheses in an eight crop recursive programming model of the Mississippi Delta [39, Part III]. Although the programming model was similar in many respects to the Henderson model, Day included four technological stages, three soil classes and four different fertilizer levels. He also updated the input-output matrix every year to reflect productivity changes and technological advances when they occurred. Day also developed a regression methodological approach to estimate flexibility coefficients. He only stratified the year-to-year historical acreage changes into two groups based on their direction changes when estimating flexibility coefficients. After the first year, the upper and lower flexibility restraints were then calculated by multiplying the preceding year crop solution acreage by the estimated flexibility coefficients. Day recognized that the use of solution acreages rather than actual acreages when estimating flexibility restraints could and probably would lead to accumulated estimated restraint errors over a period of time especially in a regional model. Nevertheless, lack of data precluded the "actual acreage" flexibility restraint approach.
Flexibility coefficients were calculated by three different methods, regression analysis, selected points, and averages. The use of regression analysis to estimate flexibility coefficients was an expected extension of Henderson's analysis. Day used a simple equation for each set of acreage changes,

\[ Y_{i,t} = a_i Y_{i,t-1} + e_{i,t} \]  

(2.95)

where

\[ a_i = 1 + \beta_i \text{ or } 1 - \beta_i \]  

respectively for the ith crop;

\[ i=1, \ldots, n \]

\[ e_{i,t} = \text{error term for the ith crop in the tth year} \]

other variables defined as before

An OLS procedure was used to estimate the flexibility coefficients. A discussion of how well these simple equation models actually fit the data was not included.

As with Henderson's [100] national crop acreage estimation results, Day's Mississippi Delta predictions for crop acreages with a recursive programming model from 1955 to 1959 compared very favorably with the Crop Reporting Board estimates. In his historical analysis, some crops were predicted accurately during some periods while others were not. Day reported that a large part of the difference was caused by incorrect prediction of crop yields. The incorrect expected yield model and the probably inappropriate price expectations model then caused errors in the relative net returns among crops. Day felt the incorrect estimation of acreage turning points and thus acreages was primarily a fault
of these expected net return inaccuracies.

In another regional model, Schaller and Dean used a recursive pro-
gramming model to explain changes in 12 crop acreages from 1951 to 1958,
predict changes from 1959 to 1961 and then to project changes from 1962
to 1965 in Fresno county, California [171]. The 1951 to 1961 crop
acreage change results were compared with the actual crop acreage levels.
During this period, flexibility restraints were estimated by using the
preceding year actual acreages. Regression equations for estimating
crop acreages were also developed and evaluated in relation to the 1959
to 1961 recursive programming acreages predictions. In the forecasting
analysis, the model was extended through 1965 using the preceding year
solution as the basis for the flexibility restraints in the following
year because the actual acreage data was unavailable. Although the
representative farm approach discussed earlier was considered for
studying the aggregate production response of the county, it was decided
to use aggregated farm data from two subregions in the model. Ericksen
and Buller, in a later recursive programming analysis of Kansas, found
that for small areas, the level of aggregation and related specification
detail is not critical for accurate production response estimates. They
did suggest that the flexibility restraint estimations should be con-
sistent with the model aggregation level.

The accuracy of crop production estimates made with
a model that requires little or no individual farm data
can be as satisfactory as those from a less aggregative
model that requires individual farm detail . . . at least
for the study area in western Kansas. The less aggrega-
tive models used in the study lacked consistency between specification detail and aggregation level because flexibility restraints could not be estimated for the disaggregated farm groups. Being able to maintain consistency may be a criterion for selecting the level of aggregation [51, p. 11].

Schaller and Dean also estimated the flexibility coefficients differently than previous studies, but stratified the acreage changes into two groups by direction as did Day. They fit the following equation separately to each data set to estimate the flexibility coefficients:

$$\frac{X_{i,t}}{\sum_{i=1, 2, \ldots n} X_{i,t}} = (1 + \beta_i) \frac{X_{i,t-1}}{\sum_{i=1, 2, \ldots n} X_{i,t-1}} + e_{i,t}; i=1, 2, \ldots n \quad (2.96)$$

Thus, individual crop acreages were converted into percentages of the total land base to account for year to year changes before the actual OLS regression equations were estimated.

The results of this study were both interesting and informative for any future recursive modeling analyses. First, the explanatory and predictive ability of the recursive programming model was less accurate than regression techniques, but a large part of the problem and "causes of predictive error for the RP model . . . traces to the interrelation of crop returns . . . that is restrained by reasonably wide bounds and a limited number of resources" [171, p. viii]. Nevertheless, in years when large structural changes occurred, the recursive model was as accurate as the regression equations for estimating crop acreages.

Second, the projection test demonstrated the recursive programming model
results appeared more stable than the regression results, that recursive programming results were as accurate as the regression estimates of two years ahead rather than one year and finally that the recursive programming acreage paths change directions more accurately than did the regression estimates.

Among the drawbacks of this analysis, as in Day's model, was that the study only examined one region, many acreages were small and finally, that the flexibility coefficient estimation, which is a major component of the accuracy of the recursive programming model were estimated with a very simple equation. Nevertheless, Dean and Schaller feel that the recursive programming has two major advantages over regression techniques for predicting changes in the aggregate production of major farm commodities.

"The major advantages of the recursive programming model over regression are as follows:

1. The RP solutions indicate why certain changes occur. This is because the model goes back to basic production relationships and the interplay of crop returns and restraints.

2. The RP model provides estimates of any crop defined as an activity regardless of whether the crop is controlled or operates in a free market. Regression results, based on a continuation of previous conditions, have limited use except for estimating production of uncontrolled crops [171, p. viii].

Finally, and more importantly, Dean and Schaller suggest that,

"This study analyzes only one region. A more advanced use of the RP approach would include a set of regional models in an 'interregional system.' Their solutions would be summed and superimposed on aggregate (national) product demand functions to estimate market prices for the next year [171, p. viii]."
A few years later, Schaller teamed up with Sharples to build a 90
homogeneous region, recursive programming model of the U.S. to study
alternative price support policies [178]. Only an overall land re­
straint and flexibility restraints were included in each producing
area. Their results were mixed and their research support group was
eventually disbanded. Some crop acreages were predicted accurately
and other crop acreages very inaccurately. A variety of methods were
employed to estimate flexibility coefficients, because none was suit­
able for all crops in all the regions.

Thus, a major critical issue in the use of programming models for
accurate estimation of production activities lies in the estimation of
flexibility coefficients or restraints and the accurate specification
of other resource constraints such as machinery, fertilizer, types of
land and labor availability [131]. The general flexibility coefficients
estimated when land is the only resource restriction carry a heavy
responsibility. They must accurately but implicitly estimate the
effect and interaction of the following variables, typically used
as decision criteria by farmers.

1. The adaptability of his soil to a given crop.
   (Thus, farmers tend to think of "corn" or "bean"
   land.)
2. His ability to grow a certain type of crop. (A
   farmer tends to grow a crop he has had good luck
   with in the past. This is, in part, a quest for
   income security.)
3. The type of specialized equipment available to him.
4. The amount of operating capital available.
5. Expected occurrence of disease, weeds, and insects.
6. Expected prices after harvest time.
7. Type of storage available.
8. Necessity to meet fixed annual payments.
9. Planned livestock program.
10. Ability to withstand possible losses [44, p. 125-126].

Doll also wondered, in his discussion of recursive programming as an analytical supply response technique,

... if the coefficients can adequately estimate the effects of the many forces affecting supply. Upon reflection, however, a coefficient reflecting an aggregate rate of adjustment appears to have considerable utility. Obviously, we can never hope to quantify all the forces which influence production decisions on individual farms. It is not clear that such quantification, even if possible, would supply the answers sought. On the aggregate level, we do not need detailed knowledge of the supply response of all farms in the region. Because of interactions within the groups of farmers and the effects of aggregate supply and demand... the flexibility coefficients, representing an overall response for a region, could reflect effects of forces not apparent at the farm level. It would also be useful to know the stability of the coefficients with respect to both time and technology. ... thus, we should study the available techniques and data with a view towards estimating parameters which are meaningful in a dynamic setting and useful for prediction and policy decisions [44, p. 126].

The problem of estimating more accurate flexibility coefficients in a dynamic context was approached by Sahi and Craddock in terms of choosing a best method of estimating flexibility constraints from among several different alternatives [169]. They built a 28 region recursive programming mode of Canadian agriculture with six crops and summer-fallow to study land use behavior, and also to compare
performance of flexibility restraints estimated by three different procedures. They consisted of 1) taking the maximum of positive and negative proportionate changes from acreage data collected from 1953-67, and 2) using simple regression equations that Day [39] and Schaller and Dean [171] had earlier estimated.

\[
X_{i,t} = (1 + \bar{\beta}_i)X_{i,t-1}; \quad \frac{X_{i,t}}{X_{i,t-1}} = 1 + \bar{\beta}_i
\]

\[
X_{i,t} = (1 - \bar{\beta}_i)X_{i,t-1}; \quad \frac{X_{i,t}}{X_{i,t-1}} = 1 - \bar{\beta}_i
\]  

(2.97)

where

\[
X_{i,t} = \text{level of the ith activity to be determined in t year;}
\]

\[
X_{i,t-1} = \text{level of the ith activity in t-1 year;}
\]

\[
\bar{\beta}_i, \underline{\beta}_i = \text{maximum and minimum allowable proportionate increase and decrease respectively in the ith crop activity from t-1 to t year, e.g., the upper and lower flexibility coefficient.}
\]

\[
i = 1, \ldots, 7
\]

3) using a more complex equation involving both economic and noneconomic variables in addition to lagged crop acreage, thereby placing the flexibility coefficient in a dynamic setting.

"The second hypothesis is that the flexibility coefficient for acreage of a crop varies from year to year depending upon the expected levels of several exogenous variables. For example, the coefficient for a crop might depend upon the farmers' expected prices, inventories, and exports for the crop in question and its major competitor. Preceding year acreage and technological and
weather conditions (e.g., precipitation) could be considered as other relevant explanatory variables. The relationship can be expressed as follows:

\[ \beta_{i,t} = f(X_{i,t-1}, P_{it}, P_{jt}, S_{it}, S_{jt}, E_{it}, E_{jt}, M_t, T_t) \]  

where

\( t \) = year or period,
\( i \) = crop in question,
\( j \) = main competitive crop,
\( X_{it-1} \) = acreage of the ith crop in t-1 year,
\( P_{it} \) and \( P_{jt} \) = expected prices of the ith and jth crops, respectively, in t year,
\( S_{it} \) and \( S_{jt} \) = expected inventories for the ith and jth crops, respectively, in t year,
\( M_t \) = springtime moisture conditions,
\( T_t \) = time trend variable to account for technological change,
\( \beta'_{i,t} = (1 + \beta_{i,t})' \) [169, p. 346-347].

Sahi and Craddock, by suggesting the third method outlined above, were hypothesizing that the estimated flexibility coefficients should be more responsive to both economic conditions and the previous production level than previous estimation procedures had indicated. In so doing, they were attempting to correct the two major limitations of coefficient estimation procedures in earlier studies. These two limitations were essentially the same criticisms leveled at the Nerlove coefficient of adjustment.
... first, they are based on an unreasonable assumption that the maximum proportion by which farmers would like to increase (or decrease) the level of an enterprise is the same in all years regardless of the level of that enterprise in the preceding year. In actual practice, producers probably vary their production patterns at different rates in different years ... Since the coefficients do not vary from year to year in response to changes in economic and noneconomic conditions, they inadequately explain dynamic production response. In reality, the maximum rates by which farmers change production patterns from one year to the next vary, even though rates are based on factors such as personal preferences, risk, and uncertainty [169, p. 345].

In the above analytical framework, flexibility coefficients are estimated every period with a good deal more information than had been previously specified. Additionally, the equation used to estimate the flexibility coefficient becomes nonlinear for the lagged production level variable. The nonlinearity reflects the hypothesis that acreages do not change at a constant percentage rate as acreages increase or decrease because of the specialization risk and resource restrictions. The flexibility coefficients can now be estimated with a multiple regression equation where the expected levels of economic variables can be taken as the preceding period's values, and the noneconomic variables are specified exogenously. Now, by substituting equation (2.98) in its explicit linear form into the general equation system (2.97), the following multiple regression equation can be obtained:

\[ y_{it} = \alpha_0 + \beta_1 x_{it-1} + \epsilon_{it} \]

\[ y_{it-1} = \alpha_0 + \beta_1 x_{it} + \epsilon_{it-1} \]

Inclusion of \( x_{it-1} \) on both sides of the equation clearly violates the assumption for least-square estimators that disturbance term and explanatory variables should be independent. Under this situation least-
\[
\frac{X_{i,t}}{X_{i,t-1}} = a_{0,i} + a_{1,i}X_{i,t-1} + a_{2,i}P_{i,t-1} + a_{3,i}P_{j,t-1} + a_{4,i}S_{i,t-1} + a_{5,i}S_{j,t-1} + a_{6,i}E_{i,t-1} + a_{7,i}E_{j,t-1} + a_{8,i}M_{t} + a_{9,i}T_{1} + e_{i,t} \tag{2.99}
\]

By using the above equation model and estimating parameters from historical time series data year to year variations in upper and lower flexibility coefficients may be easily calculated. But because historical data is used, the flexibility coefficient equation may not either reflect changes in structural conditions of production or be able to incorporate the effects of different national or regional agricultural policies. By utilizing a multiple regression procedure for coefficient estimation the flexibility bounding structures now include both the advantages and problems of multiple regression techniques discussed earlier.

Sahi and Craddock's findings were very impressive in demonstrating that their multiple regression coefficient estimation approach was far more accurate for predicting crop acreages than the two alternative methods used previously. The relative accuracy of the three alternative models was judged on the basis of correctly estimating the square estimators are biased [113, p. 300-302].

However, other problems could arise. For example, by multiplying \(X_{i,t-1}\) to both sides of equation (2.99) we will eliminate the variable from the left side of the equation, but a very serious case of multicollinearity results. The second limitation of this formulation is that the estimates of flexibility coefficients cannot be obtained directly; rather some further calculations are necessary. For computational simplicity, therefore, equation (2.99) was used [169, p. 347].
direction of change in crop acreage (turning points), Theil's U inequality coefficient and the weighted average of absolute percent deviations between actual and estimated acreages from 1958 to 1967 and finally by predicting 1968 and 1969 crop acreages. The third approach of estimating flexibility coefficients using the levels of economic and noneconomic variables was for more accurate estimating crop land use and turning points. Additionally, the third method of flexibility coefficient estimation had a Theil inequality coefficient of .019 and a weighted average of absolute deviations was 3.76 percent for crop acreages, far lower than the two alternative approaches. Thus, it seems clear from Sahi and Craddock's research that recursive programming models or for this research project, a simulation-programming model, should use a multiple regression modeling approach when estimating efficient and accurate flexibility coefficients for use in predicting agricultural crop activities' responses.

Recursive programming has many obvious advantages for aggregate production response studies either at the regional or national level. First, it is a very flexible approach for production research studies because of its broad programming structure. Any production structure included within a linear programming model can also be included within a recursive programming format. Second, like linear programming, recursive programming models are designed to explicitly demonstrated production activities' interrelationships and competition for resources at the micro level. Thus, production theory and the economic processes of
the farm are linked together. Finally, the addition of flexibility restraint parameters adds real world and dynamic properties to an otherwise static model. Flexibility coefficients and restraints reflect the upper and lower real world allowable changes in crop acreages or other activities from year to year. In the general case, these restraints reflect risk and uncertainty about weather, prices, yields, and also institutional and behavioral constraints on the production process. In essence, the flexibility restraint mechanism is designed to restrict the normative linear programming solution to a real world solution. The flexibility restraints also permit the process of economic activity selection and competition to be studies over a number of periods from a positive rather than normative point of view. Thus a more realistic, poly period aggregative production response function of the firm can be generated under a variety of conditions that is based on the optimization process and other production decision criteria.

Recursive programming models also contain certain disadvantages when utilized as a supply response estimation technique. Many of these disadvantages have already been discussed in the previous sections pertaining to interregional and farm programming models. But recursive programming models are difficult to work with for three additional reasons. First, the recursive programming model chooses crops on the basis of not only costs as do linear programming transportation models, but by net relative returns. Therefore, the specification of the objective function must be calculated more precisely than in the minimizing
cost linear programming transportation models. In recursive programming models, expected prices, yields, and relative costs are critical for an accurate solution. Thus, far many more variables can upset the solution in this yearly, polyperiod model than in long run linear programming transportation models. Second, misspecification of the flexibility coefficients may have an additive effect in relation to the net return part of the model. If the restraints are estimated too high or too low, then period to period activity level changes will be overestimated or underestimated respectively. If the net return function is inaccurate, then the misspecification of the flexibility restraints may accentuate the predictive supply response error of the model. It therefore becomes highly critical for the researcher to estimate the flexibility restraints accurately, even though in the real world it may be impossible to do so because of changes in technological, cultural, economic and noneconomic conditions effecting production response behavior by farmers. Finally, recursive programming is a very cumbersome and time consuming empirical response methodology because it is only a two period model. A new model must be developed for every period a predictive solution is made. To study production response behavior over an extended period of time with recursive programming techniques entails building a sequence of two period models, with each model relevant for only a one year response projection. Thus, the recursive programming modeling format is incapable of cycling in the same sense as simulation models, but is capable of estimating supply
behavior recursively in two period sequences.

Summary of Supply Response Methodologies and Recursive Interactive Programming

The micro and macro, static and intertemporal approaches for estimating the supply response of agricultural products are all derived, to a varying degree, from the economic theory of the firm and its production function. Many of the more popular and presently available methods for empirically calculating production response have been briefly discussed in this section with regard to both their particular advantages and disadvantages. Because each supply response technique is limited by its own methodological framework, each technique can only make a valid study of certain economic questions and is unable to answer or raise other relevant and important economic questions. More specifically, each of these techniques differs in its capacity to explicitly model and analyze agricultural production behavior because of its relative ability to incorporate the following problems within its methodological framework: specification of the underlying technical structure of production, competition for input use by different economic activities, input use and availability restrictions, technological and structural changes, market behavior uncertainty, the dynamic properties of economic systems, and other behavioral and institutional properties of the production system.

Ideally, the applied research economist would prefer to have a conveniently available supply and production response technique and meth-
ological framework that would be designed to explain and account for all of the above economic problems and associated questions. Realistically, a modeling technique that enabled the researcher to combine more of the advantages of each of the previously discussed supply methodologies with fewer of each of their disadvantages should be of great benefit for two reasons. First, many more quantitative answers would be available from the one modeling technique for policy and planning purposes. It is for these purposes that Recursive Interactive Programming, e.g., the recursive interfacing of a multifunction simulation modeling sector and a recursive linear programming modeling production sector, is suggested as an alternative technique and methodology for estimating agricultural production response and behavior.
CHAPTER III. MODEL DEVELOPMENT, DATA AVAILABILITY 
AND STATISTICAL PROCEDURES

The explanation and construction of an analytical, methodological framework for a recursive interactive programming model is developed within this chapter. This chapter is partitioned into seven sections. Many of the theoretical modeling complementaries occurring when a multifunction national simulation model is recursively interfaced with a national recursive programming model to estimate aggregative agricultural supply response and production behavior, are discussed in the first section. Different methods for interfacing or linking a programming model with a simulation model are described in the second section. The particular method chosen for this particular study will also be presented in the second section. A brief description of the four sectors within the RIP model, the respective sector interactions, and the interperiod cycling procedures developed for this model are contained in the third section. The recursive programming sector is more fully described in the fourth section. An explanation and description of the summary, simulation and revise sectors follow in the fifth, sixth, and seventh sections of this chapter. Finally, all table references preceded by an alphabetic character referred to in this chapter can be found in the appropriate appendix.
A General Overview of the Recursive Interactive Programming Model

An overview of a national recursive interactive programming model is presented in this section. Recursive interactive programming could be considered as a new analytical framework for the investigation of production behavior by economic systems. Although many of the ideas and much of the economic logic have been proposed earlier by Day in his discussion of interregional recursive programming models and dynamic coupling [36], and a year later by Spiegelman, Baum, and Talbert in their regional dynamic programming model [182], this particular type of modeling technique has only existed in theoretical schematics [36, p. 447; 182, p. 5]. The principal objectives of this section are to illustrate the modeling complementaries that evolve when a national multifunction simulation model is interfaced with a national recursive linear programming model to construct an RIP model. These modeling complementaries or strengths can provide the researcher an opportunity to develop many additional insights into the dynamic supply response behavior of producers, and the relationship of production behavior to market information and other economic factors.

The basic premises underlying the development of an RIP modeling structure are that a simulation model offers modeling and economic strengths where a recursive linear programming model has weaknesses and that a recursive linear programming model presents economic modeling advantages where a simulation model has disadvantages. The strengths and weaknesses, advantages and disadvantages of both response method-
ologies have been discussed separately in the previous chapter, but were not juxtaposed. For the moment, the problem of how to interface the two different models is left for the next section in this chapter. But by assuming a priori that the two models can be interfaced, the economic and aggregative model-strengthening characteristics occurring when each methodological technique is able to make use of the other to generate production, market and other intertemporally changing information can be detailed through a comparison of analytical frameworks. The beneficial system modeling characteristics occurring when the simulation and linear programming models are interfaced form the basis for the creation of the recursive interactive programming model.

First, recursive programming models, as well as all mathematical programming models, are able to explicitly incorporate the technical structure of production for the derivation of the aggregative supply function. This feature provides the programming model with several large production information advantages relative to simulation models.

In simulation models regression analysis of time or cross-sectional data series estimates an aggregate supply response for a single product. This response equation may be calculated either at a national or large regional level of aggregation by assuming that the resulting aggregation bias is negligible. Although the equation may be estimated with a high degree of accuracy, the underlying technical structure of production must be implicitly referenced. Some of the assumptions that must be made when using this technique are that outputs do not use
and compete for the same inputs that multicollinearity does not occur among exogenous explanatory variables and that an adequate number of observations exists to calculate variable coefficients reliably [168, p. 46-47]. In essence, the regression and simulation approach implicitly assumes that agricultural production occurs only on single product farms, rather than the more realistic multiproduct farms. Meanwhile, the methodological framework in programming models can easily and explicitly represent the multiproduct farm firm. However, because the technical structure of production is explicit, the influences of input availability, input use restrictions, competition among activities for available inputs, the optimization and decision process and behavioral or institutional restrictions on production behavior can be explained in detail. The number of production activities, inputs or resources used, and other restraints are limited only by data availability, computer capacity and the time and research funds available.

While the analytical framework of the simulation model production sectors does not contain the methodological framework necessary to estimate and produce the above information, the simulation model can provide important input information for the programming model. Distributed lag equations can be developed incorporating economic and non-economic variables to calculate changes in the availability of many "fixed" or variable inputs or resources used in the production process within a particular time period for a programming model. Since in recursive and static programming models, resource or input availability
is exogenously determined it would not be illogical for this endogenous simulation model information to be efficiently utilized by the programming model.

In brief summary then, a recursive programming model is able to generate a great deal of detailed production information at a micro level which the simulation model can only generate implicitly at a macro level. But the simulation model can estimate changes in intertemporal input availability endogenously which must be provided exogenously for the recursive programming model. Thus, the two models complement each other in the information provided by each technique with regard to the process and behavior of supply response by producers. If the simulation model could use the detailed production information captured in the recursive programming model, a much clearer picture of the intertemporal micro-macro supply response in agriculture would result.

Second, the explicit formulation of the production structure in the recursive programming model carries an additional advantage into the related areas of structural and technological change. Many times it is quite important to gauge the intertemporal effect of these changes on production response for policy and planning purposes. Structural changes resulting from government programs or other exogenous phenomena can be easily included into programming models by exogenously modifying the objective function or the resource availability vector. Incorporating these structural changes into regression equation simulation models with fixed coefficient parameters and explanatory variables is extremely
difficult because these equations are estimated from historical data. Therefore, if the nature of government programs or the economic environment surrounding agriculture changes, the equations may no longer be a valid representation of actual agricultural response behavior. Thus, regression models are methodologically unable to incorporate these changes into their calculated response behavior, while programming models are far better able to solve this problem. Technological change and investment behavior also pose the same problems for econometric models as do structural changes, but to a far lesser degree than for programming models. In programming models, the input-output or matrix coefficients can be easily altered to reflect technological change. But these altered coefficients must be estimated exogenously with other statistical methods. Usually, simulation models or regression equations are used for the coefficient calculation because technological change occurs intertemporally, and these models can reflect, even if imperfectly, a dynamic response mechanism with distributed lag models or a simple time trend [141]. Typically, linear and quadratic programming models are often inappropriate for studying investment behavior and technological change because they are one period or timeless models. But, dynamic and recursive programming models are intertemporal techniques allowing a more accurate methodological examination of these phenomena because the investment process and resulting technological changes can be explicitly incorporated through capacity constraint formulations. A sector of a simulation model could easily estimate these capacity
constraints with flexibility coefficient equations calculated from historical data [36, 39], as well as re-estimating and reformulating the input-output matrix based on past economic behavior and expected economic conditions. Therefore, it is suggested that simulation and recursive programming models are complementary techniques when studying the intertemporal phenomena of investment and technological change.

Third, the market sector modeling formulation in national inter-regional programming models has been criticized as being far too simplistic to represent the real world [36], while the degree of market complexity in national simulation models is typically limited only by the time and expertise of the investigator. In interregional linear programming models that minimize production costs, the market sector is typically composed of a set of exogenously determined fixed "equilibrium" demands which in effect determine production supplies. Unless inventories and exports are also specified as exogenous demands, production will not be large enough to meet these needs. Inventories are especially difficult to cope with because in reality inventories are a resulting product of current period demand and supply market interactions, rather than being considered as market determining variables. The quadratic programming model relaxes this assumption by allowing supplies and demands to adjust to a long run equilibrium through the use of simple linear one variable price equations. Although the quadratic objective function can be suggested as a less naive representation of market sector behavior, this formulation is still far from containing
real world market complexities. Additionally, the regional or national demands must still be specified as greater or equal to some exogenously determined level. Thus, in the short run, inventories must be specified exogenously or be represented within the linear price "as a function of quantity" equation. Historically, profit maximizing recursive programming models have been constructed as short-run models using a period to period analytical framework. These models have been specified without a market sector or a set of minimum fixed output demands. This is a result of the modeling format which uses an exogenously determined, linear objective function maximizing net return subject only to input and activity flexibility constraints. Implicit in this formulation is the cobweb production theory hypothesis where a market "disequilibrium" equilibrium occurs from period to period. Thus, the market sector that determines prices, inventories, and demands is exogenous to the model, but must be used in conjunction with the recursive programming technique to calculate the expected objective function and the activity flexibility constraint [168]. The need for this market sector by the recursive programming technique can be satisfied by a simulation model. The simulation modeling framework is extremely conducive to representing very complicated market sectors with large numbers of market variables [156, 157, 160]. The simulation market information generated within the simulation model to be used for calculating the objective function, activity input use and output coefficients, or flexibility restraints in the recursive programming model. In this situation, the information
flow is from the simulation model to the recursive programming model and is being used to build the programming models decision criteria and adjustment mechanisms.

Fourth, the programming models are interregional competition models, and by definition are able to detail the spatial locus of production and transformations in this locus resulting from competitive market situations and relative regional efficiencies in production. Usually, each region is considered as a homogeneous production unit, i.e., a farm, covering a substantial geographic area. Relevant livestock, crop and transportation activities, and specific input constraints are defined for each particular region. Thus the detailed structure of production advantage of programming models, mentioned earlier, is available for many different regions. This information can be crucial for quantitatively estimating the extremely important national policy impacts on regional and local agricultural production behavior and resulting welfare effects. The reverse is also true. Changes in local and regional production behavior in response to a wide variety of economic stimuli can also have large effects on the formulation of national policy and planning decisions.

In the historical formulation of recursive programming models, interregional competition among regions for market share does not occur because regional and national demands are not specified in the analytical framework. In this respect, this particular methodology does not reflect changes in the spatial locus of activities resulting
from relative production and cost efficiencies and specific geographic commodity and livestock demands. Rather, it is implicitly assumed that producers do not especially care where their output is transported and consumed as long as they are maximizing their own welfare by maximizing farm income. Thus, recursive programming tends to ignore the long run, normative, and efficiency production behavior problems and questions typically posed in linear and quadratic models. Rather, this technique instead focuses on short run, positive supply response behavior based on net relative returns within a region. A set of regional or national demands and relevant transportation sector could be added to the recursive programming model, but these current year demands would have to be calculated a priori to current year production and prices. Therefore, these models reflect interregional market competition and production efficiencies only as the objective function and technical matrix are modified to simulate these economic phenomena. Nevertheless, these models can be quite capable of generating the detailed regional and local supply response behavior often needed for national policy and planning analysis discussions because production information is derived from very disaggregated supply data, and production activity levels change from period to period based on relative net returns, input availability, and flexibility restraints.

On the other hand, simulation models estimate production behavior of large aggregated areas very accurately as long as neither the structure or economic conditions of production and production re-
response behavior remain relatively consistent with historical situations. But these aggregate supply responses cannot usually be broken out into disaggregated subregional supply responses unless an exogenous weighting format based on historical production patterns is used. Therefore, the use of the weighting format, in a simulation model, to allocate large regional or national production into various subareas faces many of the same methodological problems contained in input-output models discussed in the previous chapter. Since, in reality, the spatial locus of production activities changes from period to period, these weights also change and thus may be "relatively valid" for only a short length of time. Therefore, subregional allocations using historical weights could pose a serious problem when a large region or national simulation model is utilized to generate detailed geographic impacts and effects of national policies or other phenomena, for implicitly all regions must be assumed to be affected equally. Also the effect of any hypothesized or actual changes in subregional or local production behavior is subsumed within the aggregate regression equations. They, therefore, cannot demonstrate any statistical effect on aggregate behavior.

In summary, simulation modeling loses the micro to macro and macro to micro regional effects of changes in production and market demand behavior that interregional programming models are able to show easily. In this respect, the interregional programming model format could greatly assist the simulation model by providing more accurate information about
the disaggregated production response over time as a result of various government programs or other economic stimuli occurring at an aggregate or local level.

Finally, interregional programming models are "static" models. By static, it is meant that these are single time period models. In one sense, they might be considered as two time period models, an initial period and the final optimal period. Linear and quadratic programming models are therefore commonly utilized for long run projections to answer policy and planning questions concerning agricultural capacity and the "normative" efficiency of the locus of production activities under different economic conditions. Recursive regional programming models are formulated differently with "positive" flexibility restraints so that they may be used as a period to period, or short run model. Since the flexibility restraints are calculated from the previous period's solution, a more positive or real world supply function can be estimated. Nevertheless, each of these models is capable of only a one period solution before another modeling problem is generated for a following time period. None of these models has the capacity of generating a new model modeling problem for a following period endogenously or cycling recursively. For this reason, interregional competition models are of limited value when questions are asked concerning the dynamic behavior of the agricultural sector over a sequence of time periods.

Simulation models are dynamic or intertemporal analytical techniques. Consequently they are capable of cycling recursively and esti-
mating intertemporal agricultural behavior from period to period. The length of the sequence of time periods chosen depends both on the nature of the particular economic problem studied and the confidence of the economist in the cumulative predictive accuracy of his model. The strength of this methodological technique lies in its ability to generate and then solve a time related sequence of production and market behavior decisions endogenously. Thus, simulation modeling techniques possess the dynamic ability and faculty that restricts the use of static interregional programming models studying intertemporal economic phenomena. It would seem reasonable then that if a simulation model could generate the interregional programming model problem from period to period as a result of its own dynamic characteristics, the usefulness of these programming models could be extended to study a far wider set of economic problems.

In summary, the recursive interactive programming model is designed to make use of the complementary advantages of both the recursive linear programming and simulation techniques. First, the recursive programming sector within the RIP model can explicitly detail the technical production characteristics of the agricultural sector which the simulation sector can only estimate implicitly. Consequently, information about competition between crops for limited inputs, input use restrictions, the optimization and choice process, and other technical and behavioral constraints can be generated very easily. Second, because the technical structure of production is explicitly detailed, the effects of techno-
logical and structural changes can be incorporated into the quantitative methodology with little difficulty. Additionally, the simulation sector can be used to estimate the changes in input-output coefficients, resource availability, and activity flexibility restraints due to technological change or even define new production activities if certain sets of economic conditions occur. Third, the aggregate production sector in the simulation model can be disaggregated into much smaller regions by the interregional programming sector to detail the intertemporal spatial locus of agricultural activities. Fourth, the simulation sector can provide the recursive programming sector with a sophisticated market sector in which supplies are endogenously determined prior to the marketing period. As a result, prices, inventories, and demands are all endogenously determined in the RIP model rather than having to have been given exogenously. This market information can then be used by the simulation sector to estimate the objective function and other relevant programming problem data needed for a subsequent solution period. Fifth, the simulation sector can transfer its dynamic characteristics to the static programming sector by sequentially regenerating the recursive interregional programming problem to be solved from period to period. Thus, the recursive interactive programming model is able to provide more detailed, intertemporal information and the agricultural industry is more completely modeled or represented than either an interregional programming or simulation model can furnish. Finally, the advantageous characteristics of both models
are more fully utilized to study the impacts and effects of policy and planning decisions and the testing of dynamic economic hypotheses can be more fully considered.

Approaches for Interfacing the Simulation Sector With the Recursive Programming Sector

Three approaches have been suggested to solve the problem of interfacing between the simulation sector and the programming sector. Since very few attempts at interfacing have been attempted, little information in this area has been generated. Nevertheless, the first two approaches to interfacing discussed were not selected because of conceptual problems in trying to solve data generation conflicts. These conflicts revolve principally around the two different acreage and production projections by the two sectors of the complete model, the simulation sector projection, and the linear programming projection, because the two sectors remain essentially separate models.

1) The first approach was to feed the food and fiber demands generated by a simulation model into a linear programming model. The linear programming model would then be solved for the most efficient regional acreage distribution under cost minimization (see Figure 3.1). This approach is best for point-in-time estimates, say for every five or ten years. Additionally, equilibrium prices are then generated by the least-cost optimization solution, rather than as prices generated in the simulation model. Also, production information cannot be generated by the simulation model since two different acreage and production
Figure 3.1. Intra-year Demand Interfacing Between the Simulation Model and the Linear Interregional Programming Model.
predictions would then occur for each year. This would result in a set of programming model equilibrium (under efficiency) and simulation model disequilibrium equilibrium prices, respectively.

A variation of this model would have the crop production estimates from the simulation model being used in the programming model to derive national and regional acreage predictions with an objective function of minimizing cost. Again, a consistency problem occurs since the programming and simulation models then are predicting two different acreages for each crop.

Second, the information flow is one way, from the simulation model to the programming model. The programming model does not affect the simulation model's dynamic behavior. In this sense it would be in very small part a dynamic model, complete within interactions.

2) The second approach to interfacing is to use the acreage predictions from the simulation model in the interregional programming model. This model would then be solved under cost minimization for the most efficient allocation of regional acreages. But the interregional programming model also would predict production, as would the simulation model (see Figure 3.2). Therefore, this model would have the problem of estimating two different crop production estimates from a given predicted acreage. Secondly, the programming model does not affect the behavior of the simulation model, unless the programming model's predicted crop production is used in the simulation model instead of using the simulation model's predicted production. This
Figure 3.2. Intra-year Acreage Interfacing Between the Simulation Model and the Linear Interregional Programming Model
second objection, as with the first approach discussed, is that the
information flow is still one way, from the simulation model to the
programming model. Therefore, the second approach still does not
force the two models to completely interact. Nevertheless, this
"hybrid" model could be used on a yearly basis as well as for every
five or ten years if the programming model's national crop acreage
levels were set equal to the simulation predictions.

3) The third approach is the methodological approach used in this
study to interface the simulation model with a recursive, interregional
linear programming model and build a recursive interactive programming
model (see Figure 3.3). This approach would use acreage and production
predictions from a national regionalized, profit maximizing linear
programming model in the simulation model. A lagged price vector for
commodities from the market section of the simulation sector would be
used to estimate the expected net returns by crop for each production
area. The recursive programming model's flexibility restraints and ma-
trix would also be estimated by the simulation mode. The crop acre-
age predictions would then be used by the simulation model to estimate
resource use. The recursive programming model's crop production predic-
tions would be used in the simulation market submodel to calculate vari-
ous market variables. Livestock production and grain demands would con-
tinue to be estimated by the simulation model. But neither acreages nor
production of crops is estimated by the simulation model. Thus, the
Figure 3.3. Intra-year Production and Acreage Interfacing Between the Simulation Model and Recursive Interregional Programming Model
problem becomes that of building a national, regionalized recursive pro­
gramming model of U.S. agriculture that will accurately predict crop
acreages and production. On the basis of previous research, the best
approach toward building an accurate, flexible recursive linear pro­
gramming model is to use Sahi and Craddock's approach for estimating
flexibility constraints [169].

This third interfacing approach would eliminate the problem of
consistency in the two previous approaches. Instead of two crop acreages
or production estimates, only one estimate or prediction is made. Second,
the one-way information flow problem, either from the simulation model
to the programming model, or vice versa is neatly removed. With this
approach, price information and other variables used to estimate the
flexibility coefficients and restraints, the objective function and
input-output coefficients in the matrix are generated by the simulation
sector. Meanwhile, the recursive programming model generates crop
acreage and production estimates that are used in turn to calculate
input demands, prices, inventories, income and other important variables.
The simulation model then can recursively rebuild the recursive pro­
gramming problem to be solved in the following period. Consequently,
the behavior of the programming model affects the information pro­
duced in the simulation model, and the information generated by the
simulation model affects the solution of the recursive programming
model in a dynamic process. Thus, this third method for interfacing
the two different models could be used in a yearly recursive,
dynamic analysis of the agricultural sector because the recursive programming and simulation model are interfaced both conceptually and methodologically.

The Specification of the Recursive Interactive Programming Model

Sector Interactions and Interperiod Cycling Technique

A recursive interactive programming model has four basic components: the simulation sector, the interfacing linkage providing the programming model's production and acreage solution for the simulation sector, the recursive programming sector, and the interfacing linkage revising the programming sector with data calculated by the simulation sector. The cycling interaction of these four components of the RIP model will be briefly described in this chapter section. The recursive programming sector, the programming to simulation sector linkage, the simulation sector, and the simulation to programming sector linkage will then be more fully described and explained respectively in following sections in this chapter.

The cycling procedure for moving from one sector of the RIP model is presented schematically in Figure 3.4. Starting at the top of the diagram, the recursive interregional programming sector is solved for the optimal acreages of various crops in each producing area in year t using the simplex procedure [183], given expected net returns flexibility restraints and resource constraints by crop in each producing area. Production statistics are determined simultaneously with solution crop acreages. The programming solution con-
Figure 3.4. Diagram of Sector Interaction in the Recursive Programming Model
taining crop acreage and production statistics must be reorganized into an information format that can be used by the simulation sector. This problem is handled by the sector linking the programming sector to the simulation sector, the SUMMARY sector. The SUMMARY sector is utilized to rearrange and sum the individual solution data of the recursive programming sector into production and acreage summary statistics for use by the simulation sector in year t. This information is then used by the simulation sector to determine the levels of other pre-input, input and market variables. The fourth sector interfaces or links the simulation sector with the recursive programming sector. This linkage is referred to as the REVISE sector because information and data generated by the simulation sector is used by the REVISE sector, in addition to other data for redefining the programming problem to be solved in year t + 1. This programming sector's solution in year t + 1 is then sent to the SUMMARY sector. The SUMMARY sector then prepares this data for the simulation sector in year t + 1, and the information generated by the simulation sector is used in turn by the REVISE sector to rewrite the recursive programming problem for year t + 2. Thus, the four sectors in the recursive interactive programming model are linked recursively within each year or period and the RIP model is capable of cycling from year to year or period to period.

The computer program constructed to cycle and control the inter-linking sectors in the RIP model utilized for the predictive run,
1974 to 1980, in this study is presented in Table A.6. This program is a variation on MPSX programs for multiple problems presented and described by Sposito [183, Appendix A]. In essence, each year is counted as a separate problem and the control program is "looped" or cycled for as many years as the experimenter wishes. The programming sector is solved first by the MPSX routine. The control program then places the data in a predetermined solution file or memory storage area. A library subroutine called KEN1 is then called by the control program. This library subroutine was written in Fortran programming language [119] and contains the SUMMARY, simulation and REVISE sector computer programs. Each of these sectors is called in turn and then the revisions or changes in the tth programming problem for the new programming problem to be solved in the following time period are then placed in a prearranged memory storage area. These revisions in the matrix input-output coefficients, objective function and activity flexibility constraints were used to change the recursive programming problem to be optimized in year t + 1 from year t. The production area land bases available in any particular year were exogenously determined prior to each multiperiod RIP model run, but could have been made endogenously determined variables. However, because of time constraints and the additional costs this particular modeling variation was not attempted. Finally, the recursive, cycling process described above was repeated for each additional year in the relevant analysis period.
Recursive Linear Interregional Programming Sector

The recursive linear interregional programming model in this sector is constructed from four basic components: the activities, the objective function, the input-output matrix and the resource and flexibility constraints. A recursive programming model is similar to a linear programming model except that activity flexibility restraints are specified from period to period to constrain the behavior of model activities to reflect actual real world changes in the levels of various production processes. Recursive programming has been generally explained in Chapter II and will not be discussed further in this chapter section. Rather, this section will first discuss the theoretical formulation and then describe the construction of the recursive interregional programming sector used in this recursive interactive programming model. Additional specific information relevant to this sector will also be discussed in the chapter section presenting the REVISE sector linking the simulation sector to the recursive programming sector.

There are four essential assumptions that were made when using the recursive programming sector as the production sector in the RIP model. First, it is assumed that production process decisions and adjustments are not made instantaneously to changing economic conditions. Rather, land use changes are distributed over time in response to uncertainty, fixed availability of some input factors and other behavioral and institutional reasons. Some producers may change production patterns
faster than other producers in the same production area, but the total response behavior of the area is assumed to be capable of statistical estimation [104]. Second, producers are assumed to try to maximize their expected short run net returns or profits on production activities even if prices and yields are uncertain. Additionally, although the goal of short run profit maximization may conflict with a multi-period profit maximization for various reasons, it is proposed that this objective is a relatively accurate representation of producer's ambitions. Third, the production pattern in any particular period is influenced by the previous period's production patterns and prices. In effect, farmers cannot accurately know a priori the realized production, prices and income from their decisions, economic decisions are based on historical information. This knowledge expectation assumption forms an integral part of the theoretical foundation upon which the cobweb model is built [62, 71, 208]. Fourth, it is assumed production decisions made in any particular area in a production period do not affect decisions made in any other production area in this study. Therefore, the various production regions supply responses are independent within a particular year. Although regional yearly acreage response can be examined separately in this study, only the national production response and land utilization will be presented. The programming sector can be easily revised for further specific inter-regional competition research but it is the primary purpose of this research effort to describe and demonstrate a recursive interactive
programming model and its methodology. Finally, although the inter-
regional production behavior is independent within the year, it is de-
pendent from year to year. This dependence is caused by the simultaneous
increases or decreases in regional production and its effects on market
variables in any particular period, which then recursively affect the
programming problem in following periods.

The recursive programming sector is constructed primarily from
national linear programming models of U.S. agriculture built by Wade
[207] and Colette [30] and which were based on an earlier, more
disaggregated, model presented by Nicol [145]. These two models are
far more complicated than the modeling sector presented here. It was
decided to simplify these models for computational ease, to conserve
research time, and generally to facilitate this research project and
its explanation. These models have been described in detail by Nicol
and Heady [146] and by Meister and Nicol [127]. The following sections
briefly summarize the recursive programming sector model and emphasize
some of its important features.

Regional delineation

The recursive programming model in this study has two types of
regions: production areas (PA) and market regions (MR). The pro-
ducing regions include the 99 aggregated subareas defined by the Water
Resource Council. Six of these aggregated subareas were further divided
to describe regions reflecting a more uniform climatic condition or
distinct agricultural areas. Therefore, one hundred five producing
areas have been defined as relatively homogeneous in resource avail-
ability, resource use, farm structure, technology, cropping patterns,
productivity and water supplies (see Figure 3.5). These producing
areas contain contiguous counties within both the aggregated subareas
and major river basins.

The western producing areas (PA 48-105) in Figure 3.5 reflect
the production areas where precipitation is a limiting factor. In these
producing areas, irrigation activities have been included to reflect
supplemental water application procedures needed for production. It
was assumed in this study that water supplies in each producing area
would not constrain crop activity selection or levels until after 1981.

Finally, subsets of contiguous producing area have been aggregated
into twenty-eight market regions (see Figure 3.6) each with a major
population center. The crop production output from each producing
area is summed into these market regions. Cotton production in each
year is summed at the national level. Additionally, fertilizer costs
are defined on a market region basis, rather than by producing areas.
Therefore, fertilizer costs for each PA within a MR are equal. Unlike
the linear interregional transportation models mentioned earlier from
which this model was built, commodity and livestock demands are not
present in this study. Therefore a national transportation network
is not included in this model and the model does not adjust production
patterns within each year in accord with regional comparative advan-
tages.
Figure 3.5. The 105 producing areas with irrigated lands in the West (producing areas 48-105)
Figure 3.6. The 28 market regions
Model activities

Only crop production, irrigation, and irrigated to dryland switching activities were included in the recursive programming sector. These activities were defined on a producing region basis.

Seven crops were selected for inclusion in the recursive programming sector. These crops are barley, corn for grain, cotton, oats, sorghum for grain, soybeans and wheat. Irrigated and nonirrigated production activities are defined where appropriate over the continental U.S. These crop activities defined in this model are essentially the major cash crops in U.S. agriculture. There are a total of 538 cropping activities over the 105 producing areas (Tables A.1 and A.2).

These 538 crop activities were selected from the cropping activities in the Wade [207] interregional linear programming model. Those activities with less than 2,500 acres harvested in a PA as counted in the 1969 Census of Agriculture [197] for the above seven crops were not included in the model. A few exceptions to this rule were made when it could be demonstrated that a crop activity was important in the PA even though the acreage was relatively small. If the harvested acreage was larger than 2,500 acres, but of very minor importance in the PA, the crop activity was not included. The final crop activity selection used in the programming model reflects over 99% of the harvested acreage of these crops in the 1969 Census of Agriculture [197].
Corn and sorghum silage, and legume and nonlegume hay activities are not included in the crop sector because livestock activities are not endogenously included in the programming sector. Several producing areas do not contain any of the above cropping activities at appreciable levels; PA2, PA3, PA4, PA5, PA6, PA85 and PA105.

In the fifty-seven western producing areas where irrigation occurs, water buying activities were included as were interregional water transfer activities. But because the costs of transferring an acre foot of water from one region to another were usually very small, and because water supplies were not assumed to be a limiting factor of production until after 1980, each of the PA water buying activities was left unbounded. Consequently, the interregional water transfer activities did not play a role in any active model run solutions. Also, in each of these producing areas, activities were also defined to endogenously reallocate irrigated land to dryland production activities.

**Objective function**

The linear objective function in the recursive programming sector maximizes the total expected net return or income from the cropping activities specified in the programming model. The goal is not to explicitly minimize costs of production, but to implicitly minimize production costs by maximizing expected profits. The derivation of expected prices, gross return and the variable cropping costs for each of the activities in the model will be discussed more fully in the
REVISE section of this chapter. The objective function is re-estimated in every year using price data from the simulation sector, crop yield estimates and changes in variable per acre costs. Water costs per acre foot were held fixed in 1972 dollars [127] in each producing area. Other per acre variable cost components were indexed into 1972 dollars each year using U.S. Department of Agriculture input and gross national product price index tables [198, 50]. Crop prices generated in the simulation sector were also similarly indexed into 1972 dollars. Thus, the objective function is always specified in 1972 real dollars independent of the actual year for which it was being maximized. Fertilizer and water costs were separated from other cost components as a result of the activity design structure of the model explained in previous sections. Finally, it was implicitly assumed that all production output would be valued at market or support prices and disposed of directly through feed, industrial, food, and export demands or indirectly with inventory accumulation.

The objective function for year $t$ can be expressed as

$$
\text{Maximize } Z_t = \sum_{i=1}^{104} \sum_{j=1}^{28} \sum_{k=1}^{104} (P_{i,j,t} V_{i,j,k,t} - C_{i,j,k,t} X_{i,j,k,t}) \\
- \sum_{m=1}^{8} N_{m,t}^P - \sum_{j=48}^{72} W_{i,t}^P
$$

where

$Z_t =$ total net expected revenue to be maximized in year $t$
\[ Y_{i,j,k,t} = \text{yield per acre of the } i\text{th crop in the } j\text{th producing area, on the } k\text{th land type in the } t\text{th year}; i=1, \ldots \text{number of crops in the PA on the land type; } j=1, \ldots 104 \text{ producing areas; } k=1, 2, \text{ irrigated or dryland; and } t = \text{year from 1969 to 1980} \]

\[ C_{i,j,k,t} = \text{expected variable costs of machinery, labor, miscellaneous and pesticides per acre in year } t \text{ in 1972 dollars based on the 1969 costs developed by Eyvindson [61] for the } i\text{th crop in the } j\text{th PA on the } k\text{th type land. Summerfallow costs are added for wheat and barley where appropriate [Table A.1 and Table A.2]} \]

\[ X_{i,j,k,t} = \text{solution acreage of the } i\text{th crop on the } j\text{th PA on the } k\text{th type land in the } t\text{th year} \]

\[ P_{i,j,t} = \text{expected price of the } i\text{th crop in the } j\text{th producing area in year } t \text{ in 1972 dollars: Dryland and irrigated crops are equally priced} \]

\[ N_{k,t} = \text{solution amount in pounds of nitrogen used as fertilizer by cropping activities in the } k\text{th market region in year } t; k=1, \ldots 28 \text{ [127]} \]

\[ NP_{k,t} = \text{expected price in year } t \text{ in 1972 dollars of a pound of nitrogen fertilizer in market region } k \text{ which is based on nitrogen fertilizer prices developed by Meister and Nicol for 1972 [127]} \]

\[ W_{i,t} = \text{solution amount of acre-feet of water used by irrigated crops in producing area } i \text{ in year } t \]
\[ WP_{i,t} = 1972 \text{ price per acre-foot of water in producing area } i \]

in year developed by Meister and Nicol [127]

**Input-output matrix**

The recursive programming model requires an input-output matrix to generate input or resource use and production information for each period or year in the analysis. In this study, the same matrix is not used for each year of the analysis. Intertemporal changes are made in the crop activity nitrogen use coefficients and the crop yields per acre in each producing area in every year. Thus, a distinct input-output matrix was calculated for the programming model for each time period.

Crop yields per acre by producing area were allowed to vary between years in the recursive programming model. Three different estimated crop yields were available for use. From 1969 to 1980, either a set of OLS trend yield equations by crop by state or a set of Spillman trend yield production function equations by crop by state could be used. Both of these sets of state trend yield equations were weighted into the producing areas using weights developed from the 1969 Census of Agriculture [197]. These state to PA(STPA) weights can be represented by the following equation using a slightly different notation than presented earlier in (3.1),

\[ W_{i,m,k} = \frac{A_{i,k,n,m}}{\sum_{n=1}^{A_{i,k,m}}} \]  

\[ i = 1, \ldots, 7 \]  

for the seven crops; barley, corn, cotton, oats, sorghum, soybeans and wheat.
where

\[ W_{i,m,k} \] is the weight for the \( i \)th crop in the \( m \)th part of the \( k \)th PA

\[ A_{i,k,n,m} \] is the harvested acreage of the \( i \)th crop in the \( j \)th county of the \( n \)th state included in the \( m \)th part of the \( k \)th PA

\[ A_{i,k,m} \] is the harvested acreage of the \( i \)th crop in the \( m \)th part of the \( k \)th PA.

These weights were multiplied by each of the state yield estimates in a particular year and summed over the \( m \) parts for each crop in each PA to give the PA yields. Thus this procedure transfers or allocates state data to a PA data basis. It is also realized that as state crop acreages change, these state to PA weights change also.

The third set of estimated crop yields were estimated from actual harvested acreage and production data from 1968 to 1973 [198, 201]. These actual average yields were also weighted into production areas using the census weights mentioned above. A more detailed discussion of the different yield coefficient estimations will be contained in the REVISE sector discussion section.
Nitrogen used as fertilizer is an endogenous variable in the programming model. The nitrogen input-output coefficient for each crop activity also fluctuated from year to year in the programming sector. The nitrogen use coefficient was calculated as an optimum application rate and was also estimated for use in each year as an independent variable in the Spillman trend yield response function mentioned above. Many other functional forms could have been utilized to estimate this lengthier description of nitrogen use coefficient calculation and its relationship to the yield response function will also be contained in the REVISE sector discussion.

The input-output coefficients in the matrix for acre-feet of water for each irrigated cropping activity in the fifty-seven western producing areas remain constant from year to year. These coefficients have been discussed and presented by Meister and Nicol [127].

Restraints

Three different types of restraints were developed for the recursive programming sector. The first set of restraints reflects land resources available for cropping activities. The second group of restraints are activity flexibility restraints because a recursive programming technique is used. The third type of restraints employed were absolute minimum and maximum crop activity acreage restraints.

The land base utilized in a particular year is the only physical resource constraint in this sector. Water was not considered to be a limited resource until after 1980. The land base was developed for each producing area, and was not further broken out by different land
classes. An average or homogeneous land class was assumed to exist in each producing area. Thus each crop activity defines an average or homogeneous yield or water use throughout the entire producing area.

The land bases utilized for particular years in the programming sector are listed in Table A.7. Each figure reflects the total PA dryland or irrigated acreage available in a particular year for cropping activities. The PA acreage restraints were derived from U.S. Department of Agriculture data series [198, 200, 201] and other published data [6, 26, 31, 107, 115, 139, 144, 148, 149, 181, 191, 213]. The calculation of the land bases used in this study proceeded in several analytical steps. The first step was to gather and estimate a complete data set of dryland and irrigated harvested, planted and diverted state crop acreages from 1968 to 1973. Data was collected for states in the continental United States where the crops in the model were grown. In many instances, separate irrigated and dryland harvested, planted or diverted crop acreage data were unavailable and only total acreages were available [Table A.3]. When this occurred, and where over 5,000 acres or at least 5 percent of the total harvested crop acreage was irrigated, the 1969 census data [197] was used to separate the total acreage statistics. The percent harvested and irrigated crop acreage of total harvested acreage in 1969 was multiplied by the total harvested and planted acreage in a particular year, 1968 to 1973, to obtain the

---

irrigated harvested and planted acreage for that year. The revised set of state crop acreages broken out by irrigated and dryland acreages for each year from 1958 to 1973 will be referred to as the STAC in the REVISE sector.

A procedure similar to one described above was used to also separate out irrigated crop production from dryland crop production when only total state production statistics were available in states where "substantial" irrigation cropping activities occur. The same criteria, 5,000 acres and at least 5 percent of the crop acreage, was arbitrarily chosen to define substantial activity levels. The ratio of irrigated to dryland yield in 1969 was used to separate the crop yields from 1968 to 1973. This set of irrigated and dryland production data by crop and by state will be referred to as the STYLD in the REVISE sector.

Finally, all the diverted acreage resulting from government programs during the period 1968 to 1973 was assumed to be nonirrigated land in this study because a method could not be devised to allocate this land between irrigated and dryland use. In any event, it is unlikely that irrigated land would be diverted because of its high opportunity cost for the production of other crops.

The second step was to calculate a set of diverted crop acreages that could have been harvested if government programs for the four feedgrains, wheat and cotton had not been in effect. First, the feedgrain diverted acreage was reallocated back to the individual crops over the six years depending on their share of total feed-
grain dryland acreage in each PA from 1968 to 1973 with the following equation.

\[ D_{i,j,t} = \left( \frac{A_{i,j,t}}{\sum_{i=1}^{4} A_{i,j,t}} \right) D_{j,t} \]  

\[ i = 1, \ldots, 4 \text{ feedgrains} \]
\[ j = 1, \ldots, 48 \text{ states} \]
\[ t = \text{year; 1968 to 1973} \]

where

\( D_{i,j,t} \) = diverted acreage allocated to the \( i \)th feedgrain, in the \( j \)th state in the \( t \)th year
\( A_{i,j,t} \) = harvested acreage of the \( i \)th feedgrain in the \( j \)th state in the \( t \)th year
\( D_{j,t} \) = total diverted feedgrain acreage in the \( j \)th state in the \( t \)th year

The diverted acreage that could have been assumed to have been harvested was then calculated for the four feedgrains, cotton and wheat. The diverted acreages calculated from (3.2), the cotton and wheat diverted acreages in each year were multiplied by the ratio of crop acreage harvested to crop acreage planted in the following mathematical relationship,

\[ DH_{i,j,t} = \left( \frac{A_{i,j,t}}{AP_{i,j,t}} \right) D_{i,j,t} \]  

where

\( DH_{i,j,t} \) = diverted, harvestable acreage for the \( i \)th crop
in the jth state in year t; i = 1, . . . , 6
crops, j = 1, . . . , 48 states; t = 1968, . . . , 1973

\[ AP_{i,j,t} = \text{planted acreage intended for harvest of the ith dryland crop in the jth state in year t.} \]
\[ A_{i,j,t} = \text{harvested dryland acreage of the ith crop in the jth state in year t} \]

The third step to develop the land bases was to allocate each of the state irrigated, dryland and diverted but harvestable crop acreages into the 538 activities. The state to PA weights developed earlier in (3.1) were used for this purpose. The resulting set of individual, yearly, crop activity acreage statistics that was harvested from 1968 to 1973 will be referred to as the actual harvested crop acreages (AHCA). The diverted harvestable set of crop activity acreages for this period will be referred to as the diverted harvested crop acreages (DHCA).

The final step of the procedure was to calculate the five PA land bases used in the programming sector from the AHCA and DHCA land bases. The PA base acreages were developed by first summing the AHCA into irrigated and nonirrigated land components for each PA for each of the six years. The DHCA were also summed into a separate set of PA acreage statistics.

The PA land base in effect from 1969 to 1972 was the same for all the historical evaluation runs. It was derived by taking the largest
of the PA acreages from 1969 to 1972 developed from the AHCA. This land base was designed to represent a restricted acreage base caused by the government acreage divertment programs during this time period. A separate yearly land base was estimated for each of these years based on actual harvested acreage data. However, their use in the programming sector caused difficulties when the recursive programming sector was solved. The difficulties resulted from the sometimes large PA acreage level variations from year to year in the smaller acreage PAs. When the acreage increased, the programming problem was solved without difficulty. But when the PA acreage declined, the problem often went infeasible because of the inflexibility of the activity flexibility restraints. Therefore the largest observed harvested PA acreage during this period rather than the average or yearly PA acreages was used. Similarly, the land base for 1973 was calculated by taking the largest PA acreage developed from the AHCA from 1968 to 1973. This procedure led to a somewhat larger land base in 1973 than from 1969 to 1972 and reflected the dismantling of the government acreage divertment programs.

The dryland PA base acreages utilized in the predictive model run from 1974 to 1980 were derived primarily by adding the PA harvestable diverted acreages to the actual PA harvested acreages. The harvested and diverted harvestable acreages were used for the land base estimation because the actual state harvested acreage data were not available from 1974 to 1976. Since agriculture was in a "free
market" situation without acreage divertments a larger land base was needed for the predictive period. Rather than multiply every 1973 PA acreage by a fixed percentage based on the change in total national harvested cropland for the crops in the model, the land base was tied to the divertment land base. After the new set of harvested plus diverted acreages in each PA had been calculated, the set of 1968 to 1970 PA acreages was chosen to develop the new land bases because of their internal consistency and also because the sum of the PA acreages were very close to the actual harvested cropland from 1974 to 1976 [50].

The three land bases were derived in the following manner. The 1974 PA land base was derived by adding the 1968 harvested PA crop acreage to the 1968 diverted land estimated above. The 1975 to 1976 PA land base was calculated by adding the 1969 harvested PA crop acreage to the 1969 diverted crop acreages. The 1977 to 1980 PA land base was derived by summing the 1970 harvested and diverted crop acreages also estimated above. In each of these nonirrigated land bases, some PA acreage figures were modified for statistical consistency. If the 1975-76 base PA acreage was greater than either the 1974 or 1977 to 1980 base acreage, an average of these latter two acreages was used as the 1975-76 PA land base. If the 1974 PA land base acreage was larger than either the 1975 to 1976 or 1977 to 1980 land base acreage, the increase from the 1975 to 1976 to 1977 to 1980 base was subtracted from the 1975 to 1976 base and inserted as the 1974 PA base
acreage. If the 1977 to 1980 PA base acreage was smaller than either the 1974 or 1975 to 1976 base acreage, the increase from 1974 to 1975-1976 base acreages was added to the 1975 to 1976 acreage and used as the 1977 to 1980 acreage statistics. If the three base acreages in a PA were not easily modifiable to reflect the assumed increase in available harvestable crop acreage after 1973, the 1973 or 1974 PA harvested acreages were used as the 1974, 1975 to 1976, and 1977 to 1980 base acreage restraints. The PA land base acreages after 1973 used in the predictive run were in all cases larger than or equal to the 1973 PA harvested acreages.

The irrigated PA land base was held constant at the 1973 calculated acreage base derived earlier. Thus, although the PA water supplies for crop use were not restricted in the predictive run, the irrigated acreage base effectively limited water use to realistic or normal levels.

While the total land base in the model using these estimated PA crop land figures from 1974 to 1976 was approximately equal to the actual total crop land harvested for the cropping activities in the programming sector according to U.S. Department of Agriculture figures [50], it is not known if the individual PA land base crop acreages are also similar. In this research study, it was assumed that these figures are reasonably accurate, although imperfectly estimated.

Finally, these land resource restraints used in the model from 1969 to 1980 were specified as greater than or equal to restraints. Expressed in mathematical notation, these restraints are
\( \text{PAC}_{j,k,t} \geq \sum_{i=1}^{\text{number of crops}} X_{i,j,k,t} \)  \hspace{1cm} (3.5)

where

\( \text{PAC}_{j,k,t} = \) acreage available for harvesting in the jth PA,
on the kth type land in the tth year; \( j = 1, \ldots, 104 \) PAs, \( k = 1, 2 \) irrigated or dryland; \( t = \) year from 1969 to 1980.

\( X_{i,j,k,t} = \) solution acreage of the ith crop in the jth PA on the kth land type in the tth year; \( i = 1, \ldots, \) number of crops in the PA

If the base acreage restraints had been written as equalities, the modeling design would have implied that the available cropland must be completely exhausted by the cropping activities in each PA. If all or most of the important land using agricultural activities are specified in the model this hypothesis is reasonable. In this model, many important crop activities, such as silage, hays, rice, sugarbeets and other small grains have been specified as exogenous to the model. Additionally, the programming sector does not include livestock activities which would place an either a demand or an implicit positive net return or profit in the objective function for the silage and hay activities. Consequently, the solution acreages for all but one of these crops would always be at their respective lower flexibility restraint because of their negative returns (costs of production). For these reasons plus the imperfect specification of the yearly land base discussed earlier, it is assumed
land left idle by the activities in the model is not idle in reality, but is used for producing one or more of the exogenous crops or activities to the model.

Flexibility constraints are specified for the crop activities in the programming sector to limit yearly changes in activity acreages. Because these restraints change from year to year, they are dynamic and relate the crop acreages in year \( t + 1 \) with the solution crop acreages in year \( t \). Flexibility restraints are lower and upper bounds between which the permissible period to period variation in acreage levels occur. Flexibility restraints have been discussed at length in the recursive programming section in the previous chapter. The flexibility restraints can be expressed in the following manner,

\[
X_{i,j,k,t} \geq (1 - \beta_{i,j,k,t})X_{i,j,k,t-1}
\]

and

\[
X_{i,j,k,t} \leq (1 + \beta_{i,j,k,t})X_{i,j,k,t-1}
\]  \( (3.6) \)

or

\[
(1 - \beta_{i,j,k,t})X_{i,j,k,t-1} \leq X_{i,j,k,t} \leq (1 + \beta_{i,j,k,t})X_{i,j,k,t-1}
\]  \( (3.7) \)

where

\[
X_{i,j,k,t} = \text{solution acreage for the } i\text{th crop, in the } j\text{th PA, on the } k\text{th land type, in the } t\text{th year; } i = 1, \\
\text{... number of crops in the PA; } j = 1, \ldots, 104
\]
PAs, $k = 1, 2$ or irrigated or nonirrigated land, $t = 1969, \ldots, 1980$

$$X_{i,j,k,t-1} = \text{solution acreage for the } i\text{th crop, in the } j\text{th PA, on the } k\text{th land type in the } t-1\text{th year}$$

$$\underline{\beta}_{i,j,k,t}: \overline{\beta}_{i,j,k,t} = \text{maximum and minimum proportionate increase or decrease in the } i\text{th crop, in the } j\text{th PA, on the } k\text{th land type of the } t\text{th year from the } t-1\text{th year. These are also called the upper and lower flexibility coefficients.}$$

The estimation of flexibility coefficients which are needed for calculating the flexibility restraints, and the estimation of the flexibility restraints will be discussed in detail in the REVISE sector explanation.

Absolute maximum and minimum acreages for each of the seven crops defined for each PA for both dryland and irrigated activities were the third set of acreage restraints in the programming sector. These restraints are presented in Table A.2. The absolute acreage restraints used in the historical runs, 1969 to 1973, were based on the 1969 acreage levels of the 538 crop activities. The acreage restraints used in the predictive run, 1974 to 1980, were estimated from the 1973 acreage levels of the crop activities. These absolute activity acreage level restraints are not explicitly in the programming sector but are explicitly used in the REVISE sector. Essentially, if the upper or lower flexibility restraint is larger or smaller than the upper or lower absolute bound respectively then the absolute acreage bound is substi-
tuted for the flexibility restraint.

Primarily, the introduction of absolute acreage bounds in addition to the flexibility restraints is based on the economic reasoning that a certain (long run) minimum or maximum acreage of a crop in a producing area will be maintained. This behavior is due to the benefits derived from diversified cropping patterns which minimize the various risks of crop specialization. Thus, while crop specialization can occur within production areas, the extent of the specialization is limited by the absolute acreage restraints, which represent factors other than short run profit maximization.

Sahi also suggests these constraints reduce aggregation bias.

"Since an aggregate programming model assumes that all farms in a region respond in a similar way to economic stimuli, (i.e., all farms respond to the same extent or do not respond at all), an all-or-nothing type of solution can be obtained [178, pp. 1531-1532]. However, in reality farmers respond at different rates. Therefore, a region maintains at least some minimum acreages of a few crops and some maximum acreages of others" [168, p. 96].

The maximum and minimum absolute acreage restraints for the historical and predictive periods were calculated using the estimated 1969 and 1973 activity acreages (base acreages) described earlier and the following procedure based on the individual activity levels. If the base activity acreage was less than 25,000 acres, the upper bound was calculated by multiplying the base acreage by a factor of five. The lower bound limit was calculated by multiplying the base acreage by .20.
A similar technique was employed to calculate the other upper and lower acreage restraint limits. If the base acreage was between 25,000 and 100,000 acres, the multiplicative coefficients used were 4.0 and .3 respectively. If the base acreage level was between 100 and 300 thousand acres, the multiplicative coefficients used for calculations were 3.0 and .40 respectively. If the base acreage level was between 300 and 750 thousand acres, the multiplicative constants were 2.5 and .45 respectively. If the base acreage level was between 750 and 1500 thousand acres, the multiplicative figures were 2.0 and .50 respectively. Finally, if the base acreage level was greater than 1.5 million acres, the multiplicative coefficients were 1.5 and .66 respectively. Certain acreage limits were then modified if any of the estimated activity acreages from 1968 to 1973 were lower than the absolute lower bound or larger than the absolute upper bound by multiplying the estimated bound by either .8 or 1.2 respectively. The multiplicative coefficients used above were derived from the flexibility coefficient data generated for this study, and professional experience.

Thus, the recursive programming sector contains longer run absolute upper and lower bounds, as well as short run year to year flexibility restraints. In this model, the long run bounding structure is weighted by the level of a base acreage for a particular crop. As a result, small acreage crops flex more than do large acreage crops in terms of percentages. In conclusion, the absolute upper and lower bounds specified for this research study act as long run limits or bounds within
which the yearly flexibility restraints control the solution acreages.

**Recursive programming sector mathematical structure**

A summary of the equations reflecting the structural framework of the recursive programming sector are presented here. The specific form of the objective function and restraints are

\[
\begin{align*}
\text{Maximize } Z_t &= \sum_{i=1}^{104} \sum_{j=1}^{28} \sum_{k=1}^{104} (P_{i,j,k,t} X_{i,j,k,t} - C_{i,j,k,t} X_{i,j,k,t}) \\
&\quad - \sum_{m=1}^{N} \sum_{N P} X_{i,j,k,t} - \sum_{j=48}^{W_i,t} WP_{i,t} 
\end{align*}
\]

subject to

\[
\begin{align*}
PAC_{j,k,t} &\geq \sum_{i=1}^{X_{i,j,k,t}} (1 + \beta_{i,j,k,t}) X_{i,j,k,t-1} \\
X_{i,j,k,t} &\leq (1 + \beta_{i,j,k,t}) X_{i,j,k,t-1} \\
X_{i,j,k,t} &\geq (1 - \beta_{i,j,k,t}) X_{i,j,k,t-1} \\
\text{and all } X_{i,j,k,t} &\geq 0
\end{align*}
\]

**SUMMARY Sector**

The SUMMARY sector interfaces or links the information flow from the recursive programming sector to the simulation sector. In this first generation, experimental recursive interactive programming model, the only production response information the SUMMARY sector has been specified to handle is crop acreage and production data. (Figure 3.7)

Although the function of this sector is very simple, the Fortran programming necessary to make the sector operable is very complex.
Figure 3.7. The SUMMARY Sector in the RIP Model
This complexity arises because the computer is switching the information code from the MPSX language used to solve the programming sector to the Fortran language used by the simulation sector.

The SUMMARY sector is a Fortran subroutine within a larger Fortran computer program named KEN1 which also contains the simulation and REVISE sector programs. This larger computer program is, in turn, a subroutine within the main MPSX control program (Table A.6), and is used in every yearly iteration in each complete model run. The SUMMARY sector subroutine is the first major segment of KEN1 and is called as a subroutine from the simulation program. The initial task of this sector is to take the file of solution information in year t stored in the computer memory by the MPSX computer program and then reformat the MPSX information in a usable manner for the Fortran simulation sector. When this step has been accomplished the summary behavior of the sector then begins. First, the production levels of each of the seven crops already summed into each of the 28 market regions are in turn summed into national production statistics. The bushel production levels of four feedgrains, barley, corn, oats, and sorghum, are then revised into ton equivalent figures based on their relative per bushel weights [198]. These ton equivalent figures are then summed into a total tons of feedgrain produced in year t. The national crop production statistics for the feedgrains (million tons), wheat (million bushels), soybean (million bushels), and cotton (million bales) are then introduced into the simulation sector. When the production summary statistics have been completed the SUMMARY sector then sums the acreage data for each crop in each pro-
ducing area in year \( t \). The four feedgrains are first summed separately by crop and then are summed jointly into a total feedgrain acreage. Finally, after both the national crop production and acreage statistics have been calculated for transfer to the simulation sector, the computer transfers this information to the simulation sector program and begins the simulation sector computer program, the second major component of KEN1.

Simulation Sector

The simulation sector is the second major component of the KEN1 subroutine called from the main computer control program. The simulation sector is a computer program written in the Fortran programming language. It is the central program in KEN1 because both the SUMMARY and REVISE sector computer programs are called as subroutines from the simulation sector program. The simulation sector takes the national crop acreage and production statistics prepared by the SUMMARY sector from the solution data of the recursive programming sector in year \( t \) to calculate national pre-input, input demand and market output information. Although all the information generated in the simulation sector could be utilized in the REVISE sector where the new programming problem in year \( t + 1 \) is derived, the presently specified model only uses the simulation market information.

The recursive simulation sector was constructed from the national simulation model first presented by Ray [160, 162], and later extensively respecified as a forecasting model by Heady, Reynolds, and
Mitchell [94], and Heady, Reynolds, and Baum [93]. Each of these models characterize the agricultural production and marketing processes as a sequential yearly cycle rather than by quarters. By iterating the model over a sequence of yearly cycles, time paths of endogenously determined variables such as prices or incomes, can be determined. As the set of exogenous variables used in the simulation model's equations are manipulated to depict different economic environments and agricultural policy conditions, different time paths and levels of endogenous variables are generated. By comparing the time paths and levels of different projected economic environments, the impacts and effects of proposed policy changes can be evaluated for planning purposes or to test different economic hypotheses about production and demand behavior over time.

The structural framework of the simulation sector has been modified to reflect the different information communication design of the RIP modeling methodology. First, only five commodity submodels representing production activities in livestock, feedgrain, wheat, soybeans, and cotton remain in the simulation sector. The tobacco submodel was removed because tobacco activities were not included in the recursive programming sector. Each commodity submodel contains three sets of equations to represent the different time stages of the production process. These equations were econometrically estimated utilizing time series data during the period 1930 to 1967.

The commodity submodels are divided into the pre-input or planning
subsector, the input or planting subsector and the harvesting or output subsector. Before the commodity submodels were modified, these three subsectors were recursively linked. The pre-input sector determined the levels of various fixed resources such as machinery stocks, purchases of machinery, the price of land, the total stock of productive assets and the acres planted for harvesting. The input subsector determined the level of variable inputs such as labor, fertilizer, seed, machinery and other expenses including interest charges on inventories and taxes on land. In these equations, previously determined exogenous variables including input prices and tax rates and many of the pre-input variables were used as the dependent variables. The output subsector calculated the production, relevant demands, income and prices based on estimated input and acreage levels for the commodity. These commodity submodels generally contain the same variable interactions, exogenous parameters and recursive information flow.

To illustrate the modifications made in the above methodology for the RIP's simulation sector's commodity submodels, the wheat submodel is presented in a schematic diagram in Figure 3.8. This diagram was taken from the Heady, Reynolds, and Mitchell study [94, p. 7] and altered to portray the necessary changes in variable interactions, and determination. Exogenous variables are enclosed by ovals and all other variables are either predetermined, having been estimated in the preceding year or endogenous. A listing of variables and definitions can be found in Appendix A, Table A.4.
An explanation of Figure 3.8 starts in the left upper quadrant with the pre-input subsector. The initial variable determined in the pre-input subsector is the intended harvested wheat acreage. Harvested wheat acreage is not calculated endogenously with an econometric wheat acreage equation, but is an exogenous variable in the simulation sector. In the recursive interactive programming model, the level of the wheat, feedgrain, cotton, and soybean acreage variable is determined by the optimal solution of the recursive interregional linear programming sector. This information is placed in the correct format for use by the simulation sector by the SUMMARY sector. An explanation of the SUMMARY sector has been provided in the previous section of this chapter.

The other variables in the pre-input and input subsectors are calculated following the introduction of the wheat acreage variable. A concise explanation and description of these variable interactions by Heady, Reynolds, and Mitchell;

"... machinery purchases for use in wheat production are estimated as a function of last year's gross income and the ratio of last year's value of real estate to last year's mortgage debt. The total machinery stock to be used for wheat production is a function of the carryover stock of machinery and the purchase of machinery in the current year. Commodity stocks on farms at calendar year end is estimated from last year's wheat production and last year's stock of wheat.

An index of the price of land and buildings is estimated as a function of last year's price and per acre gross income from last year. The value of farmland and buildings in the current year are then estimated as a function of the current price of land and current acres. The stock of physical assets is estimated as the sum of the average commodity stock in the farm, the average machinery stock, and the value of farmland and buildings. This completes
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Figure 3.8. The Simulation Sector Wheat Submodel [94, p. 7]
Exogenous Variable on Sector Wheat Submodel [94, p. 7]
the pre-input section of the wheat submodel and establishes the values of the fixed inputs allocated to wheat production. Following the pre-input section, the variable resource requirements are estimated in the input section of the wheat submodel. The levels of resource demand established in the input section depend upon the levels of the fixed inputs from the pre-input section as well as the values of endogenous variables from previous years. For example, fertilizer and lime demand in the current year depend on wheat acreage estimates obtained from the pre-input section as well as last year's gross income, which serves as a proxy for a capital constraint. The recursive structure of the model is preserved, since the solution of the equations occurs in a sequential manner. Other variable resource demands computed in the input section include demand for: seed; labor; machinery expense; real estate expense; fuel, oil, and repairs; miscellaneous expense; interest expense; and real estate tax expense" [94, p. 7-8]. These nine input categories are all calculated in value terms. Thus, when summed, these input values constitute the estimated farm production expenses for the particular commodity.

The third subsector in the commodity submodel contains the set of output variables and is found in the lower left quadrant of Figure 3.8. The initial variable presented in this subsector is wheat production. As with the wheat acreage statistic, wheat production is exogenously determined for the simulation sector by the optimal solution in the recursive interregional programming sector. The various production area acreages are multiplied by their respective yields and summed into market regions in the programming sector. The SUMMARY sector then sums these production level statistics into a national production statistic and places it in a correct format for the output subsector to use
in the market equations. In the wheat output subsector,

"... the current supply of wheat each year is equal to the sum of current production, carryover government inventory, carryover commercial inventory, and imports. Wheat demand is estimated as the sum of estimated demand for seed, feed, other commercial uses, and exports. The demand for wheat as food is estimated from consumption trends and population. Government inventory is a function of the wheat price support level, total current inventory, and beginning-year government inventory. Government inventory is zero if no farm programs are in effect. Commercial inventory is estimated by an identity equation equal to total wheat supply less total demand and government inventory.

Wheat price is estimated as a function of last year's price of wheat, the current price support level, and the excess demand for wheat. Wheat gross income is a function of wheat price times production and wheat government payments if farm programs are in effect" [94, p. 8-10].

The livestock subsector is the remaining subsector in the aggregate simulation sector yet to be described. The livestock sector is used after 1972. Before 1972, the livestock feed demands are given to the feedgrain and soybean market submodels exogenously [198]. The livestock sector estimates livestock feed demand for the feedgrain and soybean submodels. In this particular simulation sector, the wheat livestock feed demand is fixed exogenously and is unresponsive to price changes [93, 94]. The feed demands estimated by the livestock submodel are derived demands based on livestock for consumption demands, which are estimated endogenously, and also an exogenous nonconsumption grain demand for use by pets, horses and mules. The consumption of beef, pork, chicken, lamb, and turkey per capita are estimated as a function of commodity retail prices and per capita disposable income [209]. The retail livestock prices are determined from the lagged
feedgrain and soybean prices calculated in the simulation sector using the livestock finishing feed price developed by Rahn, et al. [156]. The actual per capita disposable incomes from 1968 to 1975 were taken from published data series and deflated to 1957 real dollars using the GNP price index [52, 204]. After 1975, per capita disposable incomes in 1957 dollars were estimated using the following equation corrected for autocorrelation [161] based on published data from 1952 to 1975 [33, 52, 204]:

\[
\text{PCDY} = 1546.607 + 53.611 \times \text{TIME} \\
(77.036) \quad (4.987)
\]

\[
\rho = -.7956 \quad \text{MSE} = 2719.28 \quad R^2 = .840
\]

where

- PCDY = estimated per capita disposable income
- TIME = time trend variable with 1952 = 1
- \( \rho \) = first order autocorrelation coefficient
- MSE = mean square error

The estimated standard error (SE) of the estimated regression coefficients are indicated in parentheses below the relevant coefficient. Both coefficients were highly significant at .01 level.\(^4\) The per

\(^4\)Significance of the estimated regression coefficients refers to a test of the hypothesis \( H_0: \beta_i = 0 \) against the alternative \( H_A: \beta_i \neq 0 \) using a students t test for \( t = \frac{b_i}{\text{S.E.}(b_i)} \) with (n-k) degrees of freedom. Significance level is the level at which \( H_0 \) can be rejected when the computed t value is compared to tables of the t distribution [113].
capita consumption levels of dairy products in milk equivalent form and eggs are actual data through 1974 and projected after 1975. The total national nonconsumed livestock levels are also projected for each year after 1972. The per capita demands then multiplied by the predicted population level in each year [198, 203] to derive total national demands by each commodity class. Each of these commodity class consumption demands and nonconsumed livestock demands is then converted into grain-consuming animal units (GCAU) and summed into a national GCAU level. The national GCAU level is then utilized to estimate feedgrain and soybean feed demands. Thus as the estimated price of grains rise, the farm price of livestock rises causing retail prices to increase and consumption to fall.

The aggregate simulation sector is illustrated schematically in Figure 3.9. This diagram was developed to show how the four commodity submodels and the livestock submodel interact and influence each other's behavior. The diagram is fairly self-explanatory after the previous explanations of the commodity and livestock submodels. Essentially, the interaction and substitution effects occur because of the linkages between the submodels and the recursive properties of the simulation sector. Changes in any of the submodels can have an impact on the entire system. In one sense, the diagram is misleading because the commodity submodels do not directly interact with each other as indicated in Figure 3.9. Rather, the linkages between the commodity submodels occur indirectly through the changes in acreage and production in the recursive
Figure 3.9. Aggregate Simulation Sector in the RIP Model [94, p. 10]
Population/Total N. of Beef, Pork, Lamb, Broiler; Turkey, Eggs, Milk

LIVESTOCK SUBMODEL

Per Capita Consumption
Beef, Pork, Broilers, Lamb, Turkey, Eggs, Milk

GCAU Requirements

Total Wheat Demand
Fed Grain Exports
Industrial Demand
Population

WHEAT SUBMODEL

Feed Grain Exports
Industrial Demand
Population

FEED GRAIN SUBMODEL

Total Feed Grain Demand
Wheat Price
Feed Grain Price

SOYBEAN SUBMODEL

Total Soybean Demand
Soybean Price

COTTON SUBMODEL

Total Cotton Demand
Cotton Exports

SYMBOLS USED
Commodity submodels
Endogenous variables
Exogenous variables
Total commodity demand

Simulation Sector in the RIP Model [94, p. 10]
programming sector's optimal solution. These changes are caused by the yearly shifts in market variables used to estimate net relative returns and flexibility restraints used in the recursive programming sector.

For example, a large enough increase in wheat price in year \( t \) relative to the other commodity prices will affect the other submodels in the following manner. First, if the net relative return to wheat is high enough, wheat acreage will increase in year \( t + 1 \) and the other crop acreages will decrease in the interregional programming sector as cropland is shifted into wheat production. In year \( t + 1 \), the wheat price may fall if production has increased relative to demands, but feedgrain, cotton and soybean prices should all rise due to decreased supplies. Now, in year \( t + 2 \), the other commodity acreages will rise relative to wheat acreage in the programming sector as the system tries to move back to an equilibrium position. But, because soybean and feedgrain prices have increased in year \( t + 1 \), livestock production will fall in year \( t + 2 \) and demand for these grains will fall. Thus, in summary, the effects of a simple increase in the price of wheat becomes a very complicated task to explain. The effects of the simple price change will continue through the system over a time with further interactions between and among subsectors. Therefore, the simulation sector acts to tie together the feedgrain, wheat, livestock, cotton, and soybean sectors in a complex network of recursive equations and feedback interactions among the submodels and the recursive interregional programming
In addition to the commodity and livestock submodels in the simulation sector, a U.S. summary sector is also included to estimate gross and net farm income, stocks, and input use values. Net farm income for the commodities is equal to market gross income plus any government payments minus production expenses or the sum of the variable resource costs estimated in the U.S. input section. This summary sector was not used in the empirical analysis.

A complete listing of the pre-input, input, and output equations used in the commodity submodels in the simulation sector may be found in Appendix A of the Heady, Reynolds, and Mitchell simulation study presented earlier [94]. The livestock demand equations, various conversion ratios, the industrial demand equations and egg and dairy demand projections in the livestock submodel may be found in Appendix B of the above study if a more detailed explanation of the simulation sector of the RIP model is required.

When the simulation sector has completed its recursive sequence of pre-input, input demands and market output data calculations, the third major segment of KEN1, the REVISE sector, then begins its calculations.

REVISE Sector

The REVISE sector acts as the interfacing linkage between the SUMMARY and simulation sectors and the recursive programming sector in the RIP model. The REVISE sector is the third component and final computer program in the KEN1 subroutine. In essence, this sector is also called as a subroutine program from the main MPSX control program. Additionally,
the sector program, as with the REVISE program is a subroutine within the simulation sector program to expedite data transferral and other technical problems.

The REVISE sector is responsible for period to period, or yearly modifications in the objective function, input-output matrix and activity flexibility restraints in the recursive programming sector. These modifications are based partly on data calculated in the SUMMARY and simulation sectors. More specifically, in this particular modeling study the REVISE sector can utilize the information from the market output subsectors in the simulation sector, and the reformatted solution activity acreage levels presented by the SUMMARY sector in year \( t \) to transform the programming problem for year \( t + 1 \). The REVISE sector also can make use of exogenously provided information about crop activity acreages and market variables, and other data sets including crop costs, yields, allotments, and upper and lower absolute bounds. Finally, the REVISE sector has the capability to endogenously calculate expected prices, yields, nitrogen use, flexibility coefficients, flexibility restraints and other knowledge necessary for the periodic revision of the recursive programming sector optimization problem.

As in the simulation submodels, the recursive properties and information flows in the REVISE sector and how it interfaces or is linked to the recursive programming sector is easily explained with a diagram, Figure 3.10. The variable definitions in Figure 3.10 can be found in Table A.5. Although Figure 3.10 has been specified for the wheat cropping
Figure 3.10. Interfacing in the Wheat Sector
Recursive Programming Sector (t)

W-GRET-AC(I)_t

W-EXP-AC(I)_t

W-NTRET-AC(I)_t

RHSAC(I)_t

RHSWT(I)_t

W-ACREAGE(I)_t

LPW-AC_t

W-YTR(I)_t

LPW-PROD_t

W-PROD(I)_t

W-LBACPA(I)_t

W-UBACPA(I)_t

W-UBABS(I)

W-LBABS(I)

Endogenous or Exogenous Variable

Exogenous Variable

W-facing in the Wheat Sector
activities, the remaining six crops can be similarly schematically dia-
grammed. The wheat cropping activities were chosen for illustration for
two reasons. First, the simulation section of this chapter has already
presented the wheat submodel in detail and has demonstrated how the sub-
model uses the production and acreage data generated from the recursive
programming solution. Second, because of the complex nature of this
sector and its information flows, a diagram of the wheat activity modi-
fication calculations simplifies the explanation of the economic
premises and the modeling techniques operable within this sector.

An understanding of how this sector functions is complicated by
the many options concerning not only the interaction of variables and
variable choice mechanisms, but also the specification of which variables
are exogenous or endogenous for the REVISE sector. As demonstrated in
Figure 3.10, depending upon the goals, economic or statistical assump-
tions of the research economist as model builder, the behavior of the
REVISE sector as constructed for this research study, can be modified
to represent many different economic environment for many different
purposes. Despite the implicit breadth of modeling opportunities
presented in Figure 3.10, the objective of this first generation, experi-
mental RIP modeling effort is limited to demonstrating the feasibility
of the RIP model and a discussion of modeling problems occurring with an
RIP model in explicit form.

The REVISE sector can be conveniently separated into two submodels.
The first submodel is diagrammed as the upper loop in the REVISE sector
section and calculates the wheat objective function and input-output matrix modifications in the recursive programming sector. The second submodel is represented by the lower loop in the REVISE sector. The second submodel estimates the yearly wheat activity flexibility coefficients and restraints to be used in the recursive programming sector. Although each of these submodels will be primarily discussed in the context of the wheat activities, the relevant submodel modifications for each of the six remaining crops will also be discussed and explained.

**Objective function submodel**

The objective function or net return for each of the wheat activities in each producing area is computed from expected prices, expected yields and expected costs.

**Expected prices** The expected prices are calculated from the nominal lagged PA market price from year \( t - 1 \) and the announced PA crop support price in year \( t \). In this study, the expected price of wheat by the producer in a PA is assumed to be whichever is larger, the nominal lagged market price or the announced support price in year \( t \). In effect, a naive price expectations model is used reflecting the cobweb model of economic behavior. If the market price is below the support price, then it is assumed the producer will expect the support price in year \( t \) to be his relevant price decision variable. While more complex price expectations
models could have been built for this study, it was decided to limit the complexity of the RIP model in its initial formulation.

The lagged market price for wheat can either be determined from an exogenous data set or endogenously determined from the wheat market subsector in the simulation sector. If the endogenously determined simulation market prices were used, they were recalculated into nominal, current year prices for calculating expected net returns. This is done with a 1948 GNP inflation index (GNP48) estimated from various sources [33, 52, 204] where the index equals 1.00 in 1948. The estimated inflation rate for 1977 was estimated at six percent. After 1977, the index was held constant at the 1977 price index level. If the feed-grain prices are endogenously determined from the simulation market sector, the aggregate feedgrain price is utilized to determine the individual corn, barley, oat and sorghum prices with the following equations:

\[
\text{CORN-PR}_t = -.1322 + .031280 \times \text{FGP}_t + .022213 \times \text{LOG-TIME}
\]

\[
\begin{align*}
\text{D.W.} &= 1.83 \\
R^2 &= .994 \\
\text{MSE} &= .0005
\end{align*}
\]  

\[
\text{BARL-PR}_t = .2616 + .019050 \times \text{FGP}_t - .047420 \times \text{LOG-TIME}
\]

\[
\begin{align*}
\text{D.W.} &= 1.49 \\
R^2 &= .957 \\
\text{MSE} &= .0021
\end{align*}
\]  

\[
\text{OAT-PR}_t = .2503 + .009873 \times \text{FGP}_t - .005328 \times \text{TIME}
\]

\[
\begin{align*}
\text{D.W.} &= 1.70 \\
R^2 &= .963 \\
\text{MSE} &= .007
\end{align*}
\]  

\[
\text{SORG-PR}_t = .0280 + .024456 \times \text{FGP}_t
\]

\[
\begin{align*}
\text{D.W.} &= 1.81 \\
R^2 &= .999 \\
\text{MSE} &= .0003
\end{align*}
\]
where

\( \text{CORN-PR}_t \) = national market price of corn in 1948 dollars in year \( t \)

\( \text{BRL-PR}_t \) = national market price of barley in 1948 dollars in year \( t \)

\( \text{OAT-PR}_t \) = national market price of oats in 1948 dollars in year \( t \)

\( \text{SORG-PR}_t \) = national market price of sorghum in 1948 dollars in year \( t \)

\( \text{FGP}_t \) = national market price of feedgrain in 1948 dollars in year \( t \)

\( \text{TIME} \) = time trend variable; 1949 = 1

\( \text{LOG-TIME} \) = log of \( \text{TIME} \) variable

\( \text{D.W.} \) = Durbin Watson statistic for autocorrelation and other summary statistics defined earlier

Each of these equations was estimated econometrically with OLS procedures [161]. The coefficient's standard error is presented in parentheses below the coefficient.

Once the national wheat market prices are obtained in year \( t - 1 \), it must be weighted into each of the production areas to reflect the geographic price differentials in different areas. These wheat geographic price differentials reflect different qualities of output and transportation costs. This problem does not occur in interregional
transportation programming models because commodity transportation costs are endogenously determined by the most efficient spatial production pattern in relation to regional demands. But in recursive programming models, regional or national food and fiber demands are not specified. Thus, a transportation sector was not included in the the recursive programming sector model.

Therefore, to reflect transportation costs and quality differentials in the recursive programming sector, three different sets of local to national price ratios were estimated in the following manner. First, the ratios of state market prices for wheat to the national market price for wheat from 1968 to 1973 were calculated from U.S.D.A. state price data [198]. The first set of local to national price ratios (LNR1) was then calculated by weighting these state ratios into the producing areas with the STPA weights described earlier in (3.2) for each individual year. The second set of price ratios (LNR2) was computed by taking the average ratio from 1968 to 1972 of LNR1. The LNR2 price ratio set was assumed to reflect the average historical price differential for each PA. The third set of local to national price ratios, LNR3 was derived by taking the average of the 1972 and 1973 LNR1 price ratios.

After the lagged PA market prices for wheat activities have been determined, the PA support price for wheat is estimated from the national support price in year t. The PA support price in year t is computed by multiplying the national support price by LNR2, the average historical
local to national price ratio. This approach was chosen out of necessity because state or county support price data were unavailable. Although the choice using LNR2 to weight the national support price into smaller geographic regions can be severely criticized, a more correct or precise estimation procedure could only be derived if actual localized price support data were available. The choice of LNR2 was assumed to be a relatively correct set of statistics reflecting the historical PA to national support price ratios based on transportation costs and quality differences.

**Expected yields and fertilizer use coefficients** Once the lagged PA market prices and current support prices for wheat have been estimated and the larger of the two chosen as the expected price in year t, the wheat expected yield in each PA is calculated. The expected PA wheat yields are necessary to estimate the expected gross returns in each year. The REVISE sector was constructed so that a choice of three different yields was available to estimate gross returns.

The first set of PA wheat yields was calculated first from OLS and from ALS (autocorrelated least square) state yield equations when autocorrelation was significant. These trend yield equations were estimated from a data set comprised of irrigated and dryland harvested acreage and production data from 1949 to 1973 [6, 7, 24, 25, 26, 31, 58, 107, 115, 137, 139, 144, 148, 149, 181, 191, 198, 201, 213].

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5 op. cit. Robert Carver, p. 217.
historical acreage and production data set will be referred to as HSTAC. The average wheat yields in each year were estimated by dividing the production statistic by the harvested acreage statistic for that year. The data sets described earlier, STAC, and STYLD are subsets of this larger data set, HSTAC. In the 17 western states, irrigated and dry-land harvested crop acreages and production data were often unavailable as separated statistical data series, or for the entire twenty-five year period from 1949 to 1973 (Table A.3). The Ray-Martin OLS and ALS regression algorithms [161] were used to estimate a simple trend yield regression equation with an intercept and a time/technological trend variable,

\[ \text{TRYLD}_{i,j,t} = a_{0,i,j} + a_{1,i,j} T_t \]  

(3.13)

where

\[ \text{TRYLD}_{i,j,t} = \text{estimated trend yield of crop in state } j \]

in t year; i = 1, . . . number of crops in state, j = 1, . . . 48 states, t = year

\[ a_{0,i,j,t} = \text{estimated intercept term of the trend yield equation for crop } i \text{ in state } j \text{ in the } t \text{th year} \]

\[ a_{1,i,j,t} = \text{estimated regression coefficient on the trend variable for crop } i \text{ in state } j \text{ in the } t \text{th year} \]

T = time or technological trend variable; 1949 = 1 unless indicated otherwise in Table A. A log of T was also used as an independent variable.
As expected, fluctuating weather conditions in states from year to year produced large changes in average state crop yields. These yearly fluctuations in yields caused some of these trend yield equations to be estimated with rather low accuracy. When the $R^2$ of the "best" estimated equation was below .60, or the trend variable was insignificant using a student t statistic at the .05 level, the equation was not used. Instead, a five year average of the actual state wheat yield to the actual national wheat yield ratio was used to estimate the average trend state wheat yield. A national trend yield equation for each of the seven crops was also estimated for these purposes from U.S.D.A. data series [198]. Similar procedures were utilized for the remaining six crops. If the separated irrigated and dryland average state yields were not available to estimate a trend yield equation, the total state average yield equation was estimated. The irrigated and dryland yields were then calculated using the 1969 Census of Agriculture [197] irrigated to state total and dryland to state total average yield ratios. Finally the wheat and other crop yields were allocated into the producing areas with the STPA weights described earlier.

The second trend yield estimation procedure was to use Spillman trend yield production functions developed for the 105 producing areas and reported by Meister and Nicol [127]. These equations were modified from state yield functions estimated by Stoecker [185]. With these equations, a unique yield can be calculated for each of the irrigated and dryland crops as a function of producing area, the soil class, and the crop
rotation. In this model the equations are used to estimate a base or average yield in each PA for each crop. For a given crop, wheat, the Spillman function is expressed as

\[ Y_t = Y_{0,t} + A(1 - 0.8^t) \times PF_t \]  

(3.14)

where

- \( Y_t \) = the estimated average PA yield per acre of wheat in year \( t \)
- \( Y_{0,t} \) = the estimated average unfertilized wheat yield per acre in year \( t \) developed from a linear trend function
- \( A \) = the maximum response obtainable from fertilization
- \( X_t \) = number of pounds of fertilizer applied per acre in year \( t \)
- \( PF_t \) = proportion of the crop acreage fertilized in year \( t \), developed from a linear trend of the proportion of crop acres receiving fertilizer
- \( t \) = number of years after 1949; 1950 = 1

The \( X_t \) defined above represents

\[ X_t = P_0 \times \ln(P_X/P_1) - \ln A - (\ln(-\ln 0.8))/\ln 0.8 \]  

(3.15)

where

- \( \ln \) = natural log of base \( e \)
- \( P_X \) = weighted price of a unit of fertilizer in the PA
  in 1972 dollars
- \( P_1 \) = price of a unit of crop \( i \); \( i = 1, \ldots, 7 \) in the PA in 1972 dollars
\[ P_0^t = \text{linear function of the proportion of the optimum rate of fertilizer applied in year } t \text{ in the PA} \]

The last multiplicative factor in (3.14) represents an estimate of the optimum application of fertilizer obtained by solving the marginal conditions of a profit maximization system.

With the above set of equations, the yield of a given crop in a PA can be calculated given that the estimated parameters and the projected levels of fertilizer use for the input-output matrix are estimated for each of the years involved in the modeling process. It is assumed in this analysis that carryover nitrogen from legume rotations is not included when projecting yields. Only normally applied nitrogen from commercial sources is assumed to be used, based on trend fertilizer uses and the fertilizer to crop price ratio in each producing area. Determination of the crop prices has been previously discussed. For these equations, crop prices were expressed in 1972 dollars using a GNP price index (GNP72) with 1972 equal to 1.00 from the GNP48 price index developed earlier. Fertilizer prices before and after 1972 were expressed in 1972 dollars using the U.S.D.A. fertilizer price index [198]. In 1976 and 1977 the fertilizer index was assumed to increase at the same rate as the 1972 GNP price index. After 1977, both of the price index ratios were held constant at their 1977 levels.

The third expected yield option in the REVISE sector was to use the lagged PA wheat yield calculated from actual harvested acreage and production data. These yields were estimated from the STYLD data set.
described earlier with the set of STPA weights. These yields were
given exogenously to the REVISE sector and will be referred to as the
PAYLD data set. Although this option was not utilized in this study,
the actual PA crop yields data set was still employed. The PAYLD data
set with the 1968 to 1973 actual crop yields was important because
it was also available to be used as the yield input-output coefficients
for year to year modifications of the recursive programming sector,
as were the OLS and ALS regression equation estimates and the Spillman
production function yields.

In summary, the revise subsector calculating expected yields serves
a double purpose. First, expected yields are estimated to compute
three different expected gross returns, an optimum gross return, a trend
gross return, and the previous year’s actual return (unless the support
price is greater than the lagged market price). Second, expected
yields and nitrogen use were determined for the periodic revision of
these input-output coefficients in the recursive programming matrix.

Production costs The determination of production costs is an
important component for an accurate estimation of expected net re­
turns for a given crop. Two different sets of crop production cost
data were developed for use in the REVISE sector. The first data
set, COST1, was used during the five year period from 1969 to
1973. The second set of production costs, COST2, was developed for
the predictive period, 1974 to 1980. Both sets of cost data are
given to the REVISE sector exogenously. Modifications in these
basic data sets to reflect estimated yearly changes in production costs are based upon prespecified price indexes also exogenous to the REVISE sector.

The total production costs for crops contained in COST1 include machinery, labor, pesticides, and miscellaneous costs as defined by Eyvindson [61]. The basic source of the production cost data in COST1 was developed first from the reaggregated production area crop costs estimated from Eyvindson's original data by Nicol [145] and Nicol and Heady [146], and then finally from the 1969 per acre costs for each crop in each PA by Meister and Nicol [127]. Although this latter cost data set was adjusted for labor and machinery efficiency changes reflecting different tillage and conservation practices, only the basic straight row cropping costs were used in this research study. The sum of variable production costs tabulated in the REVISE sector during the 1969 to 1973 period for each crop activity were estimated with the following equation,

\[
\text{EXP-AC}_{i,j,k,t} = \sum_{i=1}^{4} C_{i,j,k,n} \cdot \text{PI}_{n,t} + \text{SMF}_{k,j,2} \cdot \text{TP}_t \tag{3.16}
\]

where

\[
\text{AC}_{i,j,k,t} = \text{sum of variable costs for the } i\text{th crop in the } j\text{th PA on the } k\text{th type land in the } t\text{th year;}
\]

\[
i = 1, \ldots \text{ number of crops, } j = 1, \ldots \text{104 PAs, } k = 1, 2 \text{ irrigated or dryland, } t = \text{year}
\]
\[ C_{i,j,k,n} = \text{cost in 1969 dollars of the kth input for the} \]
\[ \text{ith crop in the jth PA on the kth type land in} \]
\[ \text{the tth year; } n = 1, \ldots, 4 \text{ for machinery,} \]
\[ \text{labor, pesticide and miscellaneous costs} \]
\[ \frac{P_{i,n,t}}{} = \text{U.S. Department of Agriculture (U.S.D.A.)} \]
\[ \text{price index of the nth input in year t with 1969} \]
\[ 1969 = 1.00 [198]. \text{The farm supplies price} \]
\[ \text{index was used for the miscellaneous costs input.} \]
\[ SM_{i,j,2} = \text{total summerfallow costs in 1969 dollars associ-} \]
\[ \text{ated with the ith crop in the jth PA on dry-} \]
\[ \text{land. Only some wheat and barley activities} \]
\[ \text{costs were affected (Table A.1 and Table A.2)} \]
\[ \frac{TPI_{t}}{} = \text{The U.S.D.A. all commodities bought for use} \]
\[ \text{in production price index with 1969 = 1.00} \]
\[ [198] \text{in year t} \]

A second set of production costs, COST2, was developed for the predictive run from 1974 to 1980. Preliminary modeling runs indicated the COST1 data set was inappropriate for crop costs estimation for this period partially because of the input use and technological changes occurring after 1969 and also because of the new government support price covering full production costs, including land costs and enter-preneurial or management returns [52].

This second set of crop production costs were estimated from the 1975 F.E.D.S. budgets developed by the Economic Research Service (E.R.S.)
Per acre variable costs data by crop were made available for the production areas in this study from earlier research presented by Dvoskin and Heady [49]. This new set of summed variable production cost data was used to replace the expected expenses per acre calculated from COST1. Presumably, the efficiency and technological changes causing changes in input use since 1969 are captured within this data set.

The production costs in COST2 also included land costs, determined from the land rent figures presented in the 1975 E.R.S. farm budgets. Where crop activities in the programming model were not included in the E.R.S. budgets, the land rent was determined from the average land rent value of the closest competing crops in the E.R.S. reporting regions. Use of these land rent values assumed that the missing rent values could be determined on an economic opportunity cost basis. Grain, sorghum, cotton, soybeans and corn were generally considered as one set of closest competing crops. Wheat, barley, and oats were placed in a separate set. Where competing cropland rent information was not available, the closest PA competing crop rent information was used. These cropland rents were then weighted into the production areas with a set of E.R.S. reporting region to PA weights devised by Dvoskin and Heady.

The inclusion of land rent as a real production cost can be severely critiqued. Martin, for example, has prepared a persuasive set of theoretical economic arguments for not using land rents as pro-
duction costs,

"The motivating force for a firm then is, for a given output level, to minimize contractual costs in an effort to maximize noncontractual costs. In the more familiar textbook language, this means that a firm attempts to maximize the return to its fixed factor(s). If due to unforeseen events, the firm receives a pure profit (unexpected noncontractual cost), this is an additional return or rent to the residual income claimants or owned factors of production.

... Often this rent is included in the total cost of production and hypothetical average cost curves ... are computed for other output levels on the assumption that the rent would be the same for other levels of output. ... The concept of total cost of production has meaning only at the point where the product price line intersects the marginal cost curve. His argument is that if the demand for the product were to increase, the product price and the rent would increase. This would imply an increase in the return to the owned drawn. However, only one point on the average cost curve where the product price equals marginal cost has any relevance. The key point is that total costs are a consequence of the final equilibrium and not a determinant of it.

Since land, for example, is relatively inelastic in supply in the short run, its value will largely be determined by the demand for the output or the product price.

Thus, price policies that are based on the total cost of production which include pure profits or additional rents can be quite unstable especially on the up side" [125, p. 7].

Nevertheless, preliminary predictive simulation run results from 1974 to 1980 combined with the movement of government agricultural policies toward support prices which include not only land rents but also returns to entrepreneurial ability or management strongly indicated that land costs should also be included in production costs after 1973.
From 1974 to 1980, crop production costs per acre were calculated in the REVISe sector with the following equation,

\[ \text{EXP-AC}_{i,j,k,t} = V_{C_{i,j,k}} \times \text{API}_{t} + L_{DRNT_{i,j,k}} \times \text{LPI}_{i,j,k,t} + \text{SMF}_{i,j,k} \times \text{API}_{t} \]  

(3.17)

where

\( V_{C_{i,j,k}} \) = variable production costs as defined in the E.R.S. 1975 farm budgets [53] for crop \( i \), in the \( j \)th PA on the \( k \)th land class; \( i = 1, \ldots \) number of crops, \( j = 1, \ldots \) 104 PAs, \( k = 1, 2, \) irrigated or dryland

\( \text{API}_{t} \) = the all commodities bought for use in production price index [198] for year \( t \), with 1975 = 1.00. The 1976 and 1977 API index figures were determined from the GNP48 price index. After 1977, this index was held constant

\( L_{DRNT_{i,j,k}} \) = land rent (cost) as determined in the E.R.S. 1975 farm budgets [53] for the \( i \)th crop in the \( j \)th PA on the \( k \)th land class

\( \text{LPI}_{j,k,t} \) = land price index determined by percent land value changes in the \( j \)th PA on the \( k \)th land class in the \( t \)th year, with 1975 = 1.00. This index was developed from the state agricultural land value changes [52] weighted into each of the PAs with the STPA weights. The index was held
constant after 1977. It was assumed for approximation purposes that all agricultural land value changes within a state, irrigated and dryland, could be estimated without bias from the yearly change in the overall change in the average state land price from 1974 to 1977.

**Net returns** After the computation of crop production costs and other variables as defined earlier, the preliminary expected crop net returns per acre are determined. Preliminary is defined here as being exclusive of nitrogen fertilizer and water for irrigation costs. These preliminary per acre net returns are calculated with the following equation:

\[
NTRET_{i,j,k,t} = GRET_{i,j,k,t} - EXP_{i,j,k,t} \quad (3.18)
\]

where

- \( NTRET_{i,j,k,t} \) = expected per acre net returns of the \( i \)th crop in the \( j \)th PA on the \( k \)th type land in year \( t \); \( i = 1, \ldots \) number of crops, \( j = 1, \ldots 104 \) PAs, \( k = 1, 2 \), irrigated or dryland, and \( t = \) year
- \( GRET_{i,j,k,t} \) = expected gross returns per acre determined by the expected price multiplied by the expected yield of the \( i \)th crop in the \( j \)th PA on the \( k \)th type land in year \( t \)
and other variables previously defined.

The calculated preliminary net returns are then recomputed in 1972 dollars with the GNP72 price index. Finally, these net returns are finally placed in a prespecified memory storage area in the computer to be used for the forthcoming revision of the objective function components for each of the 538 cropping activities in the recursive programming sector.

Total variable production costs for the entire period 1969 to 1980 also included nitrogen fertilizer and water for irrigation costs. These costs were not calculated in the net return subsector of the REVISE sector, but are calculated in the recursive programming sector during the optimization process. Nitrogen and water costs could have been calculated in the net return sector if the programming sector were structured without a fertilizer or water sector. Although the nitrogen for fertilizer costs are not tabulated in the net return subsector, the nitrogen fertilizer costs in each market region are indexed in 1972 dollars with the fertilizer price index described in the previous section on expected yield calculations. These revised nitrogen prices are then used for the yearly modification of the objective function in the programming sector, and are stored with the net return data components previously calculated.

The flexibility restraint submodel

The cropping activities' flexibility restraint submodel is diagrammatically sketched for the wheat activities in the lower portion of
the REVISE sector in Figure 3.10. The restraint submodel can be conveniently described in three parts, the flexibility coefficient sector, the econometric coefficient estimation model and the flexibility restraint sector which is used in the recursive programming sector.

**Flexibility coefficients** The first sector of the submodel estimates the lower and upper crop flexibility coefficients, i.e., the lower and upper limits allowed for year to year changes in harvested acreages. These flexibility coefficients have been expressed mathematically and defined in (3.6) and (3.7). The estimation procedure for the calculation of flexibility coefficients ratios will be more fully explained in the discussion of the econometric estimation model.

As indicated in Figure 3.10, endogenous and/or exogenously determined variables are initially used to calculate state flexibility coefficients. The endogenous market variables such as prices, inventories and exports are calculated in the simulation sector and then transferred to the REVISE sector. These variables may also be given exogenously to the REVISE sector.

The state crop acreage variable, STAC, if endogenously calculated, is determined from the solution acreage data for year t-1 prepared by the SUMMARY sector. This data set of individual PA crop acreages is re-aggregated back into state data with PA to state weights, PAST, calculated from the 1969 agricultural census [197]. The PAST weights were determined in a similar fashion to the STPA weights in (3.2). As with the STPA weights it is realized that the weights change as the actual state
acreages fluctuate. But it is assumed these PAST weights are approximately valid for the time period which this research study covers.

If the state crop flexibility coefficients are estimated with the econometric model regression equations, they are checked for "calculation errors" and omissions. These calculation errors of flexibility coefficients by the regression equations are generally due to multicollinearity and the lack of sufficient degrees of freedom and observations for an accurate, unbiased estimation of variable parameter coefficients. A calculation or estimation error is defined to occur when the upper estimated coefficient is larger than the largest observed coefficient or less than or equal to 1.0. In the former case, the estimated coefficient is set equal to the largest observed coefficient in Table A.2. In the latter case, the estimated coefficient is set equal to the average upper coefficient in Table A.2. For the opposite case, when the estimated flexibility coefficient is greater than the lowest observed coefficient in Table A it is set equal to the lowest coefficient and if the estimated coefficient is greater than or equal to 1.0 it is set equal to the lower average statistic in Table A.2. The development of the upper and lower average and lowest and highest observed flexibility coefficient statistics will also be discussed in the econometric model and equation section. For those state crops without an estimating equation for either the upper coefficient or lower coefficient, the upper and lower historical average coefficient statistic were used, respectively. However, few of these situations
Once the final set of state crop flexibility coefficients has been estimated, they are then weighted into the production areas by crops with the STPA weights. Although the PA crop flexibility coefficients are endogenously determined at this point, the exogenous set of historical lower and upper average or largest and smallest observed flexibility coefficients may be directly substituted for the endogenous coefficients. Thus, the flexibility coefficients may be mostly endogenously or completely exogenously determined.

**Econometric flexibility coefficient estimation procedure**

An econometric estimation procedure was used for estimating regression equations to calculate yearly flexibility coefficients which were needed to determine the flexibility restraints in the recursive programming sector. The estimation procedures were based on the historical harvested acreage statistics in the HSTAC data set described earlier in this chapter and the Sahi and Craddock econometric equation model [168, 169].

**The regression model**

The problem of developing an approach for accurately estimating flexibility coefficients has been handled differently in almost every recursive programming problem formulation. This situation has been earlier noted in Chapter II. Therefore, choosing the "best" method of estimating accurate and realistic flexibility coefficients for each of the crops in the model puts the model builder in a somewhat precarious position because one technique
has not been proven reliable for a series of different models. But because both lower and upper coefficients need to be estimated for allowable crop acreage changes for year to year and because these coefficients are assumed to be dynamic in nature, the structural econometric model used for their estimation must also reflect the dynamic nature of changes in crop acreages. For these reasons, the Sahi and Craddock model was chosen to estimate the flexibility coefficient equations.

As previously noted, crop acreage flexibility coefficient equations were first estimated by states and then weighted into the various production areas. The equations were estimated from the historical crop acreage data series in the HSTAC data set described earlier. Where irrigated and nonirrigated crop flexibility coefficients were needed for a state, but only a total harvested crop acreage statistic series was available, equations were estimated for both the lower and upper coefficients based on the total acreage data series (Table A.3). These equations were then used for estimating both irrigated and dryland flexibility coefficients.

The Sahi and Craddock (S-C) econometric model is most easily explained in two parts. First, the structural form of the modeling equation expresses the current acreage as a nonlinear function of the preceding year's acreage level. This specification is hypothesized to reflect risk aversion and resource restrictions occurring as crop acreage increases toward full specialization. This relationship may be
expressed as

\[ X_{i,s,t} = a_1 X_{i,s,t-1} + a_2 X_{i,s,t-1}^2 \]  \hspace{1cm} (3.19)

where

\[ X_{i,s,t} = \text{harvested acreage of the } i\text{th crop in the } s\text{th state in year } t; \ i = 1, \ldots \text{ number of crops,} \]
\[ s = 1, \ldots 48 \text{ states, } t = \text{year} \]
\[ X_{i,s,t-1} = \text{harvested acreage of the } i\text{th crop in the } s\text{th state in year } t-1 \text{ and } a_1, a_2 \text{ are fixed coefficients or parameters} \]

Now, by rearranging terms and remembering equations (3.6), equation (3.19) may be rewritten as

\[ \frac{X_{i,s,t}}{X_{i,s,t-1}} = a_1 + a_2 X_{i,s,t-1} = 1 + \beta_{i,s,t} \]  \hspace{1cm} (3.20)

Sahi and Craddock hypothesized that \( a_1 \) was positive, \( a_2 \) was negative, and that \( \beta_{i,s,t} \) become smaller as the acreage level increased. These a priori hypotheses are reasonable assumptions given the relatively large regional acreage levels in their study. But many state crop acreages are relatively small. Therefore, although it would be most likely that \( a_2 \) would be negative, with a limited number of observations and if the acreage level is relatively small, \( a_2 \) could be positive. Also, \( a_1 \) could be negative for relatively small acreages.
The second part of the S-C regression model assumes that farmers do not increase their planted crop acreages, and therefore their harvested crop acreages, at the same rate from year to year. Crop acreage changes are not only a nonlinear function of the previous year's acreage, but are also a function of other relevant economic variables. Thus, the flexibility coefficients would also be a function of these explanatory economic variables.

Theoretically, when a competitive market situation is assumed, the supply of a commodity is determined by its own and competing commodity prices. Sahi additionally notes that sometimes, grain stocks and exports are also considered as variables affecting output. But they can be ignored if the following assumptions are satisfied:

1. the government does not interfere in the marketing of agricultural products,
2. prices are solely determined by the market forces (i.e., demand and supply), and
3. price acts as a force to allocate resources to alternative crops [168, p. 84].

However, constant government interference in commodity markets with price supports, the PL 480 program, acreage allotments, marketing quotas, and other diversion programs that have been implemented over the last few decades tend to undermine the validity of the first and second assumptions.

The third assumption's validity rests partly upon the validity of the two previous assumptions and is empirically questionable. Nevertheless, it is hypothesized that in the long run, prices do act as information devices to fully allocate inputs efficiently among different pro-
duction processes, as in the theoretical economic model. But in the short run, the empirical evidence of perfect competition in agriculture is limited due to the effects of various government programs, the nonhomogeneity and immobility of specialized factors of production, imperfect information, uncertainty and the changeover costs to contrasting production processes.

For the above reasons, Sahi and Craddock hypothesized that the crop flexibility coefficients should be a function of inventories and exports as well as lagged acreage levels. Weather or moisture and technological trend variables were added to the model as explanatory variables to also help explain yearly changes in crop flexibility coefficients. The functional form of the model as indicated above has already been presented in equation in terms of expected variable values (2.98), and also as an explicit linear regression equation using lagged market information and an error term,

\[
\frac{X_{i,t}}{X_{i,t-1}} = a_0 + a_1 X_{i,t-1} + a_2 P_{i,t-1} + a_3 P_{j,t-1} \\
+ a_4 S_{i,t-1} + a_5 S_{j,t-1} + a_6 E_{i,t-1} + a_7 E_{j,t-1} \\
+ a_8 I_{i,t-1} + a_9 I_{t} + e_{i,t} \tag{2.99}
\]

where the price, inventory, and export variables are actual one-year lagged values. The specific variables in the above equation have been previously defined in equations (2.97) and (2.98). The anticipated signs of the regression coefficients were that $a_2$, $a_5$, $a_6$, and
a_{9,i} were positive and that a_{3,i}, a_{4,i} and a_{7,i} were negative.

The Sahi and Craddock equation formulation was modified to reflect the characteristics of U.S. agriculture, to facilitate the speed of state crop equation estimations and to minimize state data collection costs. First, the weather variable was dropped from all the estimated equations. A problem exists when specifying the level of the weather variable for forecasting purposes. This variable could be added for other research inquiries. Second, in many states a crop will have not just one but sometimes two or more major competitors. Therefore, the additional variables of \( P_{k,t-1}, E_{k,t-1} \) and \( S_{k,t-1} \) were added to the model to represent the additional crop, where \( k \) represents the extra competing crop.

Third, in the Sahi and Craddock model, Canadian government interference in acreage response of various crops was hypothesized to occur indirectly through the inventory and export variables. In the U.S., the government has taken more direct action to modify and control crop acreage response of the four feedgrains, wheat soybeans, and cotton. Government policy variables have included price supports via crop loans and crop diversion payments, acreage allotments with different features and direct acreage diversion payments. Therefore, as indicated in Figure 3.10, in order to more accurately represent the full set of explanatory variables affecting crop production decisions, government program variables affecting the \( i \)th crop and competing crops were also added to the various state crop flexibility coefficient
equations.

Finally, despite the fact that the individual feedgrain prices can be estimated as linear functions of the aggregate feedgrain price and the trend variable, the aggregate feedgrain price was used in addition to the individual feedgrain prices. The estimation procedure selected the more significant variable. It was also decided not to use the individual inventories and exports of the individual feedgrains as explanatory variables in the regression equation for two reasons. First, feedgrain exports and inventories are estimated in the aggregate by the simulation feedgrain submodel. Second, the feedgrains are close feed substitutes for each other given relative prices. It is assumed that the individual inventories and exports of the four feedgrains can be expressed as a linear function of the aggregate feedgrain exports and inventory levels.

In summary, the complete model in multiple regression estimation format used for estimating the individual state crop flexibility coefficient equations can be expressed as

\[
\frac{X_{i,t}}{X_{i,t-1}} = a_0 + a_1 X_{i,t-1} + a_2 P_{i,t-1} + a_3 P_{j,t-1} + a_4 S_{i,t} + a_5 S_{j,t} + a_6 EXP_{i,t-1} + a_7 EXP_{j,t-1} + a_8 Inv_{i,t-1} + a_9 Inv_{j,t-1} + a_{10} GOVT_{i,t} + a_{11} GOVT_{j,t} + a_{12} TIME_t \quad (3.21)
\]
where

\[ SP_{i,t} = \text{the national support price of state crop } i \text{ in year } t; \ i = 1, \ldots \text{ number of state crops, } t = 1949 \text{ to } 1973 \text{ except as indicated in Table A.} \]

\[ SP_{j,t} = \text{national support price of the } j\text{th competing crop in year } t; \ j = 1, \ldots \text{ number of competing crops} \]

\[ EXP_{i,t-1} = \text{national exports of the } i\text{th crop in year } t-1 \]

\[ EXP_{j,t-1} = \text{national exports of the } j\text{th competing crop in year } t-1 \]

\[ Inv_{i,t-1} = \text{ending inventory of the } i\text{th crop in year } t \]

\[ Inv_{j,t-1} = \text{ending inventory of the } j\text{th competing crop in year } t \]

\[ P_{i,t-1} = \text{average national market price received by producers for the } i\text{th crop in year } t-1 \]

\[ P_{j,t-1} = \text{average national market price received by producers for the } j\text{th crop in year } t-1 \]

\[ GOVT_{i,t} = \text{government program variables at the national level applying to the } i\text{th crop in year } t \]

\[ GOVT_{j,t} = \text{government program variables at the national level applying to the } j\text{th competing crop in year } t \]

\[ TIME_t = \text{technological trend variable in year } t; \ 1949 = 1 \]

Explanatory variables The full set of independent variables chosen for their explanatory ability is listed below, with a brief explanation of each variable:
1. $F_{GP_{t-1}}$ = one year lagged national aggregate feedgrain market price; $t = 1950, \ldots, 1973$.
2. $W_{P_{t-1}}$ = one year lagged national wheat market price.
3. $C_{P_{t-1}}$ = one year lagged national cotton market price.
4. $S_{P_{t-1}}$ = one year lagged national soybean market price.
5. $B_{P_{t-1}}$ = one year lagged national barley market price.
6. $C_{NP_{t-1}}$ = one year lagged national corn market price.
7. $O_{TP_{t-1}}$ = one year lagged national oat market price.
8. $G_{SP_{t-1}}$ = one year lagged national grain sorghum market price.
9. $W_{SP_{t}}$ = national wheat support price in the $t$th year.
10. $C_{SP_{t}}$ = national cotton support price in the $t$th year.
11. $S_{SP_{t}}$ = national soybean support price in the $t$th year.
12. $B_{SP_{t}}$ = national barley support price in the $t$th year.
13. $C_{NSP_{t}}$ = national corn support price in the $t$th year.
14. $O_{TSP_{t}}$ = national oat support price in the $t$th year.
15. $G_{SSP_{t}}$ = national grain sorghum support price in the $t$th year.
16. $F_{GINV_{t-1}}$ = national feedgrain inventory ending in year $t-1$ in million tons
17. $W_{INV_{t-1}}$ = national wheat inventory ending in year $t-1$ in million bushels
18. $S_{INV_{t-1}}$ = national soybean inventory ending in year $t-1$ in million bushels.
19. $C_{INV_{t-1}}$ = national cotton inventory in year $t-1$ in million bales.
20. \( \text{FGEXP}_{t-1} \) = national feedgrain exports during year \( t-1 \) in million tons.
21. \( \text{WEXP}_{t-1} \) = national wheat exports during year \( t-1 \) in million bushels.
22. \( \text{SEXP}_{t-1} \) = national soybean exports during year \( t-1 \) in million bushels.
23. \( \text{CEXP}_{t-1} \) = national cotton exports during year \( t-1 \) in million bales.
24. \( \text{TIME}_t \) = technological trend variable in year \( t \); 1949 = 1.
25. \( \text{LTIME}_t \) = log of \( \text{TIME} \) variable.
26. \( \text{CALOT}_t \) = national cotton allotment in year \( t \) in million acres.

Data used in the time series statistics above were taken from published U.S.D.A. sources [198, 200].

27. \( \text{WWALOT}_t \) = national winter wheat allotment in year \( t \) in million acres.
28. \( \text{WSALOT}_t \) = national spring wheat allotment in year \( t \) in million acres.
29. \( \text{WWDIV}_t \) = national winter wheat diversion in year \( t \) in million acres.
30. \( \text{WSDIV}_t \) = national spring wheat diversion in year \( t \) in million acres.
31. \( \text{WWSAS}_t \) = national winter wheat set aside in year \( t \) in million acres.
32. \(WSSAS_t\) = national spring wheat set aside in year \(t\) in million acres.

33. \(WWNOT_t\) = national winter wheat no allotment dummy variable representing the change in model structure accompanying removal of acreage allotments; 0 from 1950 to 1970 and 1 from 1971 to 1973.

34. \(WWREL_t\) = dummy variable representing the removal of marketing quota penalties from the allotment program and allowing winter wheat to be planted on the feedgrain base from 1965 to 1971; 0 from 1950 to 1964, 1972 and 1973 and 1 from 1965 to 1971.

35. \(WSREL_t\) = dummy variable representing the removal of marketing quota penalties from the allotment program and allowing spring wheat to be planted on the feedgrain base from 1965 to 1970; 0 from 1950 to 1964, 1971 to 1973, and 1 from 1965 to 1970.

The spring wheat states include Minnesota, Montana, North Dakota, and South Dakota. The preceding nine wheat government program variables are discussed in more detail in Garst and Miller [70]. The explanatory variables for wheat numbered from 29 to 33 were significant very infrequently. The diversion variables were eliminated from the estimated equations whenever possible due to their lack of predictability for predictive model runs after 1973. The set aside and no allotment variables were deleted whenever possible because of their
few number of nonzero observations. The feedgrain dummy variables used for explanatory purposes are listed below:

36. $GCNDIV_t$ = a dummy variable reflecting the years during which acreage restrictions were placed on corn and grain sorghum planting from 1961 to 1972; 0 from 1950 to 1961, and 1 from 1961 to 1973.

37. $GCNDTD_t$ = a dummy variable to represent the trend effect starting in 1961 and ending in 1972 of the grain sorghum and corn divertment program; 1961 = 1, 1962 = 2, . . . , 1973 = 13 and 0 from 1950 to 1961.

38. $BDIV_t$ = a dummy variable representing the years from 1961 to 1972 during which barley was in the feedgrain diversion program; 1 in 1963 to 1966, 1969, 1970, and 1972 and 0 in other years.

A dummy variable for oats was not included in the explanatory set of independent variables.

39. $OATRND_t$ = a dummy variable representing the trend shift away from oats in crop rotations with the introduction of herbicides and the expansion of soybean acreage after 1955 at the expense of oats acreage; 0 from 1950 to 1955 and after 1967, 1 in 1966, 2 in 1967 to 12 in 1967.

In addition to the above explanatory variables, a set of six weighted or effective support prices were used as supplementary variables for the corn, sorghum and barley crops. These weighted support prices were
developed from the empirical work done by Ryan and Abel [165, 166, 167] and Houck and Ryan [106]. A more detailed discussion of the analytical modeling technique used for estimating the effective or weighted support prices will be found in these articles. Basically, these variables embody

"... the concept of an 'effective' or 'weighted' price support rate ... developed as a means of incorporating both acreage restrictions and announced price supports into a single term subject to empirical measurement or estimation. Support rates were adjusted to account for acreage controls in various annual programs. Additional payments made by the Government for withholding land from production of a specific crop were treated as a supply shifter" [165, p. 102].

Specifically, the additional weighted support price variables are listed below:

40. \( WD-CNSPR_t \) = national corn loan rate in year \( t \) weighted by acreage restriction requirements. Direct support payments were added from 1963 to 1965.

41. \( WD-GSSPR_t \) = national sorghum loan rate (per hundred weight) in year \( t \) weighted by acreage restriction requirements. Direct support payments were added from 1963 to 1965.

42. \( WD-BSPR_t \) = national barley loan rate in year \( t \) weighted by acreage restriction requirements. Direct support payments were added 1963 to 1965.

43. \( WD-TCNSPR_t \) = \( WD-CNSPR_t \) plus the corn acreage diversion payment rate weighted by the eligible diversion acreage or total weighted corn support.
44. \( \text{WD-TGSSPR}_t = \text{WD-GSSPR}_t \) plus the grain sorghum acreage diversion payment rate weighted by the eligible diversion acreage or total weighted grain sorghum support rate.

45. \( \text{WD-TBSPR}_t = \text{WD-BSPR}_t \) plus the barley acreage diversion payment rate weighted by the eligible diversion acreage, or the total weighted barley support rate.

All of the price variables were deflated into 1948 dollars with the GNP48 price deflator index. The expected signs of parameter coefficients of the above forty-five variables were determined using economic logic and knowledge of agricultural production practices for each of the seven crops in the model and are found in Table A.8. Where the expected sign of the variable parameter was unknown both a "+" and a "-" are indicated. A blank space indicates that a variable was not included in the set of explanatory variables for a particular crop.

**Estimation problems** The multiple regression model discussed above was used to estimate upper and lower flexibility coefficients by crop and by state. As in Sahi's research inquiry, three statistical and econometric problems occurred during the estimation process. These three problems are insufficient degrees of freedom, multicollinearity and autocorrelation.

As noted earlier, annual harvested crop acreage data was gathered for this analysis from 1949 to 1973 into the HSTAC data set. Additionally irrigated and dryland crop acreage statistics were developed where possible for the seventeen western states for this time
period. Although the eastern states always contained a total of twenty-four observations, the western states historical data series for the western states often contained many fewer crop acreage observa-
tions (Table A.3). These acreage change observations were then stratified into two subsets, on the basis of negative or positive changes in year to year crop acreages, where

1. positive changes were defined as \( \frac{x_{i,t}}{x_{i,t-1}} > 1.0 \).

2. negative changes were defined as \( \frac{x_{i,t}}{x_{i,t-1}} < 1.0 \).

and \( x_{i,t} \) and \( x_{i,t-1} \) are the \( i \)th crop acreage in a state for year \( t \) and \( t-1 \) respectively. The stratification of acreage changes resulted in as few as three, and as many as 21 observations within each subset. Usually, the number of subset observations ranged from eight to twelve. For this reason, it was possible to include only a few variables of the total set of explanatory variables for each upper and lower flexi-
bility coefficient estimating equation. Thus, a degree of freedom problem occurred for many of the regression equation estimations be-
cause of the low relative number of observations to the possible or hypothesized set of explanatory variables.

The degree of freedom problem also posed an additional question as to the most appropriate flexibility coefficient equation estimating procedure for use in this inquiry. In order to minimize time spent estimating these equations, and to minimize the cost of estimation, it was decided to use a stepwise regression technique [47, chapter 6]. found in the SAS computer program manual [175]. The SAS computer program
also has the additional advantage of being able to stratify the HSTAC data set into positive and negative yearly acreage changes efficiently and quickly.

The stepwise regression procedure is most often used to select a subset of variables from a larger collection of independent explanatory variables which best explain the variance of the dependent variable. While using a stepwise statistical selection process does not test a particular economic model as is traditionally done in econometric analysis [113, 116], it does permit a fast screening of many alternative economic models. It is also realized that a statistical regression model's explanation of the behavior of a dependent variable does not infer that the selected model does indeed accurately represent real world economic processes. It is assumed though, that the selection of hypothetically relevant economic explanatory variables by the economist representing economic logic and experience, would preclude the final selection of a "random" model.

The stepwise procedure in SAS contains five different stepwise techniques. Three of these were considered for the multiple regression analysis, forward selection, stepwise, and maximum $R^2$ improvement. The SAS manual provides a fairly concise explanation for each of these techniques,

1. **Forward Selection.** This technique finds first the single-variable model which produces the largest $R^2$ statistic. $R^2$ is the square of the multiple correlation coefficient; it can also be expressed as the ratio of the regression sum of squares to the (corrected) total sum of squares. For each of the other independent variables, STEPWISE
calculates an F-statistic reflecting that variable's contribution to the model were it to be included. If the F-statistic for one or more variables has a significance probability greater than the specified "significance level for entry", then the variable with the largest F-statistic is included in the model. Variables are thus added one by one to the model until no variable produces a significant F-statistic.

3. Stepwise. This technique is a modification of the forward selection technique. After a variable is added, however, STEPWISE looks at all the variables already included in the model. Any variable not producing a partial F-statistic significant at the specified "significant level for staying in" is then deleted from the model. The process terminates when no variable meets the conditions for inclusion in the model or when the variable to be added to the model is one just deleted from it.

4. Maximum \( R^2 \) Improvement. This technique was developed by James H. Goodnight; he considers it superior to the stepwise technique and almost as good as calculating regressions on all possible subsets of the independent variables. Unlike the three techniques above, this technique does not settle on a single model. Instead, it looks for the "best" one-variable model, the "best" two-variable model, and so forth. It finds first the one-variable model producing the highest \( R^2 \) statistic. Then another variable, the one which would yield the greatest increase in \( R^2 \) is added. Once this two-variable model is obtained each of the variables in the model is compared to each variable not in the model. For each comparison, the procedure determines if removing the variable in the model and replacing it with the presently excluded variable would increase \( R^2 \). After all the possible comparisons have been made, the switch which produces the largest increase in \( R^2 \) is made. Comparisons are made again, and the process continues until the procedure finds that no switch could increase \( R^2 \). The two-variable model thus settled on is considered the "best" two-variable model the technique can find. The technique then adds a third variable to the model, according to the criteria used in adding the second variable. The variable model is discovered, and so forth. This technique differs from the STEPWISE technique in that here all switches are evaluated before any switch is made. In the STEPWISE technique, removal of the "worst" variable may be accomplished without consideration of what adding the "best" remaining variable would accomplish [175, p. 127-128].

The third technique, Maximum \( R^2 \) procedure, was chosen because of its relative advantages as an equation estimating technique. Generally equations were estimated with from one to \( n/2 \) independent explanatory
variables, where \( n \) was the number of observations in the upper or lower flexibility coefficient subset. The selection of variables or model from alternative sets of variables or models was made primarily on the basis of the lowest mean square error statistic and the number of inconsistent coefficient signs with a priori expectations, and finally on the statistical significance of the regression coefficients. Either a lagged acreage or at least one price variable was included in each equation. The lagged acreage variable was often eliminated by the maximum \( R^2 \) routine as a statistically insignificant variable. Unlike Sahi's formulation, the lagged acreage variable was not forced to be included in the estimated equations [168, p. 93]. Preliminary analysis indicated that the forced inclusion of this variable not only often increased the number of incorrect signs of coefficients, but also increased the mean square error (lowered \( R^2 \)) because variables became selected for reasons of multicollinearity with the lagged acreage variable.

Other estimation problems occurred when the coefficient signs were inconsistent with a priori expectations for a given variable for a given crop. When the sign was inconsistent, the variable was removed from the set of explanatory variables and a new set of equations was estimated. For a few equations, enough explanatory variables were eliminated so that an equation with a set of consistent coefficient signs and an \( R^2 \) above .70 could not be found. When this occurred, a judgment choice was made to select a "second" best equation.
an equation could be found with an $R^2$ above .70, and only one inconsistent parameter sign, it was selected for use in the model. In all cases, if more than one equation was available for a crop in a state, the equation with the lowest mean square error and the fewest dummy variables or government program variables was selected. Also, if a variable was not statistically significant according to a student t-test criteria in a set of n variables, but decreased the mean square error relative to the n-1 variable equation and had a consistent coefficient sign it was kept in the model. Otherwise it was deleted from the explanatory variable set.

If a lower or upper state crop flexibility equation could not be found with an $R^2$ above .70, consistent parameter signs, or because too few degrees of freedom were available for estimated, the average upper and lower flexibility coefficients estimated from historical data were used. High and low average and highest and lowest observed crop flexibility coefficients were determined from each of the upper and lower subsets created as dependent variables for the econometric equation analysis. Certain flexibility coefficient ratio observations were eliminated from these subsets for historical periods when the state crop acreage levels were substantially different from those during the six year period 1968 to 1973. For convenience, it was assumed these subsets of observations constituted random samples from normal, independently distributed populations [104]. The upper and lower averages were calculated by summing all the subset observations and
then dividing by the number of observations. The highest and lowest
crop flexibility coefficients limits were then determined by adding or
subtracting twice the standard deviation of the subset from the upper
and lower average respectively. When the upper or lower limits calcu-
lated above were greater or less than the historical largest or smallest
flexibility coefficient, these coefficients were substituted for the
above estimated limits. The lower and upper averages and highest and
lowest limits were then weighted into production areas with the STPA
weights, and are found in Table A.2.

Multicollinearity among many independent variables was often ob-
served in many data subsets and was undoubtedly the cause of many equa-
tion estimation problems. Time series data often exhibits multi-
collinearity between and among explanatory economic variables. Multi-
collinearity has been discussed earlier in the Chapter II section on
regression analysis. Generally, in recapitulation, multicollinearity
has three effects. First, the quantification of the effect of changes
in a single explanatory variable on the dependent variable becomes
difficult to detect in the presence of multicollinearity because the
sampling variances of the least squares coefficients are expected to
be large [192, p. 216]. Second, the multicollinearity between indepen-
dent variables biases the regression coefficients towards zero [193,
p. 348]. Third, the signs of variable parameters may be inconsistent
with their expected a priori signs. For these reasons, the estimated
variable parameters are likely to be highly unreliable [168, p. 91].
The multicollinearity problem is compounded by the small number of observations. It was noted earlier in Chapter II that Johnston has suggested that a larger number of observations might act to minimize multicollinearity.

Finally, ratio variables were not used even though a few degrees of freedom could have been saved in each equation and multicollinearity possibly could have been minimized in each data set.

However, the use of ratio variables has three major limitations. First, the estimate of the regression parameter of this variable appears conceptually inconsistent. For example, the regression coefficient of the ratio variable of wheat and flaxseed prices indicates that both prices have almost equal effects on wheat acreage. This would probably not be the case. The second limitation is that the use of ratio variable requires an erroneous premise that the levels of individual prices are unimportant. A third reason for avoiding ratio variable is the difficulty in interpreting the estimated coefficients [168, p. 92].

Autocorrelation has also been discussed earlier in Chapter II together with multicollinearity. To briefly summarize this earlier discussion, autocorrelation error normally occurs due to incomplete specification of the econometric model. In this analysis, it could be reasonably argued that many significant variables were eliminated due to lack of degrees of freedom and also due to multicollinearity, because a variable's significance may not have been recognized statistically. It was demonstrated earlier that the presence of serial correlation causing autocorrelation, does not bias the estimated variable parameters or make them inconsistent when the lagged dependent variable is omitted from the model. However, autocorrelation does lead
to biased estimates of the standard errors of regression parameters. Since variables were not deleted from the set of explanatory variables on the basis of the student t, correcting for autocorrelation in this case was not carried out for the estimated flexibility coefficient equations in the model.

On the other hand, when a lagged dependent variable is included in the econometric equation, autocorrelation can be shown to cause bias and inconsistency in estimates of regression coefficients. As Nerlove has demonstrated, autocorrelation can be reduced in agricultural supply equations when the lagged dependent variable is included in the equation [141, 142]. But in the formulation of the econometric model in this study, the lagged dependent variable is not used as an independent explanatory variable. Rather, the lagged numerator or the denominator of the dependent variable was utilized in the equation. The standard Durbin-Watson test for serial correlation becomes inappropriate when a lagged dependent variable is in the estimated equation. Also the "large sample" Durbin test for autocorrelation is inappropriate if less than thirty observations are available [113, p. 112-113]. Thus, testing for significant levels of autocorrelation in the flexibility coefficient equations where the lagged acreage variable was included, could not be accomplished in this analysis. In summary, although autocorrelation was recognized as a possibly serious problem, further biasing regression coefficients estimated from multicollinear data and too few observations, the problem of autocorrelation was disregarded
in this study. Equations were used as estimated with the OLS regression technique in their original form, uncorrected for possible serial correlation.

**Flexibility restraints** The third segment of the flexibility restraint submodel calculates the acreage flexibility restraints for each crop activity in the recursive programming sector. The final flexibility restraints are determined in a series of calculation and decision processes, found in Figure 3.10 continuing from the estimation of upper and lower flexibility coefficients by crop in each producing area.

The flexibility coefficients, which may be either endogenously determined with regression equations or exogenously determined are multiplied by the relevant PA crop acreage lagged one year. This interaction determines the preliminary flexibility restraints for the next year. The lagged crop acreage may be exogenously given from the actual harvested acreage statistics for a particular year from 1968 to 1973, or the lagged acreages may be taken from the endogenous recursive programming sector solution in year t-1 during and after this period. Use of the lagged endogenous solution acreages completes the interfacing moving from the recursive programming sector to the SUMMARY sector to the REVISE sector.

After the initial calculation of the upper and lower flexibility restraints for each activity, these restraints are then modified as needed to reflect other acreage restrictions relevant for the forthcoming year. These restrictions include absolute upper and lower
acreage level bounds, and allotment acreage restrictions, if any, as they apply to the wheat and cotton cropping activities. The derivation of the upper and lower absolute bounds for crop activity acreages has been discussed earlier in this chapter in the recursive programming section. Briefly, again, if the preliminary upper or lower acreage restraints are greater than or less than the absolute restraints, the preliminary restraints are set equal to the upper or lower absolute acreage restraint respectively. The remaining acreage restraint is calculated normally. But these restraints are not necessarily the finally estimated activity upper and lower bounds.

If a national wheat or cotton allotment program is in effect, the preliminary estimated flexibility restraints are also modified to reflect this situation in the following manner. The PA wheat and cotton harvested crop acreages from 1968 to 1970 were divided by the national allotment for each year for each respective crop. The resulting figures showing the proportion of the national allotment harvested of each crop in each producing area were then averaged. These final PA to national allotment average ratios are then multiplied by the national allotment for cotton or wheat in a given year to estimate the upper allotment restraint level. The lower allotment restraint level is then determined by multiplying the upper allotment restraint by the lower flexibility coefficient determined earlier. Now, if the upper allotment restraint is greater than the preliminary flexibility restraints, the upper and lower preliminary restraints are
used. If this is not the case, then the upper allotment and lower estimated flexibility restraints are used as the final upper and lower activity acreage level restraints.

After the process of determining the final crop acreage restraints from the preliminary estimates and the various restrictions, the final upper and lower activity bounds are placed in a predetermined computer memory storage area. Once this is accomplished the flexibility restraint subsector of the REVISE sector computer program is complete, and the computer returns to the main control program.

The main control program then interfaces the information generated in the REVISE sector with the recursive programming sector as demonstrated in Figure 3.10. The upper and lower crop flexibility restraints, nitrogen fertilizer prices, expected activity net returns, and expected activity yields and nitrogen use input-output coefficients relevant for year $t$ are transferred to the recursive programming sector. This information is used to construct a new programming sector problem in year $t$ from the previous year's problem. As indicated, any changes in land availability or water use restraints can also be included in the new programming problem. The recursive programming problem in year $t$ is then solved to maximize expected returns to each activity in each producing area. The optimal solution of wheat and other crop acreages levels then determines the total production for each crop in the twenty-eight market regions. The individual wheat acreage and production data are summed in the SUMMARY sector and presented for use in the simula-
tion sector as national statistics. From the simulation sector, the model then moves to the REVISE sector to generate information to generate a new programming problem in year $t+1$. Thus, the four sectors in the complete recursive interactive programming model are able to interact and cycle in a year to year time framework. Naturally, the total number of years or periods is determined by the research inquiry.
A national recursive simulation and linear programming
model of some major crops in U.S. agriculture

by

Kenneth Harry Baum

Volume 2 of 2

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CHAPTER IV. EMPIRICAL RESULTS

The purpose of this chapter is to present the empirical results of the first generation recursive interactive programming model constructed in this thesis study. The RIP analytical economic and methodological framework has been described in the previous chapter. Tables containing summary information concerning national acreage, market variable and turning point statistics can be found in the Appendix. These tables will be referred to during the discussion of the various explanatory model simulation runs and the predictive model simulation run. The evaluation of the performance of the RIP modeling research will be considered in the context of an initial methodological modeling research study.

The chapter will be divided into three sections. The statistical evaluation procedures used to analyze the empirical results of the various RIP simulations are presented in the first section. The explanatory performance of the five alternative model simulation runs during the historical period, 1969 to 1973, will be briefly discussed in the second section. A results summary for each of the different RIP modeling variations will also be included in this section. An evaluation of the predictive behavior of the model from 1974 to 1980, will be presented in the third section of the fourth chapter. Many of the methodological and empirical problems encountered while trying to use this first generation model as a predictive analytical tool will also be discussed in this third section.
Choosing the statistical evaluation procedures for analyzing the recursive interactive programming model was difficult for two reasons. First, the recursive programming model is a new modeling technique combining elements of both simulation and programming models. Techniques designed to statistically analyze either of these models are not wholly appropriate for investigation of the larger interactive model. Second, a large number of statistical evaluation techniques are available for analyzing macro and micro models [176]. Distinguishing between relevant or applicable formal statistical methods to evaluate a particular empirical economic model is dependent upon the goals of the research inquiry and is also a function of the experience and judgement of the model builder. For these reasons, three statistical evaluation procedures for examining the relative accuracy different RIP model run results were chosen for use in this study. They are national summary statistics, Theil U coefficients and statistics involving crop acreage turning points.

National summary statistics include the individual predicted and actual crop acreages, their differences, their percent differences and the market information estimated in the feedgrain, wheat, cotton, and soybean simulation subsectors for the historical model runs, 1969 to 1973 and the predictive model run from 1974 to 1980. Although the recursive programming sector solution data could be analyzed by producing area or market region, this procedure would be difficult and consume a
great deal more time than is available for this study. For example, a more disaggregated analysis would need twenty-eight market region or ninety-nine producing area data tables for each year for each different modeling run in the complete study. Over a five year period, 140 or 495 data tables would be generated respectively. Additionally, while the RIP model can be used in the future for disaggregate agricultural production and policy analysis, the emphasis of this research study is to develop the economic modeling methodology and then to empirically demonstrate a national RIP model. Therefore, it was decided that only national, yearly aggregated acreage, production and market statistics would be presented to simplify the examination of modeling run results.

The process of model and predictive validation, or the comparison of model generated values with actual data to gauge how accurately the model reproduces the economic behavior it is intended to simulate, was also estimated by a Theil's inequality coefficient, $U$. These coefficients were only generated for the historical period model runs. The Theil $U$ inequality coefficient is designed to indicate the extent of errors generated by a model where actual variable values are known before the model is run. An error, then is defined as $(P_t - A_t)$ where $P_t$ is the predicted value of a variable in year $t$ and $A_t$ is the actual value.

The Theil $U$ coefficient was estimated in this analysis with the following equation:
where $P_{i,t}$ is the predicted acreage of the $i$th activity and $A_{i,t}$ is the actual acreage of the $i$th activity [192, p. 31-42]. The above mathematical formulation follows Theil's initial view that $P_{i,t}$ and $A_{i,t}$ are predicted and actual values in year $t$, respectively [192, p. 34].

Theil later redefined $P_{i,t}$ and $A_{i,t}$ as predicted and actual changes should be used, rather than actual and predicted values [193, p. 28]. The properties of the initial Theil $U$, where $P_{i,t}$ and $A_{i,t}$ are actual values, and that $U$ varies between zero and unity, where unity indicates perfect inequality between predictions and actual observations and zero indicates perfect prediction. The original $U_1$ can be decomposed into a bias, variance and covariance proportions but these additional statistics are not relevant to this inquiry. Finally, the $U_1$ coefficients are used in evaluation procedures in a comparative fashion. The value of a Theil $U$ coefficient yields information as to relative model's accuracy only in comparison with another model's Theil $U$ coefficients.

The third evaluation procedure used turning point statistics, both for individual crops by year and total predicted turning points nationally. A turning point was defined as the correct prediction of the activity acreage direction from year $t-1$ to year $t$. This definition is a slightly different and more comprehensive definition of a turning point found elsewhere [169], where a turning point is a
directional change in a variable after more than two consecutive increases or decreases in value. Turning point statistics were also estimated only during the historical period from 1969 to 1973.

**Historical Simulations**

Five variations of the recursive interactive programming model were selected and tested during the historical period for which comparative data was available, from 1969 to 1973. The choice of which model variations were to be used for the explanatory simulations was a very difficult decision to make, because many possible model variations were available for immediate use in this first generation model. Cost and time considerations also complicated this decision process. As previously explained in Chapter III, the population of possible RIP model variations is based on choices of which parameters or variables in the model are estimated from exogenously or endogenously determined information (Table 3.8). The final decision as to which model variations were to be finally chosen, was based on their individual and complementary hypothesized ability to test the accuracy of the RIP model and to demonstrate the flexibility and development of the economic modeling methodology used in this thesis study.

More specifically, the primary objective of these simulation runs was to test the explanatory performance of the different RIP model variations with regard to the national spatial distribution of crop activities, and the acreage and production response levels during this period. The secondary objective of these simulations was to further
examine how this modeling methodology actually works in practice when applied to an economic system.

Each historical simulation began in 1968 with a predetermined fixed bound solution for each crop activity acreage in the recursive programming sector. The 1968 crop production levels were given exogenously to the simulation sector. The exogenously given crop export levels and support prices given to the simulation and REVISE sectors from 1968 to 1973 can be found in Tables A.9, and Tables D.1.1 and D.1.8.

**Historical simulation run number 1**

The first simulation run during the historical period utilized the RIP model as a national recursive programming model. The objective of this modeling variation was to try to accurately predict harvested crop acreage levels on a year to year basis. For this reason, all of the information used by the REVISE sector to generate the recursive programming sector tableaus after 1968 was taken from an exogenously determined data set. Thus, the crop acreage information calculated in the SUMMARY sector, and market information estimated in the simulation sector was not used in the first historical run. Rather, the changes in the objective function and flexibility coefficients were estimated in the REVISE sector for year t with the actual state acreage, price and other relevant market information in year t-1 and government variable information relevant for year t, taken from an exogenous data set.

Additionally, the following REVISE sector variations were chosen. First, the objective function for year t in the recursive programming
sector was calculated with the one year lagged local to national crop price ratio. Second, the Spillman optimum trend yield was used to estimate the expected gross return of producers. In effect, the economic hypothesis being tested was that producers base their production decisions on an expected net return function that included an optimum yield expectation combined with the previous year's local to national price ratio, or shipping pattern. Third, the flexibility restraints were estimated with the regression calculated flexibility coefficients and the actual lagged acreage level of the crop activity, rather than the endogenously determined acreage levels of each crop activity.

The summary statistics utilized to evaluate the first historical run are separated into dryland, irrigated and aggregated crop tables. The national acreage and turning point statistics for the first historical run can be found in Tables C.1.1 to C.5.3. The various crop Theil U coefficients are found in Tables B.1.1 and B.1.2. The yearly aggregate Theil U coefficients are found in Table B.6, and the yearly aggregate correct percentage of turning points are found in Table C.33.

1969 The dryland crop acreages were estimated fairly accurately in 1969. Cotton and oats acreages were underestimated by over five percent, while the other crops were overestimated from six to thirteen percent. The irrigated crop acreages varied greatly in their estimation accuracy. Corn, barley, cotton and wheat were estimated within four to ten percent of their actual acreages, while oats were underestimated by over 22 percent and soybeans and sorghum were overesti-
The aggregated crop acreages were generally close to the actual national levels. Cotton and wheat acreages were estimated within seven and six percent respectively. The other five crops were within approximately ten percent of their actual levels.

The turning point statistics also suggest a fairly accurate directional choice for most of the irrigated, dryland, and aggregated crop activities in the model. Cotton and wheat dryland turning points were estimated with the most accuracy, with over 96 and 82 percent respectively. The remaining crops had turning point accuracies of over 60 percent, except for sorghum which had a poor 42 percent record, although the total estimated acreage was estimated fairly accurately. The irrigated crops turning point accuracy were inconsistent with their predicted acreage level accuracy, except for cotton. Cotton, sorghum, oats, and soybeans turning point accuracy were all above 85 percent. Irrigated corn acreage, which was estimated very accurately, only had 37 percent turning point accuracy. After aggregating, cotton and wheat had the largest turning point estimation accuracy, as well as the acreage level accuracy. The remaining five crops turning points were estimated within a range of approximately 60 to 65 percent. Overall, the correct percent of predicted turning points was over 68 percent.

The Theil U statistics when compared between irrigated and dryland crops tend to confirm the relative accuracy of the acreage level
statistics. Among the dryland crops, wheat and cotton have the lowest Theil Us, while barley has the largest, almost .2. Among the irrigated crops, corn and wheat have the lowest Theil Us while soybean and oats have the largest figures. The aggregate Theil U statistics for the individual crops also follows the aggregate crop acreage accuracy levels. The overall Theil U statistic in 1969 was .062.

1970 The crop acreage levels were predicted with a great deal more success in 1970 than in 1969. Cotton dryland acreage was estimated within 11,000 acres or .14 percent and -1.05 percent on irrigated land. Corn dryland acreage was overestimated by 3.42 percent on dryland and underestimated by 3.27 percent on irrigated land. Wheat acreages were estimated within 1.45 and -4.35 percent on dry and irrigated land respectively. Irrigated barley acreage was underestimated within one percent but overestimated on dryland by over 15 percent. Oats acreage was again underestimated for both dryland and irrigated crop activities, but by a lesser amount than in 1969. Sorghum for grain acreage was overestimated on both irrigated and dryland by 11 and 20 percent respectively. Soybean acreage was fairly accurately estimated for dryland activities, but was overestimated by almost 75 percent in 1970 crops on irrigated land.

The aggregation of both irrigated and dryland crop acreages demonstrated an overall accurate crop acreage estimation in 1970. Cotton, corn and wheat harvested acreages were estimated within three percent of their actual figures. Oats and soybean acreages were within approxi-
mately seven and eight percent respectively. Barley and sorghum acreages were overestimated by approximately 13 percent.

Eleven of the fourteen crops estimated a fairly high level of correct turning points. These figures ranged from 61 to 88 percent correct. Dryland cotton, irrigated sorghum and irrigated wheat had the highest percentages with 88.5, 85.2, and 84.2 respectively. Although the dryland and irrigated corn activity national acreage levels were very accurate, the turning point percentages of both did not indicate this circumstance. Dryland corn turning point accuracy of 37.7 percent was the second lowest of all the fourteen crops. Both the irrigated and dryland soybean turning point accuracy were fairly low, 31.9 and 40.0 percent respectively. The total percentage of correct turning points for the 538 activities was 60.4, almost eight percent lower than in 1969.

The Theil U coefficients also indicate that most crop acreages were estimated with greater accuracy in 1970 than in 1969. Although eleven of the fourteen coefficients were less than .10 as in 1969, six of the seven dryland crop coefficients were less than those in 1969. The dryland sorghum coefficient was larger. The irrigated crop Theil U coefficients varied from .025 for barley to .319 for soybeans. Interestingly, the Theil U coefficient increased for irrigated corn despite the greater accuracy in total estimated acreage and turning point accuracy from 1969. The aggregate Theil U coefficients followed the pattern of the dryland crops. The overall Theil U coefficient for 1970 was .042.
1971 The crop acreages predicted by the RIP model were consistently close to their actual acreage levels. For the dryland crops, corn was estimated to within one percent while oats and wheat were estimated within 2.25 percent. Barley, sorghum and soybean acreages ranged between approximately four and eight percent of their actual acreages. Cotton acreage or dryland was overestimated by almost 18 percent after being closely estimated earlier. Most of the estimated irrigated crop acreages were very close to their actual values ranging between 1.94 to -2.45 percent error. The soybeans acreage was overestimated by almost 34 percent, and cotton overestimated by nine percent. The aggregated crop acreages were also very accurately estimated except for cotton which was overestimated by 15 percent. Sorghum acreage was underestimated by almost eight percent after being overestimated earlier in 1969, and 1970. Corn, cotton and wheat acreages were all predicted within approximately two percent.

Almost half of the 14 crop turning point accuracy statistics were less than 60.0 percent. These were evenly split between the dryland and irrigated crops. Dryland corn only had about 64 percent turning point estimated correctly, yet the total estimated acreage was less than one percent error. The same situation occurred for dryland barley and soybeans, and irrigated corn, cotton and wheat. Dryland cotton had both low turning point and acreage estimation accuracy. In the national aggregate statistics, sorghum, oats and wheat were estimated with the highest percentage of turning points. Cotton had the lowest
1971 The crop acreages predicted by the RIP model were consistently close to their actual acreage levels. For the dryland crops, corn was estimated to within one percent while oats and wheat were estimated within 2.25 percent. Barley, sorghum and soybean acreages ranged between approximately four and eight percent of their actual acreages. Cotton acreage or dryland was overestimated by almost 18 percent after being closely estimated earlier. Most of the estimated irrigated crop acreages were very close to their actual values ranging between 1.94 to -2.45 percent error. The soybeans acreage was overestimated by almost 34 percent, and cotton overestimated by nine percent. The aggregated crop acreages were also very accurately estimated except for cotton which was overestimated by 15 percent. Sorghum acreage was underestimated by almost eight percent after being overestimated earlier in 1969, and 1970. Corn, cotton and wheat acreages were all predicted within approximately two percent.

Almost half of the 14 crop turning point accuracy statistics were less than 60.0 percent. These were evenly split between the dryland and irrigated crops. Dryland corn only had about 64 percent turning point estimated correctly, yet the total estimated acreage was less than one percent error. The same situation occurred for dryland barley and soybeans, and irrigated corn, cotton and wheat. Dryland cotton had both low turning point and acreage estimation accuracy. In the national aggregate statistics, sorghum, oats and wheat were estimated with the highest percentage of turning points. Cotton had the lowest
percent turning point accuracy, followed closely by barley. The total predicted turning point statistic was 60.8 percent, almost the same as in 1970.

The Theil U coefficients for the 14 crops also indicate that some crops were estimated with better accuracy in 1971, and some were estimated with larger relative errors. Dryland barley, corn, and soybeans and irrigated corn, oats and sorghum Theil U coefficients showed marked improvement. The remaining crops had either relatively the same degree of relative errors or larger relative errors. The various changes in relative errors are also indicated for the aggregated crop Theil U coefficients. Although sorghum acreage was more closely estimated than that of cotton, the sorghum Theil U statistic, .136, was greater than that of cotton, .103, indicating greater relative estimation errors. Finally, the total aggregate Theil U statistic was calculated as .55.

1972 Many of the crops in the model were estimated with excellent accuracy in 1972 except for dryland corn and sorghum, and irrigated sorghum and soybeans. Dryland barley, cotton, oats, soybeans, and wheat, and irrigated barley were estimated within four percent of their actual values. The remaining irrigated crops were estimated within about 6.5 to 9.5 percent of actual acreages. Dryland corn and sorghum acreage was overestimated by 16 and 20 percent respectively, while irrigated soybean acreage was underestimated by over 60 percent. The aggregative crop acreages show that oats and wheat
acreages were estimated within one percent of their national totals; corn within 15.3 percent; sorghum within 18 percent; and the remaining three crops within 3.5 to 4.5 percent.

Despite large acreage estimation errors, dryland corn and sorghum had two of the largest turning point accuracy statistics, 80.3 and 72.2 percent respectively. Dryland wheat also had a large or high turning point accuracy of 82.5 percent. Cotton had the only dryland turning point accuracy under 50 percent, 46.2. The turning point accuracy of the irrigated crops was not closely related to the acreage accuracy. Soybeans had the highest statistic of 100 percent, followed by irrigated corn and sorghum. Irrigated and aggregated cotton and barley had turning point statistics under 60 percent. The remaining five crops in the aggregate had turning point statistics of between 61.3 percent for oats to 81.1 percent for corn. The model total predicted turning point figure was almost 68 percent in 1972, an improvement from 1969 and 1970.

The individual crop Theil U statistics were reasonably good for 1972 except for irrigated soybeans and dryland barley and sorghum which were all over .10. The remaining irrigated crops had Theil U statistics ranging from .012 for irrigated barley to .088 for wheat. The dryland crops ranged from a .021 Theil U statistic for oats to .082 for wheat. Dryland corn Theil U was also relatively large at .078. The national aggregate Theil U statistics for 1972 followed almost the same pattern as the dryland crops, with sorghum and barley
having the largest coefficients and oats and soybeans the lowest coefficients. The overall Theil U coefficient for 1972 was .074.

1973 An interesting pattern of estimated harvested acreage predictions occurred in 1973 with some crops acreages very accurately estimated, and others estimated not very well. The dryland barley, corn, sorghum, soybean and wheat acreages were mostly estimated within 3.5 percent of the actual figures. The cotton acreage was overestimated by 26.2 percent and the oats acreage was underestimated by over 13 percent. The irrigated corn acreage was estimated almost perfectly. The irrigated barley and sorghum acreages were also closely estimated at -3.45 and 4.76 percent respectively. The remaining four irrigated crops were underestimated from between almost 16 to 21 percent, except for cotton, which was overestimated by 11.3 percent. The aggregated acreages of cotton and oats were overestimated and underestimated by almost 22 and 13 percent respectively. Wheat aggregated acreage was the most accurately estimated at .89 percent error, followed closely by sorghum with a 2.5 percent error and barley and corn acreages with -2.8 and 2.8 percent errors. Thus, on the average, the aggregate crop acreages were fairly consistently estimated.

The estimation of turning points for many individual crops was relatively high. Dryland barley, cotton, oats and soybeans all had statistics above 70 percent, with soybeans at almost 94 percent accuracy. Cotton had the next best figure at almost 81 percent, although the acreage level was severely overestimated. Sorghum had the lowest
turning point statistic of the dryland crops at 50 percent, although it had one of the lowest acreage level percentage errors. Irrigated corn and cotton also had the lowest turning point accuracy figures at 41.7 and 38.9 percent and relatively good acreage predictions. Irrigated sorghum was the only consistent crop and had the highest accuracy with 81.5 percent followed closely by irrigated oats and soybeans at 80 percent. Most of the aggregated crop turning point statistics ranged between those of corn at 55.2 percent and oats at 74.2 percent. Soybean turning point accuracy was 92.3 percent. The total aggregate turning point accuracy statistics for 1973 was 66.91.

Only two of the individual crop Theil U statistics were above .10; dryland cotton at .233 and irrigated wheat at .131. Most of the dryland crop Theil U coefficients were below .05, while the irrigated crop coefficients were, on the average, slightly higher. The aggregate crop coefficients were relatively small compared to the cotton coefficient. These aggregate Theil U coefficients follow the relative aggregate crop percent acreage differences. The national aggregate Theil U coefficient for 1973 was .049, demonstrating a lower overall relative error than the predicted activity acreages produced in 1972, 1971, and 1969.

Summary In the first historical simulation, the RIP model was used as a recursive programming model. The statistical results of this simulation indicates that this modeling variation is fairly accurate for predicting the spatial distribution and the four national
aggregate feedgrains, wheat, soybean and cotton harvested crop acreages and therefore their supply response from year to year. The correct aggregate turning point percentages were above 60 percent in all five years. In 1969, 1972, and 1973 the correct number of turning points was over 67 percent. The national, total aggregate Theil U coefficients were less than .075 in each of the five years, and were under .050 in 1970 and 1973. Thus, the prediction results of the modeling variation of the RIP model chosen for the first simulation shows a close correspondence to the actual national crop production patterns and supply responses.

Although the overall predictive response or behavior of the recursive programming variation of the RIP model can be considered close to the actual production behavior of the segment of the agricultural industry contained in the model, a note of caution must be introduced into the analysis. In most years, most of the disaggregated and aggregated crop acreages were estimated within 10 percent of their actual values. Additionally, many of these crop acreages were estimated with much better precision, to within five percent. But other crops were not estimated with a great deal of accuracy. For example, in 1972, the aggregate corn and sorghum acreages were overestimated by over 15 and 18 percent respectively, yet oats and wheat acreages were estimated to within one percent of their actual levels. In 1973, corn and sorghum acreages were estimated within three percent of their actual values. The example presented above could be repeated
with either the disaggregated or aggregated turning point statistics or Theil U coefficients. Therefore, the results from this simulation present somewhat uneven crop acreage and production response patterns each year and between years.

Finally, these uneven results for the various individual crops in the model can be traced back to four sources of error. First, there are undoubtedly many estimation errors in the calculation of flexibility coefficients because of the unreliability of the flexibility coefficient regression equations. Because of the possible errors in upper and lower flexibility coefficients the flexibility restraints would then have been inaccurate also.

Second, the use of incorrect expected net returns for various crops within a production area could produce turning point errors. For example, a crop that should have been at its upper bound in a producing area may have been at its lower bound or between bounds because it was not specified as one of the most profitable crops. This turning point error could have occurred for two reasons.

"One is that errors result from the fact that land utilization patterns were estimated using highly aggregate models. . . the models presuppose perfect homogeneity in the response of individual farm firms. But this assumption does not hold in the real world because there are many interfarm differences which create variations in response to price and other economic variables.

The second hypothesis for explaining the turning point errors is that the expected net returns per acre for crops included in the model are not accurate. This inaccuracy could be a result of the application of inappropriate expectation models for estimating prices, costs, yields . . . and/or quotas. In other words, the expectation model utilized in this study (i.e., the current
year expected values equal to the preceding year actual data) does not appear to be the true model used by the prairie grain producers. These two hypotheses are not necessarily independent; together they make the programming model in some years insensitive to price changes." [168, p. 122-123]

Therefore, the errors in the activity level changes could have been caused by either inappropriate use of aggregative data, and incorrect net return per acre coefficients in the objective function. An additional confounding problem causing estimation error is that the STPA and PAST weights were changing over the five year period. Yet, in this research project, these weights were assumed to be fixed.

Third, the model estimates harvested crop acreages. An implicit assumption made was that weather conditions remained "normal" from 1968 to 1973 over each producing area in the continental U.S. Thus, the same percentage of planted acreage is assumed to be harvested in each year, when in reality, this percentage varies with changes in the weather.

Fourth, the actual harvested dryland and irrigated land base for each producing area was not used in each of the years 1969 to 1973. The land bases actually used are described in Chapter III. The land base used from 1969 to 1972 is obviously too large in some years, most notably 1969 to 1972 because many crop acreages were overestimated. When the land base is too large in a producing area, the model is in Stage 1 (Figure 2.6) and crops do not compete for available land. Thus large acreage overestimation errors may occur.
Additionally, as Sahi notes, these sources of acreage estimation errors

... were additive: an error in the solution acreage of one crop creates discrepancy between the estimated and actual acreages of other crops. Furthermore, even a small error in the estimates of wheat or ... [another major crop]. ... causes a sizeable error in the solution acreages of the more minor crops [168, p. 127].

Finally, all these reasons for estimation errors are relevant to each of the following modeling variations of the basic initial RIP model. Therefore, a detailed concise explanation of changes in crop acreages and production response can prove to be extremely complicated and will not be attempted here. Rather the analytical objective of the discussion of each simulation is to present only a broad sketch of the empirical results and behavioral characteristics of the RIP model, where appropriate.

**Historical simulation run number 2**

The second historical simulation again utilized the RIP model as a year to year recursive programming model, as in the first historical simulation, but with a hypothesized significant variation. In this second historical simulation run, the expected gross returns for each crop activity were calculated by using the trend OLS yields rather than the optimum Spillman trend yields. The economic hypothesis was that producers make production decisions based on trend yields as being the most probable yields. Thus, producers would then form expectations of probable net returns based on a function that includes
trend yields rather than optimal yields. Again, as in the first historical simulation run, the lagged local to national price ratio was also used to estimate the expected relevant production area crop price. The remainder of the model was specified exactly the same as the first simulation, with respect to the use of exogenous data for the REVISE sector calculations. Therefore, the only yearly change in the recursive programming sector tableau was the estimated net returns in the objective function.

The changes in the expected net return coefficients in the objective function would cause changes in land use among crops if relative net returns among crops also change. Additionally, it is necessary for the land restraint in the producing area to be binding, unless the expected crop net returns are negative. For these reasons, the second historical simulation run was primarily compared and evaluated with respect to the first simulation run by changes in the total number of correct acreage turning points, and the relative Theil U coefficients. The Theil U coefficients were used because of their ability to measure the relative prediction error of the model which changes as the turning points accuracy changes.

The estimated individual and aggregated crop acreage and turning point statistics for the second historical simulation can be found in Tables C.6.1 through C.10.3. The Theil U coefficients for the various crops are found in B.2.1 and B.2.2. The aggregate total of correct turning point percentages by year is found in Table C.33. The aggre-
gate Theil U coefficient for each year is found in Table B.6.

1969 The revised crop net returns calculated with the OLS trend yields predicted crop acreages slightly less accurately in 1969 than the use of the Spillman trend yields. Only the dryland wheat and irrigated corn acreages showed a more significantly accurate predicted harvest acreages. On average, the other crop acreage percentage errors were almost the same, except those of dryland oats and sorghum. These two crops were under and overestimated by about an additional two and four percent respectively. The aggregated crop acreage percentages were fairly similar and within one percent of the first simulation run, except for oats and sorghum which were less accurate by about two percent.

The four feedgrains had a larger or equal number of correct turning points for both dryland and irrigated activities than in the first simulation run. Dryland cotton had a significantly lower number of correct turning points. Otherwise the number of turning points was relatively the same for both simulations for the individual and aggregate crops. The national aggregate correct turning point statistic was 70.6 percent, almost two percent higher than in the first simulation.

The individual Theil U crop coefficients reflect little difference between the two simulation runs, except for dryland sorghum and irrigated barley which seemed to be more relatively closely estimated in the first simulation. Otherwise the other crops coefficients
were within a few hundredths of each other in the different model variations. The aggregate national Theil U coefficient in 1969 was virtually indistinguishable from the first simulation, .061 and .062 respectively.

In 1970, dryland and irrigated cotton, dryland sorghum and irrigated oats and soybeans acreages were estimated with noticeably greater error as crop relative returns changed. But even these percentage change in errors was usually two percent, except for the irrigated soybeans. Thus, among the individual crops, the acreage estimation differences were slight. The aggregated crops acreages were relatively the same as in the first simulation, except for cotton and sorghum which were estimated with about two percent less accuracy.

In the second simulation, dryland barley was the only crop to have more than two more correctly estimated turning points than in the first simulation. Dryland cotton had appreciably fewer correct turning points. The remaining crops had almost the same number, one or two, of correct turning points as in the first simulation. This same pattern was repeated in the aggregate crop turning point statistics. The national aggregate correct turning point statistic for 1970 was 50.2 versus 60.4 for the first simulation. This difference represents one less correct turning point.

The individual and aggregated crop Theil U coefficients in 1970 were almost the same as those in the first simulation. Irrigated soybeans and oats coefficients were slightly larger in the second simu-
lation. The aggregate Theil U coefficient for 1970 was .042, the same figure as in the first simulation.

1971 The second simulation estimated dryland corn, cotton, sorghum and soybean and irrigated corn, cotton and sorghum acreages did appreciably better than the first simulation. Dryland sorghum and irrigated cotton and sorghum acreages demonstrated the largest improvements in accuracy, with an average decrease in error of almost six percent. Dryland oat acreage predicted accuracy decreased by over two percent. The aggregated acreage statistics showed that sorghum and cotton were more accurately estimated with OLS trend yields in the second simulation, while the oats acreage accuracy fell substantially.

The difference between the number of turning points correctly estimated between the first two simulations in 1971 varied irregularly among the individual crops. The dryland corn and oats, and the irrigated corn and sorghum all had four fewer correctly estimated turning points in the second simulation run. But the dryland soybean, and irrigated barley and cotton crops had four and three more correctly estimated turning points. The aggregated turning points statistics showed a similar pattern. Barley, cotton, and soybean noticeably increased while corn and oats decreased their respective turning point accuracy. The aggregate total turning point accuracy statistics for 1971 was 60.4 percent, a decrease of two correct turning points from the first simulation.
The Theil U coefficients in this simulation for the individual crops show that the relative error for each crop is at least as good as, if not better than for the first simulation. The largest relative improvement was for dryland oats and soybeans and irrigated cotton and sorghum. This development was also true of the aggregated crop coefficients, with cotton, oats and sorghum showing the most improvement. The aggregate total Theil U coefficient was .047, an improvement from the first simulation. Thus, at least in terms of the Theil U coefficient criteria, the OLS trend yields were definitely superior for calculating the expected crop net returns in 1971.

1972 The accuracy of the individual crops' acreage predictions fell markedly in 1972 in the second simulation run, except for dryland and irrigated cotton. Dryland barley, oats, soybeans and wheat acreage became even more underestimated by a few more percent, while the dryland and irrigated sorghum error almost doubled to over 37 and 23 percent respectively from the first simulation run. The corn acreages were estimated with almost the same accuracy. The aggregated acreage statistics reflect the same account as the disaggregated crops statistics. Barley and sorghum were estimated with notably worse precision, and national cotton acreage was estimated within 82,000 acres.

Although the accuracy of estimated individual crop acreages fell in 1972, the number of correct turning points increased or remained at the same level for almost all the crops. The most noticeable
differences were for dryland cotton and soybeans and irrigated barley percentage statistics which increased by approximately ten percent. The most notable decline in correct turning points was for irrigated cotton which fell from 44.4 to 16.7 percent and for irrigated corn which had four fewer correct turning points. In the aggregate, barley, oats, and sorghum showed increases in correct turning points, while corn and cotton statistics fell. The aggregate total of correct turning points was almost one and a half percent higher in the second simulation than in the first, 69.1 percent versus 67.7 percent.

The 1972 Theil U coefficients for the individual crops showed that the dryland individual crops were estimated with about the same relative error as in the first historical simulation. Although the acreage error was large for corn, the Theil U coefficient was only .079, but sorghum increased to .170, and the other crops were only slightly larger. Irrigated barley, and sorghum Theil U coefficients were similar to the first simulation. The aggregate crop coefficients followed the same pattern as the dryland crops, with sorghum having the only large increase, but with the cotton coefficient declining marginally. The aggregate Theil U coefficient for 1972 was .080. This was slightly larger than the first simulation.

The dryland and irrigated acreage predictions in 1973 for the OLS trend yield simulation were slightly more accurate, on average, than the first simulation's results. Among the largest percentage decreases in acreage level error were dryland and irri-
gated cotton, and irrigated soybeans. Dryland oats and sorghum increased their acreage errors by almost four and two percent to -16.8 and 3.5 percent respectively. Among the other individual crops, the difference in estimated harvested acreages was less than one percent. The aggregated crops closely resembled the disaggregated, individual acreage statistics. The only noticeable differences were that cotton and oats had decreased and increased errors of about three percent.

The turning point statistics for the disaggregated, individual crops showed different prediction patterns for dryland and irrigated crops in 1973. The dryland crops had fewer correctly estimated turning points, mostly by wheat than did the first simulation. The only dryland crop to show an improvement in turning points was cotton. On the other hand, each of the irrigated crops generally showed an improvement of one or two correct turning points, except for sorghum which had one less and soybeans which remained constant. The aggregated turning point statistics closely resembled the first simulation, except for cotton which increased accuracy by four turning points, almost a nine percent increase. Other aggregate changes in turning point statistics, if any, were minimal. The total turning point accuracy statistic for the second simulation was 66.4 percent, a drop of .5 percent or three turning points.

The individual dryland and irrigated Theil U coefficients in the second simulation run closely resembled those in the first simula-
tion. Dryland sorghum and irrigated sorghum were the only crops to have their Theil U coefficients decline by more than a couple hundredths of a point. The aggregate Theil U coefficients also reflected this situation, with sorghum being the only crop estimated with noticeably less error. Oats was the only crop with more than a slight increase in its Theil U coefficient. The total aggregate Theil U coefficient for 1973 was .048 in the second simulation, almost identical to the first simulation.

**Summary** The objective of the second simulation was to compare the relative accuracy of the model when OLS trend yields were used in the objective function with the first simulation when Spillman yields were used in the objective function. As can be seen from the brief comparative analysis of these two modeling variations above, the individual crop, aggregate crop, and total aggregate summary statistics do not clearly indicate which variation is the more accurate. For this reason, the choice of which model variations is the best predictor becomes extremely difficult and somewhat subjective. Therefore, it was decided to evaluate the two models just using the total, aggregated yearly, correct turning point percentages and Theil U coefficients.

The overall turning point percentages indicate that Spillman yields were more accurate when used to formulate expected net returns for all crops in the model for three years. But this accuracy was only really a function of one, two or three more correct turning
points each year out of a total of 538 possible turning points. On the other hand, the OLS trend yield variation had quite a few more correct turning points in 1969 and 1972. Thus, the second variation was almost as correct as the first variation for predicting turning points in three years, but relatively much more accurate in two years.

The aggregate Theil U coefficients indicate that both variations were just about equally accurate in terms of relative error but with a slight accuracy edge given to the second variation. The OLS trend yield model variation Theil U coefficients were slightly more accurate in 1969 and 1973 by one thousandth of a point, and equal to Spillman trend yield variation in 1970. In 1971, the second simulation was lower in relative error than the first simulation by eight thousandths of a point, but this situation was reversed in 1972. Overall, then, the OLS trend yield second model variation was slightly more accurate than the first simulation for this historical period, 1969 through 1973.

In summary, both the aggregated, total, summary turning point statistics and Theil U coefficients indicate that the second model variation was a slightly more accurate predictor of crop acreages both nationally and spatially. The second model variation used the OLS trend crop yields to estimate the expected net returns for each crop activity.
Historical simulation run number 3

In the first two model variations, the RIP model was used as a recursive programming model. These simulations effectively divorced the simulation and SUMMARY sectors from being linked to the REVISE and recursive programming sectors. The modeling variation utilized in the third historical simulation run had two objectives. First, this modeling specification completes one of the interfacing steps needed to correct this situation by linking the simulation and SUMMARY sectors to the recursive programming sector via the REVISE sector. Second, the third modeling variation allowed an examination of the predictive errors occurring when the information flow is just from the econometric sectors to the programming sector. Because much data utilized in the REVISE sector was being endogenously determined in this simulation and subject to estimation error rather than being the actual and exogenously given data, it was hypothesized that prediction errors in crop acreage levels, turning points and Theil U coefficients would be larger than in the first two historical simulations.

In the third historical simulation, the REVISE sector utilized the simulation sector to estimate endogenous crop market or season prices received by producers and ending year inventory levels to calculate flexibility coefficients, and the expected net returns of crop activities in the objective function. The state acreage levels used in the flexibility coefficient regression equations were also
endogenously estimated in the REVISE sector. The state acreage levels were calculated from the solution crop acreage levels in the previous year's recursive programming sector problem. In this respect, information was passed from the recursive programming sector to the econometric sectors, but this individual, solution crop activity level data was not used for the estimation of flexibility restraints. Rather, the flexibility restraints were determined from the calculated upper and lower flexibility coefficients and the actual (as estimated from the HSTAC data set) producing area crop activity acreage levels in each year, 1968 to 1972. Therefore, the flexibility restraints were determined from exogenous, historical crop acreage levels, rather than using the endogenous activity levels provided by the SUMMARY sector.

Other variations were also made in the REVISE sector's calculation of the recursive programming problem tableaus. First, the objective function's expected net returns for each crop activity were calculated with the endogenous simulation market sector crop prices and the five year average of the PA to national price ratio from 1968 to 1972. The five year average was used because it was thought that producers may utilize a longer run local to national price ratio to determine expected net returns. Also, the OLS trend crop yields were used in the objective function calculations because of their slightly superior estimation accuracy in the second simulation run. Second, the actual yearly crop yields for each activity from 1969 to
1973 were used in the input-output matrix. The choice of these yields rather than the optimal (Spillman) or trend (OLS) yields would impart a more realistic approximation of the real world production levels actually observed during this historical time period. Third, the crop fertilizer use input-output coefficients were also estimated with the endogenous crop price data generated in the simulation sector.

The yearly national crop summary statistical results for acreages and turning points are found in Tables C.11.1 to C.15.3 for the third simulation. The individual and aggregate Theil U coefficients are found in Tables B.3.1 and B.3.2 respectively. The total yearly aggregate, correct turning point percentages and Theil U coefficients are found in Tables C.33 and B.6 respectively. Finally, the actual and predicted national harvested crop acreages and other selected market data can be found in Tables D.1.1 to D.1.8 for the third historical simulation run.

1969 The price of feedgrains, wheat, cotton, and soybeans used in the objective function and flexibility restraint estimation were estimated higher than the actual observed prices in 1969. The aggregate feedgrain and wheat ending year inventories were also larger and cotton and soybean inventories lower than actual figures.

The individual crop acreage statistics indicate that dryland barley, oats and corn had the largest decreases in acreage level error, around two percent, while dryland sorghum acreage prediction
error more than doubled to over 25 percent from the second simulation run. The remainder of the crops were estimated with relatively the same error. When the dryland and irrigated crop acreages were aggregated the above results were seen again, with the sorghum acreage error almost doubling, while the barley, oats, and corn percentage errors fell by a few points.

The disaggregated correct turning point percentages showed little variation from the second simulation. The only exceptions were dryland barley and sorghum which had eight and four more correct turning points respectively, and soybeans which had four fewer correct turning points. These differences also carried over into the aggregated crop turning point statistics. Overall, the total correct number of turning points increased by two over the second simulation, and the total percent correct was 71.0.

The Theil U coefficients for the dryland crops show that barley and corn were the only crops estimated with a lower relative degree of error. Among the irrigated crops, oats was the only crop with a lower Theil U coefficient. Dryland cotton, sorghum and soybeans and irrigated sorghum, soybeans and wheat all had noticeable increases in their Theil U coefficients. The dryland pattern carried over into the aggregated crop coefficients. The total aggregate Theil U coefficient for 1969 was .063, only marginally larger than the second simulation.
1970 The estimated crop prices used in 1970 from 1969 were larger, and cotton prices were almost 50 percent larger, than the actual published prices received by farmers. Cotton inventories were about one million bales smaller, but the feedgrain and wheat, and soybean inventories were about 28 and 15 percent larger respectively than actual inventory data.

The irrigated and dryland crop acreages were very similar to the crop acreages in the second simulation. Dryland barley and oats acreages were the only crops to have a two percent error decrease, while dryland sorghum, and irrigated oats acreages had between a two and three percent error increase. The aggregated oats acreage had almost a three percent error decrease. The remainder of the aggregated and disaggregated crops were estimated with almost identical acreage errors.

The disaggregated turning point statistics showed that dryland wheat was the only crop with more than two correct turning points difference. Dryland wheat had six less correct turning points, but the acreage error decreased by about .6 percent indicating that these activities levels were at relatively low levels. The aggregate statistics showed that corn and oats had three less correct turning points, and wheat six less than the second simulation. Additionally, the remaining four crops correct turning point percentages were within a couple of percents of the second historical simulation. Therefore, the overall total of correct turning points
was less in 1970, and the percentage of correctly estimated turning points fell to 58.9 percent.

The crop Theil U coefficients did not indicate a clear pattern of changes in relative estimation error when compared to the second simulation. Dryland barley, corn and oat and irrigated sorghum crop Theil U coefficients fell noticeably. But dryland sorghum, and soybeans and irrigated oats and soybeans crops coefficients increased appreciably. The aggregated crop coefficients showed barley, corn and oats coefficients fell, and sorghum and soybeans increased. The aggregate total Theil U coefficient for 1970 was exactly the same in the third simulation as in the second, .042.

1971 The estimated crop prices in 1970 were fairly close to their actual values or support price (cotton) but slightly higher. The feedgrain and wheat ending year inventories were almost 50 and 40 percent overestimated, while soybean inventory was almost 100 percent higher. The estimated cotton inventory was only two-thirds of its actual value.

Almost all of the fourteen crop acreages in the model were estimated with less error than in the second simulation run. Barley and oats showed the largest error decreases among the dryland crops, while irrigated corn and cotton acreage errors decreased by over 50 percent. The only two crops to show an error increase were dryland wheat and irrigated sorghum, but both changes were less than .5 percent. The aggregated crop acreages demonstrated decreases in
estimated error, except for wheat which increased by less than .5 percent. The crops with the largest decreases in percentage error from the second simulation were barley and oats.

Among the disaggregated crops, dryland barley, corn and oats all had at least three more correct turning points than the second historical simulation. Dryland barley was estimated with ten more correct turning points. The remaining crops were estimated within one correct turning point. Barley and corn were the only aggregated crops with more than two extra correct turning points. Barley was especially noticeable with 12 extra correct turning points. The aggregate total of correct turning points was substantially higher in the third simulation than in the second with 63.8 versus 60.4 percent.

All the dryland crop Theil U coefficients except oats were lower in 1971 in the third simulation run, except for oats. Wheat and sorghum coefficients demonstrated the largest decreases. Among the irrigated crops, cotton and sorghum Theil U coefficients decreased appreciably, and the barley coefficient increased. The remaining dryland and irrigated coefficients were relatively the same values as in the second historical simulation. The cotton sorghum, and wheat aggregate Theil U coefficients were smaller, but the oat coefficient was the only one that was larger. The total aggregate coefficient for 1971 was .044, which is smaller than both the first two simulations.
In 1972, the feedgrain, wheat and cotton market prices estimated in 1971 were between ten and 20 percent larger than their actual values. But the only estimated individual feedgrain season price greater than the 1972 support price was oats. The soybean price estimated in 1971 was 20 cents lower than the actual observed value. The feedgrain, wheat, and soybean ending year inventories were approximately 24, 33, and 100 percent overestimated respectively, while cotton inventory was underestimated by about ten percent from their actual 1971 levels.

The third simulation's dryland and irrigated crops' acreage statistics were very similar to the second historical simulation results. Most were within two percent of each other, except for dryland and cotton whose error decreased and increased by almost 3.5 percent respectively. The dryland corn and both sorghum acreages were again overestimated. The aggregated crop acreage statistics closely resembled the dryland statistics, with wheat and cotton estimated with the least error and corn and sorghum with the worst error.

Except for dryland soybeans and wheat correct turning points statistics which fell slightly, the remaining 12 crops were estimated with at least as many correct turning points as in the second simulation. Dryland barley with four more correct turning points was the only crop with more than one or two extra correctly estimated changes in acreage levels. The aggregate barley, oats and sorghum crops had at least three more correct turning points, while soybeans
was the only crop to fall by the same criteria. The total aggregate percentage of correct turning points was 70.6 or eight extra correct turning points.

The Theil U coefficients in 1972 for the dryland crops in the third historical simulation were all larger or equal to the coefficients in the second simulation run. The largest increases were for sorghum and wheat. Some of the irrigated crop coefficients were larger and some were smaller. The largest increases in relative error were in irrigated barley, sorghum and wheat, and the largest decrease was for cotton. The aggregated Theil U coefficients showed the largest noticeable increases to be for the barley and sorghum crops. The remaining aggregate crop coefficients were estimated within a few thousandths of a point, a very small difference. The total aggregate Theil U coefficient for 1972 was .081, slightly larger than the second simulation.

1973 Because of overproduction in 1972 and in earlier years, the feedgrain market prices were lower than both their 1973 support and actual 1972 market prices, and ending inventory was more than doubled from its observed level. The 1972 estimated wheat price was fairly accurate, but its ending year inventory was almost 75 percent too high. The soybean price was underestimated by over a third, and inventory by almost 60 percent. The cotton price received by producers was again overestimated by almost 15 cents and inventories were about 700 thousand bales smaller than their actual level.
Among the dryland crops, wheat was estimated within 16,000 acres of its observed value. Dryland barley and soybean had acreage error increases of over four percent. But soybeans was the only irrigated crop to show noticeable decrease in acreage estimation error. The remaining crops were estimated with just about the same acreage errors as in the second simulation. The aggregate crop acreage statistics showed that barley, corn and soybeans were estimated with error increases and that sorghum was the only crop with a noticeable error decrease.

The disaggregated turning point statistics showed that dryland and irrigated sorghum and dryland oats received the largest share of the extra correct turning points estimated by the model in 1973. The remaining crops were within one or two correct turning points of the second simulation results. Irrigated corn and cotton were the only two crops with less than 50 percent correct turning points. The aggregated crops were almost all estimated with more correct turning points than in the second simulation. Oats and sorghum crops received an extra four and eight correct turning points respectively. The total aggregate percentage of correct turning points was 70.6, higher than either of the first two simulation runs.

Except for irrigated oats, sorghum and soybeans, the individual crop Theil U coefficients are all larger than in the second simulation. Both the barley crops and the other dryland crops demonstrated noticeable increases in Theil U coefficients. Among the aggregated
crops, wheat, soybeans and corn had the largest relative increases in coefficients. None of the aggregate crop Theil U coefficients declined. The total aggregate Theil U coefficient for 1973 was .066, almost a third increase from the second simulation figure of .048.

**Summary**  It was expected that the third simulation of the historical period would be more prone to prediction errors than the second simulation because more endogenously determined information was being used in the RIP model. More specifically, it was assumed that the errors in estimating state acreage levels, season or market prices and ending year inventories would increase the estimation errors when the objective function and flexibility coefficients were being determined.

However, the aggregate turning point statistics do not suggest the above hypothesis is true. In 1969, 1971, 1972, and 1973, a higher percentage of total correct possible turning points occurred. In only one year, 1970, was a lower percentage correct figure observed. Thus the third simulation modeling variation was a more accurate model for estimating turning points than the second modeling variation. The total aggregate Theil U coefficients show that the third simulation model had relatively substantially more error in only one year, 1973. Less relative error was observed in 1971, but the 1969, 1970, and 1972 coefficients were almost identical to the second simulation's coefficients. Overall, the aggregate Theil U coefficients do not
either demonstrate modeling variation as superior, or with distinctly less error.

In conclusion, the third simulation modeling variation linking the econometric sectors to the recursive programming sector could be regarded as being at least as accurate, if not more accurate, than the second simulation modeling variation. Therefore, the hypothesis that the RIP model with a one way interfacing would be a less accurate model than the fuller dichotomized second simulation variation was shown to be false in this dissertation research study.

**Historical simulation run number 4**

The fourth historical simulation was designed to demonstrate and test the accuracy of the complete RIP model. The complete RIP model interfaces the recursive programming sector with the simulation sector via the SUMMARY sector, and the simulation and SUMMARY sectors with the recursive programming sector via the REVISE sector. Thus, the fourth simulation is the first demonstration of the RIP model using fully endogenous information in the various model sectors, and more specifically, for the calculation of flexibility restraints.

The fourth simulation's RIP model variation was developed from the model variation chosen for the third simulation, and is exactly similar except for the flexibility restraints formulation. In the third simulation, and also in the first two simulations, the upper and lower flexibility restraints developed for each yearly pro-
The programming problem were based on actual historical crop acreage figures from the HPAC data set. In this simulation, the flexibility restraints in year $t$ are calculated from the estimated flexibility coefficients generated in the REVISE sector and the various crop activity solution acreages taken from the recursive programming sector in year $t-1$. In the previous simulations, these exogenous acreage levels from which the flexibility restraints were estimated acted to correct inaccurate crop activity levels determined in the previous period found in the programming sector's optimal solution. The sources of these errors have been previously discussed in the summary section of the first historical simulation run. But in the fourth historical simulation, these errors were not corrected and allowed to accumulate. Therefore, it was expected that the final set of model results in 1973 would be considerably more erroneous than any of the earlier simulations. But it was also expected that the errors would be corrected through time due to the recursive properties of the model. In order to gauge the results of this simulation, the second simulation results were used as a basis for comparison.

The individual, or disaggregate and aggregate harvested crop acreage and turning point statistical results for this simulation can be found in Tables C.16.1 to C.20.3. The crop Theil U coefficients are found in Tables B.4.1 and B.4.2. The actual and predicted aggregate harvested crop acreage and selected market statistics are presented in Tables D.1.1 to D.1.8. Finally, the total aggregate
correct percentage of turning points and Theil U coefficient for each year are found in Tables C.33 and B.6 respectively.

1969 The empirical results for 1969 are the same as those found in the third simulation because the 1968 recursive programming solution was determined with a set of fixed bounds taken from the HPAC data set. The crop production levels in 1968 were also given to the simulation sector. Therefore, the 1968 estimated market variables and activity acreages would be the same for both the third and fourth simulations. As a consequence, the flexibility restraints and market variables used in the REVISE sector to generate the 1969 recursive programming sector problem were the same in both simulations.

In brief summary, the RIP model results showed reasonable aggregate crop estimation accuracy in 1969, except for sorghum which was 24 percent overestimated, a little over 3.2 million acres. Wheat was only overestimated by two million acres or a little over four percent. The remainder of the crops were estimated within 8.5 to 10.8 percent of their actual levels, and 71.2 percent of the possible turning points were estimated correctly. The total aggregate Theil U coefficient showed that in 1969, the relative predictive error of the crop acreages estimated within the model was only marginally greater than in the second simulation.

1970 The 1969 market information used in the REVISE sector to generate the 1970 recursive programming tableau was also the same
as in the third simulation also for the reasons just discussed. Essentially, the feedgrain season price was the only price accurately estimated. The wheat, soybean and cotton prices were overestimated by about 22, 12 and 55 percent. Since the cotton support price had been used for the second simulation's expected net returns calculations the price was not crucial except in the flexibility coefficient estimation. The overestimation of the feedgrain, wheat and soybean and underestimation of cotton ending year inventories also increased the inaccuracy of the flexibility coefficient estimation. The inaccuracy of these inventories was due to the inaccurate acreage and resulting production figures occurring in 1969.

Among the individual crops, dryland corn, cotton, oats, sorghum and irrigated cotton acreage estimation errors noticeably increased. It appeared that the dryland corn and sorghum acreage increases were at the expense of the dryland oats, cotton and sorghum crops, because the net relative returns of these latter crops were lower. Wheat was the only remaining aggregated crop accurately estimated with a -2 percent acreage error. The aggregate corn, cotton and soybean acreages were estimated within 9.5 to 11.5 of their actual levels.

The relative accuracy of correct turning point percentages for the disaggregated crops fell noticeably for both dryland and irrigated corn and wheat. The drop in turning points was five, six, 19, and eight respectively. The number of correct dryland barley turning points increased by seven and the turning point decrease
in the irrigated barley crop was seven. The remainder of the crops had almost the same number of turning points. The aggregate turning point percentages showed that the only large differences were for corn and wheat which dropped to about 27 and 46 percent from approximately 40 and 69 percent in the second simulation. The total aggregate turning point percentage was approximately 53.0, a decrease of about seven percent.

Many of the disaggregated crop Theil U coefficients greatly increased from the figures found in the second simulation results, especially among the dryland crops where six out of seven coefficients almost doubled. Among the aggregated crop Theil U coefficients, soybeans was the only crop that did not almost double in value. The total aggregate Theil U coefficient increased to .077 in 1970 from .042 in the second simulation. Thus, the error of the model increased from 1969 to 1970 and also from the second simulation as expected.

In 1970, the aggregate feedgrain, and soybean prices were estimated with close precision, despite large overestimations of ending year inventory due to overproduction in 1969 and 1970. Estimated wheat inventory fell from 1969 to 1970, but was still over 30 percent overestimated. Wheat price was estimated to be 21 cents higher than its actual value. Cotton ending inventory was underestimated by almost 50 percent due to underproduction in 1969 and 1970, therefore making the 1970 season price much higher
than in reality, and almost two cents higher than the support price.

The individual crop acreages demonstrated a varied error pattern when compared to the second simulation results. Dryland barley was overestimated by five percent rather than being underestimated by almost six percent. Dryland oats acreage fell dramatically while sorghum acreage increased by replacing it. It appeared that barley and corn crops were also substituted for oats, despite the fact that the estimated oat price in 1970 was six cents larger than its actual price. Evidently the increased barley and sorghum market prices changed the relative net returns enough for Stages 2 and 3 to occur in many producing areas for these crops. Dryland cotton was only overestimated by a little over three percent instead of 15.5 percent. This was probably due to its higher price in 1970. Among the irrigated crops, cotton, oats, and wheat acreage fell substantially from the second simulation, while sorghum and soybean acreages increased substantially. The differential effects of price changes were magnified in the irrigated crop acreages.

Although the dryland cotton acreage estimation error decreased noticeably, only four of 26 possible turning points were called correctly. The turning point percentages also fell noticeably for dryland corn, wheat, and oats, and irrigated oats and sorghum crops. The change in oats turning points was obviously expected.
The percentages for the remaining crops were relatively the same. The aggregated turning point statistics show an increase in error for all seven crops, most noticeably for corn, cotton and oats which had 12, 10, and 32 fewer correct turning points. The total correct predicted number of turning points was less than even chance would dictate, 46.3 percent.

The Theil U coefficients for the disaggregated irrigated or dryland crops indicate the relative error again increased substantially from the second simulation. Dryland wheat was the only crop with a smaller coefficient. Ten of the remaining crop Theil U coefficients either more than doubled or were close to doubling from their second simulation levels. The aggregated Theil U crop coefficient also demonstrated the above increases in relative error, except for the wheat coefficient which decreased slightly. It was not surprising that the total aggregate Theil U coefficient in 1971 was almost two-thirds larger than in the second simulation, .073 to .44. Additionally, it was also noted that the 1971 coefficient declined slightly from its 1970 level.

1972 The lagged aggregate feedgrain price from 1971 was again closely estimated. Of the four feedgrains, only the oats 1971 market price was larger than the given support prices, which included both the loan rate and diversion payment. The increase in feedgrain ending inventory from 1970 was due to the increased sorghum and other feedgrains production (larger yields), as these crops
were substituted for oats. Because wheat acreage increased by only one instead of four million acres, the ending inventory only increased by 60 million bushels, and thus in total was only overestimated by 18 percent from its actual value. Wheat price remained overestimated by around 22 cents. The soybean season price, $2.83, was underestimated by 20 cents, partly because inventory was over 200 percent larger than in reality. This ending year inventory overestimated was a result of the continuing overproduction of soybeans from 1969 to 1971. The cotton season price increased to 42.2 cents and inventories fell to 1.9 million bales, 1.33 million bales under its actual level despite slightly larger than actual production in 1971.

From the disaggregated crop acreage statistics, it appears that the corn and sorghum net returns were large enough, using the full support prices, for not only substitution of these crops for the other crops in the model to occur, but also to use all the "surplus" land in the available land base. This "surplus" land is the acreage that was set aside in the 1972 agricultural program, but not eliminated from the land base in the model for empirical reasons explained earlier in Chapter III. The largest error increase was for dryland and irrigated sorghum, almost 62 and 35 percent respectively. The dryland and irrigated oats were again underestimated relative to the second simulation by over 20 and 30 percent. Both wheat acreages were also underestimated. Dryland barley and soybeans had noticeably lower underestimation errors. The cotton crop acreages
remaining feedgrains, primarily sorghum and also to soybeans. The underestimation error for soybeans decreased by almost four percent.

As expected from the change in net relative returns among the crops and the accumulated acreage errors, the turning point accuracy fell substantially for most of the dryland and irrigated crops. Estimated correct turning points for the dryland barley, corn, oats, sorghum and wheat crops fell by 14, 16, 25, 16 and 9 respectively. Irrigated oats and wheat both had five fewer correct turning points. Despite the decrease in the number of correct turning points for these crops, dryland cotton, soybean and wheat and irrigated barley, corn, sorghum and soybeans remained above approximately 60 percent correct. The aggregate crop statistics show oats and sorghum with the largest percentage decreases in turning points, while cotton and wheat possessed relatively the same direction of acreage change statistics. In all, the number of correct turning points estimated by the model in 1972 in the fourth simulation fell by about 100, compared with the second simulation. Thus, the aggregate percentage of turning points was only 51.7.

The 1972 Theil U coefficients for the individual crops indicate that while the relative error of estimated crop acreages for the individual crop activities increased in relation to the second simulation, these coefficients did not increase relatively as much as in 1971. Dryland barley and irrigated soybeans were the only crops
whose coefficients decreased. Dryland corn and wheat were the two crops with the lowest percentage coefficient increases, about 37 and 20 percent respectively. The oat crops received the largest increases in relative error, approximately 400 percent relative to the second simulation results. The aggregated crop coefficients demonstrated much the same results as the dryland crops mentioned above. Barley decreased its relative error, accompanied by small increases in corn and wheat coefficients, and much larger increases in cotton and sorghum and oats coefficients. The aggregate total Theil U coefficients in 1972 increased to 0.113, a relatively smaller increase relative to the second run results than in 1971.

1973 The steady increases in feedgrain production occurring due to acreage overestimation starting in 1969 and the substitution of corn and sorghum for oats contributed to an ending year feedgrain inventory of almost 97 million tons in 1972. The increased inventory over actual levels caused the aggregate estimated price to fall in 1972 rather than increasing as was actually observed. The drop in the aggregated feedgrain price from which the individual feedgrain season prices were estimated was large enough so that each of these crops was using their respective support prices in 1973 as their expected prices. Both the estimated wheat inventory and price were fairly closely estimated to their actual values. The soybean ending inventory showed a large drop in 1972 but was still much larger than its actual value. Although the soybean price rose, it only rose by
ten cents and was severely underestimated in 1972. Thus, the soybean expected net returns as with the feedgrain expected net returns were all underestimated. The cotton season price was again overestimated due to low inventories but since the support price in 1973 was only two cents lower, the expected net returns would not have been greatly affected. The cotton estimated ending inventory was about 32 percent underestimated at 2.70 million bales.

The disaggregated and aggregated crop acreages were estimated with poor precision in 1973. The only exceptions were irrigated corn and cotton acreages which were approximately 2 and 2.6 percent overestimated. Dryland and irrigated cotton acreages were the only crops to be estimated with less error than in the second simulation. The dryland feedgrains had the greatest acreage errors, with barley and oats severely underestimated, while corn and sorghum were overestimated by almost 16.5 million acres. These acreage estimation errors can be traced back to the changes in net relative returns for these crops because of the inaccurate market prices calculated in the simulation sector in 1972. The aggregate acreage statistics also reflect this situation. Wheat acreage was the most closely underestimated acreage at -9.6 percent and cotton was the closest overestimated crop at 13.2 percent. Both corn and sorghum were overestimated by large percentages while barley, oats and soybeans were underestimated. Thus, it appears that corn and sorghum acreages increased because of their positive net returns at the expense of these other crops despite
already large feedgrain inventories.

The pattern of turning point statistics for the various crops was quite interesting. The only crops with an increase in turning point accuracy compared to the second simulation results were irrigated barley and cotton. The irrigated sorghum and dryland soybean and wheat had 13, 11, and 12 fewer correctly estimated turning points. Although the decreases in corn, sorghum and barley statistics were anticipated by their acreage errors, the oat crops turning point percentages were still estimated with about 70 percent accuracy. Additionally, the disaggregated turning point statistics for soybeans and cotton were also above 70 percent. The aggregated statistics showed that cotton increased its accuracy above the second simulation results to almost 82 percent, while sorghum, soybeans, and wheat decreased by 16, 11, and 16 turning points or almost 26, 21, and 14 percent respectively. The change in oats percentage was less than four percent indicating that some larger oats producing areas had incorrectly estimated changes in crop acreages. The total aggregate turning point percentage for 1973 was 56.7, a decrease of almost 10 percent from the second simulation but an increase of five percent from 1972.

The individual, disaggregated crop Theil U coefficients demonstrated large increases in relative error, relative to the second simulation, reflecting the large increases in acreage errors. The only exceptions were the cotton dryland and irrigated coefficients
which increased by around 21 and 46 percent respectively. The remaining crop coefficients at least doubled. Both the disaggregated corn and sorghum coefficients more than tripled, and the dryland wheat coefficient increased by 522 percent but was still less than 0.1. The aggregated Theil U coefficients reflected the results discussed above. The total aggregate Theil U coefficient in 1973 was 0.125, much larger than in the second simulation, but only slightly larger than in 1972.

Finally, the market statistics in 1973, indicate that acreage changes for the various crops would have occurred in 1974 if the model had been run through 1974. These acreage changes would have occurred because the relative net returns of crops would have changed. The increase in feedgrain inventory was relatively small and the aggregate feedgrain price was similar to its 1972 level. Thus, the individual feedgrain 1973 season prices would have been below their support prices again. But the estimated wheat, and soybean prices showed substantial rises in 1973 as demands increased on available supplies so that ending year inventories fell. The cotton ending year inventory was overestimated, but the cotton season price was only 1.4 cents overestimated from its actual value in 1973 and about 2.3 cents larger than in 1972. Thus, as a consequence, it would be expected that soybean and wheat acreages would increase in 1974, quite possibly decreasing corn and sorghum crop acreages in many producing areas.
Summary The recursive interactive programming model in its complete simulation sector to programming sector to simulation sector, and so forth, was tested in the fourth simulation. The objective of this simulation was to explain and accurately predict or estimate land utilization patterns and the production response of the various crops in the model. Although larger errors in solution acreages of some crops occurred with respect to the second simulation results both on the national level and on the producing area level, and increased over time, the estimated crop acreage solution levels and production behavior behaved in accordance with the traditional economic theory of production.

In general, as relative crop returns and prices increased, crop acreages increased. Also, when relative crop net returns and prices decreased crop acreages decreased except when expected prices declined below support prices for corn and sorghum and the support prices were still higher than unit production costs. Additionally, the interaction of the recursive programming sector and the simulation market sector is quite interesting for a number of reasons. First, the production levels of the different crops have a direct influence on the price level in that year. When the production levels were incorrectly estimated, incorrect prices resulted as inventories accumulated or were worked down as demands changed. Second, although the simulation market sector's estimated prices were often in error with actual figures, they reflected the condi-
tions existing in the model due to both the production behavior of the recursive programming sector with its accumulation of acreage errors and the accumulated error within the simulation market sectors. Thus, if the position is taken that the model is a self-contained economic system responding to its own endogenously determined stimuli or economic conditions then the evaluation of the model results for the fourth simulation shows that the model is consistent with expected economic behavior, but is not perfectly consistent with actual observed highly fluctuating behavior by the agricultural sector during this time period. Finally, if we take into account the accumulated errors resulting from inaccurately estimated prices and net relative returns for model activities, errors in flexibility coefficients, weather and changes in harvesting of planted acres percentages, and a suspect available land base, a subject evaluation of the predictive results of the RIP model indicate that this modeling methodology has more than adequate explanatory capability to justify its development.

**Historical simulation run number 5**

The fifth historical simulation again demonstrated the full, completely interfaced RIP model introduced in the fourth simulation, but with a slightly different modeling variation. In the fourth simulation, actual crop yields were used in the recursive programming tableaus to reflect actual weather and production conditions. In the fifth historical simulation, the OLS trend crop yields used to
calculate the expected net returns for year \( t \) in the objective function were also used in the input-output matrix as the expected yields in year \( t \).

This modeling variation was primarily designed to gather information about how the RIP model would operate, and the extent of accumulated acreage error over a five year period when trend yields rather than actual yields were used in the model over a five year period. In effect, the RIP model was used to try to gauge the probable error in predicting crop production and acreage changes under a similar model variation projected for use during the 1974 to 1980 predictive simulation run. Although the RIP model was greatly modified for the predictive simulation due to certain unanticipated factors and circumstances that will be more fully discussed in the following section in this chapter, the fifth historical simulation results provided insights into the behavioral problems occurring with this particular modeling methodology not entirely apparent in earlier simulations, and in particular the fourth simulation.

The national disaggregated and aggregated yearly crop acreage and turning point statistics can be found in Tables C.21.1 to C.25.3. The national disaggregated and aggregated yearly crop Theil U coefficients will be found in Tables B.5.1 and B.5.2 respectively. The national aggregate total turning point statistics and Theil U coefficients for each year are found in Tables B.6 and C.33 respectively. Finally, the actual observed and estimated harvested acreage
and selected market statistics for the various crops in the model are listed in Tables D.1.1 to D.1.8.

1969 The 1969 results have been previously discussed in the third simulation and again in the fourth simulation. But because the crop yields were different in the fifth simulation, the ending year inventories and season prices predicted in the simulation sector are different than in the third and fourth simulations.

1970 In 1969 the feedgrain production declined by almost three million tons although the same number of harvested acres were predicted by the model. This decrease in production led to a slight increase in the aggregate feedgrain price and slightly higher expected individual barley, corn, oats, and sorghum prices in 1970. As in the third and fourth simulations, the lagged season price was still lower than their support prices. The same 1969 inventory and price behavior as noted above in the feedgrain sector also occurred in the wheat and soybean sectors. The cotton price fell imperceptibly although as estimated ending inventories and season price almost con­ceded with their actual levels.

The small change in crop prices and net relative returns produced changes of less than one percent in the disaggregated crop acreages compared to the fourth simulation with two exceptions. Irrigated oats and soybeans decreased their errors by 2.3 and 5 percent respectively. The aggregated acreages statistics were virtually indistinguishable from the previous simulation results.
The turning point statistics for 1970 were also almost indistinguishable from the fourth simulation for each of the disaggregated and aggregated crops. A total of two more correct turning points were estimated for the model as a whole, but the turning point percentage was still a relatively poor 51.3 percent.

The national dryland and irrigated crop Theil U coefficients were also very similar, suggesting virtually no changes had occurred in the crop acreage at upper, lower and in between bounds. The only noticeable change was for irrigated oats whose coefficient declined noticeably, but was still large at .194. The total aggregate Theil U coefficient for 1970 was the same as in the fourth simulation, .077.

1971 Because of the trend yields used in the recursive programming sector in 1970, the feedgrain production was overestimated by around 28 million tons, and ending inventory was overestimated by 51 million tons. For this reason, the 1970 season aggregate feedgrain price fell substantially. The lagged corn and sorghum prices fell below their 1971 support prices by 30 and 29 cents respectively. Although the barley and oat prices also fell, these prices were still larger than the given support prices. Thus, corn and sorghum net returns improved noticeably against barley and oats returns. The wheat market sector results showed that the 1970 acreage and production figures were closely estimated to observed values. The wheat price was again larger than its observed value but inventories were slightly diminished from the fourth simulation’s level, and
larger than the observed value due to overproduction, but was almost 40 million bushels smaller than the fourth simulation. The soybean price was about ten cents lower than its actual value, lowering its net relative return. Finally, the cotton production in 1970, unlike the previous simulation results, was very close to its actual level, as was ending inventory. The cotton price fell slightly and was just a few cents above the 1971 support price of 35 cents.

The estimated individual dryland and irrigated crop acreages were very similar to the fourth simulation results, but with a few exceptions. Dryland barley and sorghum decreased their overestimation errors by almost 3.5 and 2.2 percent respectively. Among the irrigated crops, cotton and sorghum increased their acreage errors by around five percent. Only aggregated barley acreage was estimated with a noticeable decrease in error. The remaining six aggregate crop acreages were estimated within one percent of the fourth simulation results. It appeared that corn, sorghum and soybean crops were being substituted for wheat and oats on a national basis.

The only noticeable difference in the number of correctly estimated turning points among the individual crops was for dryland barley. This crop had four fewer turning points than in the fourth simulation, although the acreage error decreased. Both aggregate corn and oats crops received relatively low turning point percentages again with 38.8 and 26.9 percent correct. The total aggregate
number of turning points increased slightly in 1971, and the percentage correct increased to 46.8 versus 46.3 in the previous simulation.

The Theil U coefficients indicate that some crop acreages were estimated with less error and most with more error than in the fourth simulation. Dryland barley and wheat, and irrigated barley, cotton, sorghum and soybean all had relatively noticeably larger coefficients. But dryland sorghum and irrigated oats received lower coefficients. Among the aggregate crop coefficients, sorghum was the only crop whose coefficient declined. The total aggregate Theil U coefficient for 1971 was .077, a slight increase over the fourth simulation.

1972 The large surplus of feedgrains continued in 1971 and produced a very low aggregate feedgrain market price. Because each of the individual feedgrain prices were below their respective 1972 support prices, the support prices were used for net return calculations. The barley support price increased by 24 cents in 1972, and its net return was not expected to fall relative to corn and sorghum. The 1971 wheat price increased by six cents over its fourth simulation level as production increased by less than demand, and ending inventory fell slightly. The soybean price was again underestimated from its observed value, although ending year inventory was lower than in the previous simulation. The increased cotton carryover from 1970 and the increased production in 1971 produced a lower cotton price than was observed in the fourth simulation.
As expected, the lower expected net returns for cotton produced a greater underestimation of both dryland and irrigated cotton acreages. Evidently dryland corn and irrigated sorghum were substituted for cotton. Irrigated barley and soybeans were the only other crops which had noticeable acreage error changes. The aggregate crop acreages showed large overestimation of corn and sorghum acreages, and underestimation of the remaining crops. A combination of expected incorrect net relative returns among the feedgrains, and the specification of a larger than actually available land base in 1972 were undoubtedly the large causes for errors.

The disaggregated crop turning point statistics were very similar to the fourth simulation results. Dryland barley lost six turning points and was the only crop with more than a one turning point difference. Dryland barley and dryland and irrigated cotton and oats were all estimated with less than or equal to a third correct turning points. The aggregate turning point statistics were also similar to the previous simulation results, except for barley which fell noticeably. The total aggregate turning point percentage for 1972 was 49.4, a decrease from 1971.

The disaggregated crop Theil U coefficients varied from the fourth simulation results. Dryland sorghum, and irrigated oats coefficients showed noticeable declines. On the other hand, dryland barley and irrigated barley, cotton and sorghum demonstrated increases in their respective relative errors. The aggregate barley
Theil U coefficient obviously demonstrated a noticeable increase in error, but sorghum's declined although its acreage error was large. The remaining crop coefficients were within a few thousandths of the previous results. The aggregate Theil U coefficient in 1972 was .11, an expected increase from 1972, but a small decline from the fourth simulation.

1973 The 1972 estimated season prices for the four feedgrains declined again as available supplies were swelled by an overestimated 14 million acres worth of grain plus the huge 105 million ton 1971 carryover. Consequently, their support prices were used again for activity expected net return calculations. In effect, these net returns were continuing to be held above (or below) estimated per acre variable costs. Thus, the model was being prevented from demonstrating a cobweb behavior system for the feedgrains. Actual wheat production was underestimated in 1972, and wheat price increased by ten cents over the fourth simulation's level as ending inventory also fell. The soybean price was underestimated again, despite a very low inventory of less than 100 million bushels. Finally, the estimated cotton market price in 1972 was less than the 1973 support price, in contrast to the previous simulation. This occurred due to the increase in supplies from a larger carryover from 1971.

The crop acreages in 1973 did not demonstrate any large changes due to the above market information compared to the fourth simulation. As expected, the overestimation of dryland cotton acreage fell by
three percent and the irrigated cotton acreage was underestimated by over six percent rather than being overestimated by over two percent. It appears that irrigated sorghum and soybeans were substituted for this cotton acreage and also some irrigated corn acreage. Overall, the aggregate crop acreages reflected the above situation as the over-estimation of cotton acreage fell by over five percent and sorghum increased by three percent.

The individual, disaggregated crop turning point statistics showed no substantial (more than two turning points) changes from the fourth simulation results. The aggregate crop turning point statistics indicate though that only barley had more correct turning points. The total aggregate turning point percentage in 1973 rose to 55.4, which was still seven fewer correct turning points than in the previous run.

The Theil U coefficients for the disaggregated crops again showed that some crops were estimated with less or more relative error than the fourth simulation. Dryland and aggregate barley and wheat crop coefficients fell, as did irrigated oats and soybeans. Irrigated cotton and sorghum had the largest increases in relative errors. The remaining aggregate crop coefficients were very similar to the previous simulation coefficients. The overall aggregate Theil U coefficient for 1973 increased as expected from 1972 to 1973 to .123 but was slightly less than the fourth simulation.
Finally, although the historical simulation period ended in 1973, the market data generated in 1973 indicated that additional acreage changes would have probably occurred in 1974. First, the feedgrain price fell further in 1973, because of large overhanging supply available for market. Consequently, the support price would have again been used for expected net returns estimations. Second, the 1973 wheat price jumped by over 40 cents due to the extreme tightness of supplies. In fact, wheat demand exceeded supplies in 1973 so that zero inventory was available for carryover into 1974. Consequently, the 1974 price would have also been much higher. Third, the soybean price also increased but like the wheat price did not rise enough to reflect the actual tightness of supply due to the underestimation of production by eight million acres in 1973. The 1974 soybean price would have also been expected to increase. The cotton price and ending inventory were estimated closely with their actual values. In summary, then, the relative increase in soybean and wheat net returns would have started substitutions for the feedgrains, cutting acreages and production. Eventually, inventories would decline and price would rise, as supply became more in line with demand.

**Summary**

After five years, the model showed that considerable final acreage errors occurred for the feedgrains and soybeans. Barley and oats acreages were underestimated by over 21 and 36 percent. Corn and sorghum acreages were overestimated by about 17.4 and
46.3 percent respectively. Cotton and wheat acreages were only over and underestimated by around 8.2 percent. Finally, soybean acreage was underestimated by approximately 15 percent. The other summary statistics also indicate empirical problems with accurate national and spatial distribution of production activities. The total aggregate Theil U statistic almost tripled from the second simulation run's level and almost doubled from the third simulation when solution acreage errors were corrected each year. Finally, the total national correct turning point percentage was 55.4 percent, 11 percent below the second simulation and almost 13 percent below the third simulation. This latter statistic indicates that a great deal more crop specialization was occurring in the fifth simulation than these other simulations.

The national crop acreage errors, decline in correct turning points or increase in crop specialization, and increase in relative acreage error in this simulation are a result of a combination of factors. The empirical results of this simulation strongly suggest that corn and sorghum crop substitution errors accounted for the large share of cumulative acreage errors in the model. These substitutions occurred for a number of reasons which are confounded with each other. It is strongly indicated that the primary or central error producing problem is that the net returns model used in this time period was very inaccurate.
The expected net returns are dependent upon an accurate price expectations formulation, accurate expected yields and accurate expected crop costs. Each of these three areas has probably been inaccurately empirically portrayed for these historical simulations. Nevertheless, it was the purpose of this simulation to demonstrate empirical methodological problems occurring within the RIP modeling framework.

The net returns model used in this thesis study first multiplied the lagged crop price by the expected yield in year $t$ to calculate the expected gross return. If the crop support price was larger than the lagged price, the support price was used as the expected price. The variable costs of production in year $t$, exclusive of ownership costs, were then subtracted from the gross return to estimate the expected net crop activity returns.

Evidently, two different "expected price" errors occurred in the modeling specification which would alter the hypothesized cobweb or recursive properties of the model. These price expectation error situations are illustrated in Figures 4.1 and 4.2, and are developed from Waugh's price support models:

"Essentially, an effective price support puts a kink in the price curve. When output is very low, prices are on the old curve. But as output increases the price drops until it reaches the support level. As output increases still further, the price remains at the support level, assuming that the support is fully effective.

... when price rests upon the support, the government will have to buy the "surplus"; that is,
the difference between production and consumption. The support price modifies the cobweb. It reduces the fluctuations in quantity and in price" [208, p. 741].

In Figure 4.1, the price curve is drawn with an upper and lower limit, above and below the equilibrium price or unit production cost. If the market price is between or equal to these limits, then the crop will demonstrate alternating periods of over and underproduction and prices will vary accordingly. If the lower price limit was specified as the government support price, and if output was greater than \( q_3 \), say \( q_1 \), then the quantity \( q_3 - q_1 \) would be acquired by the government and possibly disposed of the following year when underproduction occurred. In effect, the lower price limit prevents large price declines in periods with large overproduction. Additionally, the upper price limit prevents large increases in periods with large underproduction. Thus, the upper and lower price limits act to reduce the crop's price and quantity fluctuations.

The estimation of prices in the simulation sector's wheat and soybean submodels reflects the situation outlined above to a large extent. In years where large overproduction or underproduction occurred, or where large or small excesses in supply occurred, the prices of these crops did not respond as might have been expected and as observed behavior in these agricultural markets suggests. A large part of this problem may be attributed to the
fact that these market sectors were estimated with data series only extending through 1967. In effect, these crop prices fluctuated in a narrow price range, consequently preventing larger fluctuations in these crop acreages. It is suggested that larger crop acreage fluctuations would have contributed to a more accurate supply response behavior pattern for not only these crops, but also on the corn and sorghum crops. Perhaps the acreage accuracy of the barley and oat crops would have also improved.

The second figure, Figure 4.2, illustrates the second economic situation where the lower price limit, or support price, \( p^* \), is above the equilibrium price or cost per unit. Here, the support price completely interrupts the cobweb properties of the market sector. Starting in period \( t-1 \), if farmers expect a price, \( p_1 \), higher than the support price, then quantity, \( q_1 \), will be forthcoming in period \( t \). But even if the market price would decline below \( p^* \), \( p^* \) would be the expected price in production period \( t \). Also, \( q_2 \) would be produced with price expectations of \( p^* \), the support price, with a resulting continuing surplus of \( q_2 - q_3 \). Since there would not be any periods of underproduction, the government's surplus would be continually increasing, and the large overhanging and increasing surplus would further cause market prices to decline.

This behavior can be readily seen in the feedgrain sector of the RIP model. From 1968 to 1973, the production of feedgrain was continuously overestimated with consequent continuing increases
Figure 4.1. Price Support Below Equilibrium [208, p. 742]

Figure 4.2. Price Support Above Equilibrium [208, p. 742]
in the feedgrain ending inventory. For this reason, the aggregate feedgrain market price fell steadily during this period. The expected market price in 1971 (1970 lagged price) was less than the support price for barley, corn, and sorghum. In the following year, 1972, the lagged 1971 market price was less than the 1972 support price for all four feedgrains. Nevertheless, while the barley and oats acreages were declining from 1971 to 1973, as expected, because their support prices fell below their equilibrium price, corn and sorghum acreages were increasing steadily during this period. These acreage increases are attributed to their hypothesized positive net relative returns. Thus, their respective support prices must have been greater than their variable per unit costs during this period. One suggested alternative support price specification would use only the loan rate for corn and sorghum and perhaps barley instead of the loan rate plus the diversion payment. But because corn and sorghum crop acreages were continually increasing, and replacing the lower yielding oats and barley crops the total feedgrain acreage and production was continually increasing, and the aggregate feedgrain price was declining. Since the oats and barley market prices are determined from the aggregate feedgrain price, their prices could not rise until corn and sorghum production fell, and the overhanging inventory was distributed until normal levels were reached. The model specification of one aggregate feedgrain market obviously prevented this behavior pattern from developing.
Although misspecification of the expected net returns of the various crops in the model contributed in large part to the acreage errors and market variable inaccuracies, the sources of error mentioned earlier in this chapter also had a confounding effect with these mistakes. Briefly, these additional sources of error include inaccurate estimation of flexibility coefficients, the assumption of a constant or "normal" harvested to planted acreage ratio for each crop, and the use of acreage bases that were too large in many producing areas during this five year period. The acreage base noticeably contributed to estimated crop acreage errors in 1972, but it was necessary to use these larger acreage bases to prevent the large costs of solution infeasibilities in the recursive programming sectors.

Finally, separation of the final total acreage and market variable errors attributable to the net return formulation misspecifications or any of the other three sources of error mentioned above will not be attempted in this summary and evaluation section, nor in this thesis study. Rather, the examination of the relative contributions of the various sources of error to the total model error will be left for future research studies.

The Predictive Simulation

The final RIP model simulation discussed in this chapter is the predictive simulation from 1974 to 1980. The term "predictive" is used here in the sense that state acreage and production data were
unavailable for comparison with the RIP simulation results from 1974 to 1980. Therefore, the model's performance from 1974 to 1976 was evaluated with respect to national acreage and production figures. The period from 1977 to 1980 was evaluated as projected production response behavior based on the model's behavior and results from 1974 to 1976.

The examination of the historical period simulations and an initial predictive simulation run indicated that many empirical modeling specification problems were occurring in the first generation RIP model utilized in this thesis study. These model specification errors or related problem areas suggested that the RIP model in its present format, could not be used as an accurate, projective tool for agricultural policy evaluation and planning analysis in different economic environments. Consequently, the RIP model specified here was not considered as a precise duplication device for the prediction and projection of real world supply and production behavior of the crops included in the model. Rather, the primary objective of the predictive simulation was to try to realistically model the supply behavior of the various crops in the model from 1974 to 1976 with government programs in effect during this period and their probable behavior after 1976 in a "free market" environment.
Initial predictive simulation model specification

The initial model specification for the predictive simulation was quite similar to the fifth historical simulation model except that the initial recursive programming sector solution was given exogenously with the 1973 ARCA data set crop acreages and the 1973 production levels were given exogenously from observed data [198]. The simulation, REVISE, SUMMARY and recursive programming sectors were left in their original programming formats. The exogenous data sets used by the simulation, REVISE, and recursive programming sectors were revised to reflect the actual economic environment from 1974 to 1976 and a hypothesized "free market" environment from 1977 to 1980.

The first adjustment made was to the harvestable land base. The land base available for harvesting of crops in the recursive programming sector was expanded to approximately 255 million acres from about 224 million acres in 1973. The increase in land available was designed to reflect the complete relaxation of government acreage control and acreage divertment programs. These new production area land bases included the diverted acreage that could have been harvested from 1968 to 1973 if the same percentage of planted acreage of the various crops had been harvested on the diverted acreages during this period.

The simulation and REVISE exogenous data sets were also revised to reflect the actual and hypothesized economic environment from 1974
to 1976, a five year average of exports from 1972 to 1976 was used as
the expected projected level of exports (Table A.9). The government
support and loan rates for each crop in the model from 1974 to 1980
were also specified (Tables D.2.2 to D.2.5). These support prices
were held constant after 1977. Because of the hypothesized "free
market" economic environment without government interference in
the various commodity markets, the weighted support prices were
set equal to the crop support or loan rates. Also, dummy variables
representing government commodity programs and diversion or allotment
variables were set equal to zero.

The REVISE sector modeling variation was changed slightly from
the variation used in the fifth simulation. Instead of the 1968 to
1972 average local to national price ratio, the average 1972 to 1973
local to national price ratio was used to estimate the production
area expected prices. The OLS trend yields were used in the net
returns calculations and in the input-output matrix. Also, as
in the fifth historical simulation the endogenous market and activity
level information generated in the simulation and SUMMARY sector
were utilized for the calculation of yearly flexibility coefficients
and restraints.

The initial predictive simulation results were disappointing
but instructive for modification purposes. The aggregate feedgrain
price ended in 1980 at a negative $2.00, due to high yields and result­ing extremely large inventories. Soybean acreage jumped to
60 million acres in 1974 and 65 million acres in 1975 and 1976, leading to large inventories and low market prices. Afterwards, the soybean acreage fell by about a million acres a year to 1980. Although the feedgrain and soybean sectors had very poor initial results, the wheat and cotton crops showed similar production behavior to observed acreage and other market statistics from 1974 to 1976. But afterwards, wheat inventories grew to almost 2.3 billion bushels in 1980 and cotton inventories were often negative as cotton prices did not increase by enough to increase cotton production.

The results of this initial predictive simulation strongly suggested that changes should be made in the RIP modeling specifications so that real world events would be more accurately reflected in the model's behavior. After a thorough examination and consideration of these results, it appeared that the errors in production behavior exhibited by the model could be confined to four separate yet confounded problem areas: 1) the high support prices relative to the Eyvindson variable costs per unit used by the model preventing a recursive cyclicability in crop production (Figure 4.2), 2) the confounding effects of crop specialization in producing areas from 1974 to 1980 and high trend OLS yields relative to the actual yields from 1974 to 1976, 3) the inability of the simulation market sectors to cope with "extreme" situations where very large or small production surpluses occur, and 4) an incorrect or too large land base
available for harvesting by the crops in the model that permitted a semicontinuous phase 1 and 2 relationships in most producing areas (Figure 2.6). To try to correct the problems produced by these four confounded subjects, a revised RIP model was constructed for the predictive simulation.

Model specification changes in the predictive simulation model

Numerous changes in the modeling specifications of the recursive programming, simulation, and REVISE sectors were effected to try to improve the accuracy of the RIP model's supply response behavior from 1974 to 1975, and its forecasting reliability from 1977 to 1980. One problem that surfaced repeatedly during these revisions was the quantification of the effect that these modifications would have on the total behavior of the full model. Because the various sectors and activities within the model are interactive, changes made in one area will affect and perhaps create unanticipated modeling problems in other areas. Therefore, these changes should be regarded as experimentation measures acting to constrain the model into a "real world" simulation solution. Use of the same model for policy and planning analysis simulations might or could result in highly unlikely economic results.

The recursive programming sector was revised to use three new estimated sets of land bases available for harvesting. The derivation of these land resource constraints has been previously discussed in Chapter III. Essentially, the observed harvested land base in
1968, 1969, and 1970 was added to the diverted but harvestable acreages in these years to expand the available land base in the programming sector from approximately 225 million acres in 1968. These new harvestable acreage bases totaled about 235 million acres in 1974, and 240 and 245 million acres during the 1975 to 1976 and 1977 to 1980 periods respectively. The previously used land base of approximately 255 million acres was discarded.

The simulation sector also underwent many modifications, but of a relatively minor nature. First, the national feedgrain, soybean, cotton and wheat acreages derived in the SUMMARY sector were multiplied by their national average per acre observed yields from 1974 to 1976 [50], instead of using the endogenously given OLS trend yields and production levels determined within the programming sector and summed by the SUMMARY sector. From 1977 to 1980, the OLS trend yields and production levels determined within the model were used in the simulation market sectors.

Second, the estimated commodity prices were multiplied by various ratios because the price equations did not provide accurate commodity prices in situations where commodity inventory or surpluses were at extreme values. This problem occurred primarily because the market submodel equations in the simulation sector were estimated with data through 1968, and with data accumulated under almost continuous and various government programs. More specifically, if the ending year inventory of feedgrains was between 12 and 20 million tons, or if
cotton was between 1.6 and 2.5 million bales, or of wheat was between 100 and 250 million bushels, or of soybeans was between 100 and 200 million bushels, then each of these respective commodity prices was multiplied by 1.125. If the ending year inventory of any of these commodities was less than the lower limits specified above, the respective commodity price was multiplied by 1.25, except for soybeans which was multiplied by 1.30. Finally, because the soybean price equation was in log linear form and used the lagged price as a dependent variable, the soybean price was also multiplied by a ratio at large inventory levels. Therefore if the ending year soybean inventory level was between 400 and 475 million bushels or between 476 and 575 million bushels, the soybean price was multiplied by .95 and .875 respectively. If the ending year inventory was greater than 575 million bushels, the soybean price was multiplied by .70. An additional change made in the simulation market sectors was to set the 1973 wheat price at $3.95, its observed price because the estimated 1973 price was only $2.00.

The third set of changes to the simulation market sectors related to the determination and handling of government inventories. Unlike the historical simulations, the government inventories of feedgrains, wheat and cotton were only calculated if the corn, wheat and cotton market prices in a given year were less than 95 percent of their support or loan prices. Since a government soybean inventory equation was not available, it was assumed for this analysis that if the soy-
bean price was less than 95 percent of its support price, the government inventory was 50 percent of total ending year inventory. Additionally, unlike the historical simulation specifications, if government inventories were calculated, these inventories were assumed to be withheld from the domestic commodity supply in following years or disposed of in a manner such that domestic demands or exports were unaffected by government inventory disposal behavior. Finally, the minimum allowable feedgrain, wheat, cotton and soybean levels were set at 10 million tons, 50 million bushels, 1.5 million bales, and 50 million bushels, respectively.

The final set of model specification changes substituted a new set of crop costs for the Eyvindson crop costs that had been previously used in the REVISE sector. This set of cost data included variable costs (labor, machinery, fuel, repairs, pesticide, and other miscellaneous costs) developed by Dvoskin and Heady [49] and land ownership costs. The development and detailed explanation of these costs has already been discussed at length in Chapter III. These costs were used from 1974 to 1980, the entire period of the predictive simulation.

**Predictive simulation results**

The yearly national crop acreages and selected market statistics results of the predictive simulation with the revised RIP model can be found in Tables D.2.1 to D.2.5. The yearly disaggregated, irrigated and dryland crop acreages, and the aggregated crop acreages are com-
pared with each of their respective levels in 1973 in Tables C.26.1 to C.32.3. Theil U coefficients and turning point statistics could not be calculated for the predictive simulation due to lack of an appropriate individual acreage level data set from 1974 to 1976, and obviously from 1977 to 1980.

1974 The predicted 1974 national crop acreages exhibited varied production responses to the estimated 1973 simulation market or season prices and 1974 support levels. The aggregate feedgrain acreage was underestimated by five million acres due to the underestimated aggregate feedgrain price. Oats and barley acreages declined as did their observed levels. The corn acreage also declined, but should have increased. Part of the decline in corn acreage was nullified by an increase in predicted sorghum acreage although the 1973 sorghum price was also underestimated. The wheat acreage increased by almost six million acres from 1973 to 1974 in response to the high lagged market price. Part of the underestimation of acreage response was undoubtedly due to undervalued upper flexibility coefficients. The predicted soybean acreage increased to over 61 million acres in 1974, while the observed acreage level fell by over three million from its 1973 level. If the 1973 lagged price was closer to its actual value, soybean acreage would have probably increased even further. Estimated cotton acreage fell by over two million acres when it should have increased because the lagged market cotton price was underestimated by almost ten cents from its actual value, and the
38 cent support price was obviously not large enough to cause the acreage increase that should have occurred.

1975 The predicted aggregate feedgrain acreage, as did the observed aggregate feedgrain acreage, increased in 1975 in response to the rise in the estimated 1974 aggregate feedgrain price caused by the low 1974 production surplus. But the feedgrain acreage was still underestimated in 1975, now by over seven million acres and ending year feedgrain carryover fell to its minimum allowable level, ten million tons. The increase in corn acreage from 1974 to 1975 compared favorably with the actual observed acreage increase, but the total corn for grain acreage was again underestimated by about six million acres. The sorghum acreage increased also and was about 3.4 million acres overestimated. The sorghum price in 1974 was undervalued by 23 percent, but the corn price was undervalued by only 17 percent. Both the barley and oats estimated acreage decreased by over 1.0 and 1.5 million acres, when they should have increased by about .5 and .4 million acres respectively. Consequently, oats acreage was over 3.5 million acres underestimated. Thus their relative returns must have fallen, even though their expected prices increased. The wheat price in 1974 and the increase in acreage in 1975 were closely estimated. Because total wheat acreage was underestimated in 1974 and 1975, the production surplus was much lower than actually observed, thus keeping the 1974 and 1975 prices high. The national soybean acreage in 1975 was again overestimated but not
by as large a margin as in 1974, six million acres. Due to the overestimated acreage and production, the ending year inventory in both years were greatly above their actual level. Also, the price decrease in 1974, although small, still helped to cause an acreage decrease of 1.3 million acres in 1975. Finally, the underestimation of cotton production in 1974 drove up its price, to closely estimate its actual value. Nevertheless, the 1975 cotton acreage fell to just over eight million acres, only 800,000 acres below the observed 1975 cotton acreage, which also fell from the 1974 level. Finally, because cotton production was underestimated in 1975, ending year inventory fell to its minimum allowable level and its price rose substantially.

1976 This is the last year for which harvested, observed acreage demonstrated a varied pattern of accuracy when compared to these values. The aggregate feedgrain increased by over four million acres and was only 4.4 million acres from its observed value of 106.8 million acres. This response demonstrated the recursive programming net relative return characteristics, because the price increase in 1975 was only about one-third of the price increase in 1974 when feedgrain acreage declined. Thus, the model demonstrates that it is not the price level that is the primary cause of acreage fluctuations, but rather the change in net relative returns between crops that accounts for much of the changes in crop acreages. Also, the underestimation of production from 1974 to 1975 caused ending
year inventories to fall to their minimum allowable levels causing higher than observed individual feedgrain prices in 1975. It appears that from 1974 to 1976 commercial demands were overestimated because the aggregate feedgrain (and soybean) prices were not high enough to force large enough cutbacks in livestock production, thereby decreasing commercial demands.

The individual feedgrain acreages showed noticeable differences in their reaction to higher expected prices in 1975. Their observed 1975 market prices fell from their 1974 levels, and except for corn the remaining three feedgrain acreages declined. The predicted corn acreage was again underestimated, but increased by over four million acres as did its observed value. The sorghum acreage continued to increase and was predicted to be 20.9 million acres larger when the observed level was only 14.9 million acres. The barley and oats acreages continued to fall in 1976, despite their higher expected prices, to approximately 6.8 and 8.9 million acres.

The expected wheat price in 1976 increased slightly and ending inventories in 1975 only increased marginally as production was underestimated from its observed level. Wheat acreage increased by a million acres, and again was underestimated by over five million acres. The underestimation of acreage again kept wheat ending year inventory far lower than its actual observed value in 1976. Soybean acreage fell in 1976 in response to its price decline in 1975 due to the large inventory buildup. The predicted 1975 soybean price,
as in previous years was noticeably underestimated from its actual value. Nevertheless, soybean acreage in 1976 was slightly overestimated by about five million acres and 1976 ending inventory was overestimated by almost 775 percent. Despite the large predicted cotton price increase in 1975 to over 60 cents, nine cents over its actual 1975 value, cotton acreage fell by about a quarter of a million acres. With only an observed 8.6 cent increase in 1975, the observed cotton acreage actually rose by over two million acres. This three million acre underestimation of cotton acreage again forced the 1976 ending year inventory to its minimum allowable level, 1.5 million bales.

1977 The production response of the various crops in the model in 1977 closely resembled the 1976 response pattern. The feedgrain acreage increased to almost 108 million acres, very close to the 1976 observed aggregate feedgrain acreage level. The increased production finally allowed a 39 million ton carryover into 1978, after three years of minimal feedgrain yearly inventory carryover. As a result of this production surplus, the aggregate feedgrain price fell substantially, after having been kept at higher than observed values in 1975 and 1976 due to the underestimation of production. Corn acreage reached 71 million acres in 1977, very close to its 1976 observed value. Sorghum acreage also increased by another 1.4 million acres to 22.3 million acres. Oats and barley acreages declined again despite their highest expected price values in the
previous three years. The predicted barley and oats acreages were 6.5 and 7.96 million acres respectively.

The predicted wheat price in 1976 declined as did its observed price and wheat acreage fell slightly in 1977. The use of OLS trend yields produced the same kind of increase in ending inventory as was produced in the feedgrain sector. Consequently, the wheat price fell again in 1977 to $3.29. The predicted soybean acreage also declined in response to the price decrease in 1976. The increase in ending year inventory despite the five million acre decrease in 1977 soybean acreage caused the estimated 1977 price to fall far below the 1977 support price of $3.50. Therefore, the government was assumed to take 50 percent of this inventory, leaving only 335.3 million bushels of soybeans to be carried over to 1978. The cotton acreage finally increased in 1977 to almost 9.5 million acres in response to a very high expected price of almost 80 cents, the market price in 1976. Nevertheless, the ending year inventory was still at its minimum allowable level, and the 1977 market price rose by another 17 cents to over 96 cents. This price reflected the continuing imbalance of supply and demand in the cotton sector from 1975 through 1977.

1978 In response to the lower expected aggregate feedgrain price in 1977, the total feedgrain acreage also declined. But ending year inventory increased as production fell only slightly, and resulted in a fall of the 1978 market price. Corn acreage fell by around 2.3 million acres as did sorghum acreage, but not by as much as would have
been expected from the crop in its 1977 price. Barley and oats acreages also fell, but only slightly. It appeared at this point that many of the barley and oats crops had reached or were nearing their minimum absolute bounds placed upon the programming sector to prevent crop specialization.

Wheat acreage declined in 1978 to 62.6 million acres, in response to its decline in net returns caused by a declining price. The 1978 wheat price also declined as production declined only slightly and ending year inventory increased. The soybean acreage declined to a little over 45.6 million acres, with producers using the support price as their 1978 expected price to calculate net returns. Because the estimated market price was again less than the support price, the government again took control of half the ending year inventory in an effort to help force the market price higher. The cotton acreage was the only crop acreage to increase in 1978. The cotton acreage increased to 11.72 million acres, and production was large enough to produce a 3.07 million bales ending year inventory. This inventory acted to decrease the 1978 cotton price by almost 11 cents from its very high level in 1977.

1979 The sharp decline in the 1978 feedgrain price was largely responsible for the almost nine million acre drop in total feedgrain acreage to 95.64 million acres. Because acreage fell, feedgrain production fell but decreased commercial demands prevented ending year inventory from also falling dramatically. Nevertheless,
the slight decrease in ending year inventory helped to produce a
slightly higher aggregate feedgrain price. The individual feedgrains
exhibited varying acreage responses to their lagged 1978 prices.
Corn acreage fell by close to eight million acres, but sorghum acreage
fell by only 1.5 million acres. Barley and oats acreages also de­
clined, but the extent of their acreage decreases was only 240 and
200 thousand acres respectively, as more activities fell to their
lowest absolute acreage bounds.

The 1979 wheat acreage level fell by over seven million acres
to just over 55.3 million acres, very close to the 1973 observed
level in partial response to its lower expected price. Wheat pro­
duction also declined because of the acreage decline, but ending year
inventory climbed to almost 1.2 billion bushels. This large production
surplus and overhanging supply helped to decrease the wheat price
even further to $2.51. The continuing problems with the soybean
sector were demonstrated again in 1979. Acreage and production
fell as expected given the expected price of soybeans was its support
level. The demands generated within the market sector were larger
than the available supply, and still left an ending year inventory
larger than 50 million bushels. Consequently, soybean price rose
substantially reflecting the imbalanced supply and demand situation.
In response to the higher expected cotton market price, and the
available harvestable cropland not being used by other competing
crops, cotton acreage again rose substantially to over 14.4 million
acres. The supply of cotton was large enough so that government inventories were calculated for the first time, and the market price of cotton decreased by over nine cents. An interesting aspect of the cotton sector in 1979 was that it illustrated the recursive programming situation where the expected crop price declined from the previous year, yet the crop acreage level increased. Thus, the difference in acreage or production response estimates occurring when net relative returns as opposed to price levels are used has again been demonstrated by the RIP model.

1980 The slight increase in the expected aggregate feed-grain price did not produce an increase in feedgrain acreage in 1980. Rather, predicted feedgrain acreage continued to decline, but by a smaller amount than occurred in 1979, only about 3.6 million acres. The production decline and increased commercial demands from the expected lower feed costs in 1980, decreased ending year inventory by over 11 million tons, to 40.56 million tons. Consequently, the aggregate feedgrain price rose in 1980, possibly creating an economic environment for increased feedgrain acreage in 1981. Both the corn and sorghum expected prices rose, but acreages continued to fall. Evidently a larger price rise would have been necessary for increased acreages of these crops. The barley and oats acreages fell minimally by 100 and 140 thousand acres respectively as their expected prices rose by only five and one cents. It is doubtful if barley acreages would have fallen by much more even if its price fell below its support
level. The oats expected market price remained below its support price, and the support price was again used as the expected price to calculate its net relative returns.

Wheat acreage again fell by over seven million acres to just over 48 million acres. As a direct consequence, production fell by over 200 million bushels, but the ending year inventory only decreased by 70 million bushels. The large 1.1 billion bushel carryover into 1981 helped contribute to the low estimated wheat market price in 1980, which declined from its 1979 level. The high expected soybean price in 1980 was probably the main reason why soybean acreage increased by over four million acres. Despite the acreage increase and consequent production increase, the soybean carryover into 1981 remained at its minimum allowable level. For this reason, the 1980 season price for soybeans increased by $1.36. Soybean acreage would have been expected to have also increased in 1981 due to its even higher price in 1980. Cotton acreage also increased to 15.86 million acres. The acreage increase was about 1.4 million acres, a smaller increase than in each of the previous three years. The declining cotton expected price undoubtedly helped to decrease the relative increase in cotton acreage. The production level was large enough to accommodate commercial ending inventory of 5.2 million bales, and a government inventory of 5.8 million bales. This overhanging production surplus helped to push the cotton market price down to 69 cents, a decline of 6.7 cents. It is most likely that cotton
acreage would have started to fall in 1981 given the fall in its expected market price, and the increases in the prices of corn and soybeans, both direct competitors with cotton for land.

**Summary and evaluation of predictive simulation results**

The evaluation of the predictive simulation results from 1974 to 1980 utilizing the modified RIP model indicates that the model is capable of reflecting real world production and supply responses of the agricultural crops in the model. Although the various crop acreage and market variables estimated by the model were not completely accurate from 1973 to 1976, the production response behavior estimated by the model resembled closely the production response behavior exhibited by these crops. As expected, acreage, production and other relevant market variable estimation errors in any particular year had a cumulative effect throughout the period of analysis. Nevertheless, the various crop supply response behavior projected after 1976 appear to realistically reflect or respond to changes in their respective relative net returns and other market phenomena.

The feedgrain sector underestimated total acreage response in 1974. Production was also underestimated. Consequently the feedgrain production was striving to catch up to demands through 1977 instead of 1976, as ending inventories fell very low. The feedgrain price peaked in 1976 and feedgrain acreage peaked in the following year. After 1977, the buildup of ending year inventories to more normal levels brought the aggregate feedgrain price down to levels more
compatible with lower acreage levels. Thus, the aggregate feedgrain acreage level continuously declined through 1980, although the aggregate feedgrain price was again beginning to rise. This price rise indicated possible acreage increases after 1980.

The individual feedgrains showed different production response to the different price levels from 1974 to 1980. Corn and sorghum acreages followed the same general acreage changes the aggregate feedgrain acreage, primarily because these are the largest sources of the feedgrain acreage. Corn demonstrated much larger changes in acreage to price changes than did sorghum although on a percentage basis these two crops were very comparable. Barley and oats acreages decline continuously throughout the analysis, despite large price increases until 1977. It is entirely possible that barley and oat acreages declined due to their lower net relative returns from 1974 to 1977 than either grain sorghum or soybeans whose acreages were substantially overestimated. From 1977 to 1980, the oat market price was continuously less than its support price and the barley price hovered close to its support price. Thus, it appears that during this latter four year period, the expected net returns for these crops in many producing areas were negative.

The wheat production response pattern during the predictive period also closely resembled the aggregate feedgrain acreage and production response pattern. The wheat acreage was continuously underestimated by five to six million acres from 1974 to 1976. Consequently
production was also underestimated, and the 1975 and 1976 prices were overestimated. Interestingly, although the 1974 acreage response was underestimated by six million acres, the 1974 through 1976 acreage changes were very similar to those acreage changes actually observed. After 1976, wheat acreage fell with acreage falling more rapidly as the price fell due to the rapid buildup of ending year inventories to about 1.2 billion bushels in 1979. The price fell in 1980, and it appeared that acreage would have also declined in 1981 and maybe 1982 before declining supplies would have forced the market price to again increase. Thus, wheat acreage would have presumably eventually increased in response to the change in its net relative return.

The soybean sector was undoubtedly the cause of many problems or incorrectly estimated acreage and production responses from other crops in the model. It is not possible to quantify the precise influence of the soybean crop acreage on other crop acreages in this thesis study without a great deal of detailed study, which is not possible in this study. But if the soybean acreage had not been so substantially overestimated, it is entirely possible many of the other initial declines in crop acreages, notably corn and cotton and indirectly on oats and barley acreages, may not have occurred. From 1974 to 1976 soybean acreage was overestimated by almost nine, six, and five million acres. The extent of the overestimation declined due to the continuous buildup of ending year inventories and total
yearly supplies which decreased prices from their initial estimated $4.63 level. In reality, the soybean acreage was hovering between about 49 to 54 million acres, inventories were very low and observed prices were much higher than those estimated by the model. This divergence of price and acreage behavior divergence from the model's predicted soybean supply response behavior strongly suggests that the soybean net return sector is specified incorrectly. The problem could be that either the naive price expectations model is imprecise or the costs per acre specified for soybean crops has been severely underestimated and should include implicit costs such as erosion costs. It is more likely that the naive price and trend yield expectations model should be replaced with another expectation model reflecting the likeliness that producer's soybean net return calculations are formed from information taken from more than one production period.

In 1977, and 1978, soybean acreage and total production declined in partial response to the earlier buildup of a large overhanging year yearly inventory. By 1979, this inventory had been worked down to its minimum allowable level, and the soybean market price increased rapidly anticipating a four million acreage increase in 1980. The market price rose again in 1980, suggesting that acreage increases would also be occurring through the early 1980's. The combination of minimum allowable inventories in 1979 and 1980, and the very low market prices in 1977 and 1978 highlight the problems developing in the soybean
market submodel in this latter four year period. Thus, it appears that a further respecification of the soybean market submodel in the simulation sector should occur for a more realistic representation of the soybean production response and associated market behavior in future simulations.

The cotton sector first showed falling acreage and production levels despite a rapidly rising market price. This behavior suggested that the cotton activities in many production areas must either be the "loose crop", or the crop whose solution acreage was between its upper and lower acreage bounds, or at its lower bound. Either of these two circumstances would have occurred if the net relative returns of cotton activities were not the most profitable cropping activities in the producing areas. Since the main cotton competitors for land, corn, sorghum and soybeans crops, were increasing or already at higher than observed levels, the net returns for cotton must have still been relatively too low. Perhaps cotton acreages would have responded more accurately if the soybean crop acreage, which was severely overestimated, had been estimated closer to its lower, observed levels. Nevertheless, cotton acreage did not begin to increase until 1977, when soybean acreage fell to almost 49.4 million acres from its 1974 high of over 61.1 million acres. These acreage increases and corresponding production increases eliminated the very low ending cotton inventory problem in 1978. Consequently, cotton prices began to decrease throughout this three year period and government inven-
tory accumulation began in 1979. The increase in soybean and feed-grain prices in 1980 and the lower cotton prices suggested that cotton acreage would again be declining again in the early 1980's, although another small cotton acreage and production increase could have occurred in 1981.

In brief summary, the modified recursive interactive programming model demonstrated a fairly representative but varied economic cob-web behavior pattern for the crops included in the model. While the modifications in the RIP model specifications helped to prevent or minimize many of the earlier noted modeling problems, the predictive simulation results indicated that further experimentation and respecification are necessary for a more realistic and accurate crop production response model. In aggregate, the feedgrain crops did not respond to increased prices as quickly as was actually observed during the 1974 to 1976 period partly because their prices were underestimated. The corn and sorghum acreages increased but oats and barley decreased due to their lower relative net returns. After 1976, all the feedgrain crops decreased in partial response to the buildup of carryover inventories and lower prices. The wheat acreage response from 1974 to 1980 was very similar to the aggregate feedgrain sector behavior, first increasing acreage and then decreasing acreages as its expected prices increased and decreased. The soybean sector exhibited many estimation problems in its market submodel variables and also was the most likely cause of much of the inaccuracy
of other crops acreage and production patterns, most notably corn and cotton. Soybean acreage and production were substantially overestimated. Consequently, as the overhanging supply increased and price fell, the soybean acreage fell also. The low production levels in 1979 and 1980 caused the soybean price to rise significantly leading to increasing production and acreage in 1980, and quite possibly afterward. The cotton sector also demonstrated the effect of modeling misspecification, as the cotton acreage and production decreased from 1974 to 1976 as its expected price increased. After 1976, cotton acreage and production increased as its price steadily declined. This behavior can be attributed to its presumably lower relative net returns than competing crops from 1974 to 1976. Additionally, although its price was declining, its higher relative net returns after 1976, combined with acreage decrease and lower price for competing crops were responsible for the acreage and production increases.

As in the historical simulations, many of the estimated aggregate national crop acreages errors or inaccuracies from 1974 to 1976, and the resulting crop production and supply response behavior through 1980 can be attributed to six confounded factors. First, the present specification of the market and livestock submodels in the simulation sector is inadequate for use in this structural format. The price, inventory and demand equations are neither as sensitive
to changes in production levels or other economic conditions or able
to manage extreme shortage or surplus supply situations as are needed
for the accurate representation of real world events. Second, in-
complete and inaccurate cost data may have severely biased the esti-
mation of relative net returns among crops in the various production
areas even if the expected price and yield figures were also used
in the net return sector. Third, the naive price expectations model
and/or the trend yield estimation are in many cases incorrectly speci-
fied. For example, the soybean acreage results strongly suggest that
its expected price or yields are formed over several periods. Addi-
tionally, the value of barley or oats as a cover crop was not included
in the estimation of their net returns. Fourth, the inadequate
estimation of the new harvestable acreages bases for
the recursive programming sector undoubtedly contributed to the crop
acreage and production estimation errors from 1974 to 1976 and quite
possibly did not constrain acreages as much as perhaps it should have
after 1976. Inaccurate individual production area base acreages could
have very easily caused imprecise activity solutions because the
individual crop activities' competition for land may have been cir-
cumvented with too large or too small an acreage base. Fifth,
the estimation of upper and lower crop acreage flexibility coefficients
and restraints were inaccurate, i.e., many of these coefficients and
restraints could have been either larger or smaller than would have
actually occurred in similar economic conditions. Finally, the sim-
plistic and incomplete recursive programming structure of the aggregate
agricultural sector also was responsible for many of the inaccuracies
and improbable response behavior of the RIP model in its predictive
simulation format. Respecification of the programming sector to in-
clude a regionalized livestock sector, and the different hays, alfalfa,
rye, corn and sorghum silage and other important crops would obviously
help to eliminate this last problem.
CHAPTER V. SUMMARY AND CONCLUSIONS

A first generation national, quantitative simulation and linear programming model of some of the major crops in U.S. agriculture has been developed in this thesis study to illustrate the modeling and methodological framework necessary for successfully interfacing an econometric simulation model with a recursive programming model. The modeling technique utilized to recursively link, or interface a simulation model with a programming model may be conveniently referred to as recursive interactive programming, or RIP. The crops used in this model were the four feedgrains, corn, sorghum, barley, and oats, wheat, soybeans, and cotton. Once constructed, the recursive interactive programming model was then initially used in various simulations of the production and supply response behavior of the crops in the model from 1969 to 1973. These initial historical simulations served two purposes. First, these simulations employed different model specification variations to validate and determine the accuracy of this modeling technique with regard to differences in predicted and observed crop acreage levels, crop production, crop prices, and other important market variables, and the spatial location of the various cropping activities. The second objective of these historical simulations was to examine and acquire knowledge about the special model specification problems peculiar to this modeling technique, in general, and within this model, in particular. Finally, a modified version of the national RIP model was
used in a predictive or projective simulation from 1974 to 1980. In this final simulation, a "free market" situation was assumed without government restrictions on land use, but with government acceptance and disposal of large surplus crop inventories if these occurred.

Statement of Methodological Economic Problem

and Recursive Interactive Programming

A first generation, national, interregional, recursive interactive programming model of some major crops in U.S. agriculture has been presented and developed in this thesis study. Recursive interactive programming is a complicated analytical systems modeling technique because it is synthesized from two already complex modeling techniques, econometric simulation and recursive programming. Although mathematical programming models have been often characterized as "normative" models, and econometric simulation models often characterized as "positive" models, these two complicated methodological techniques are each limited by their own methodological structure. When viewed from a different perspective, each technique's strengths can be easily seen to complement the other technique's weaknesses in their respective ability to examine particular aspects of agricultural production behavior and policy analysis.

Interregional programming models have been extremely useful for predicting or selecting a particular solution of optimal regional production activities at a point in time. These models are based on an economic optimization process, either to minimize costs or to
maximize net revenues. Economic research studies involving the optimal spatial location of production activities and intra and interregional competition for resource use under different environmental or export environments by production activities are particularly appropriate for these models. The use of these models for such problems is legitimate because these models have the structural ability of being able to optimize and select those activities providing maximum return or minimum costs, while the underlying technical input-output and production relationships of the firm or region are explicitly recognized. Thus, interregional programming models possess three significant advantages for examining agricultural production, policy, and planning questions. First, these models can demonstrate a particular spatial locus and level of production activities in response to differently specified economic environments. Second, the competition for different resources by alternative production activities can be shown both for region specific resources such as land, and for nonregion specific resources such as water or fertilizer. In addition, the effect on spatial location and the level of production activities with different restrictions on resource use can be easily shown. Third, the interregional programming technique, as with all mathematical programming techniques makes use of explicit technical production relationships and changes in such relationships in an input-output tableau. The input-output tableau or matrix of technical production coefficients as they relate to differ-
ent production activities permits the model builder to explicitly replicate the underlying technical structure of production. This last structural property of interregional programming model allows the incorporation of technical and structural changes in the production process to be partially formulated in the modeling design, although technical change is an intertemporal process. Therefore, the micro foundations of the production process and the economic decision making process can be represented with this modeling technique. In summary, the spatial distribution, resource competition, and the explicit representation of the underlying technological structure of production and the economic decision process to efficiently allocate resources to attain a particular economic objective are the three main strengths of interregional programming models.

Although these models contain the advantages briefly discussed above, these models also possess two weaknesses. First, these models are static or one time period models. Consequently the dynamic aspects of production behavior response to different economic conditions cannot be simulated with these models. Thus, for prediction purposes, profit maximizing or cost minimizing solutions are useful for indicating the direction and extent of what firms within regions would do given certain restrictions limiting production process specialization. These restrictions are usually formulated to be responsible for "forcing" the model to approximate a real world solution. In the long run, when all restraints, explicit or implicit,
reflecting changeover costs, established production customs, lack of knowledge, capital restraints and other factors affecting short run production decisions are removed, these solutions may very well indicate the long term equilibrium solution. Therefore, these interregional programming models are not intended to predict short run or year to year production adjustments because the actual process of adjustment mechanisms have not been properly or explicitly portrayed in these restrictions, even if the real world input-output coefficient matrix of production relationships has been specified. For these reasons, the real world feasibility of attaining the efficient spatial distribution and production levels of agricultural activities of these interregional programming models is often questioned.

The second problem with interregional programming models is the specification of realistically, complex market sector for the various agricultural commodities produced in the model. Cost minimizing, linear interregional programming models have typically used fixed minimum demands exogenously specified from projected figures. The quadratic interregional programming models have made use of very simplistic, linear, one variable minimum demand functions for commodities. In both models, inventories and exports must be specified prior to each model solution and are therefore exogenous, rather than endogenous variables within the agricultural industry. In reality, the various commodity market structures and behavior are far more
complex than is represented in these models, although the simplifying assumptions utilized in these models must be made in order to use these models for evaluating alternative agricultural policies for planning purposes.

An alternative methodology for studying various commodity production responses in agriculture is with econometric simulation models. Recursive, econometric simulation models have been extremely useful for predicting or forecasting an average or aggregate land use, resource use, and supply response of many agricultural commodities, if levels of exogenous variables and technical coefficients generated from time series data have been correctly specified. Usually, recursive simulation models have been used for national aggregate analysis because these models are often constructed from linking a series of relevant macro variable calculating equations which have been estimated with regression analysis from time series or cross-sectional data. Because equation estimation with regression analysis has been often used to predict agricultural supply response with fairly high accuracy when compared with conventional interregional programming models, simulation models have been used often for aggregate policy analysis and planning studies. Because these equations are estimated with actual observed behavioral response data, the simulation technique is able to implicitly include the parameters of likes, dislikes, changeover costs, and other factors which influence the level of many important economic vari-
ables in the economic environment.

Although production response accuracy is generally conceded to simulation techniques, simulation techniques also contain two advantages that are among the mathematical programming techniques most serious disadvantages. First, because of the structural formulation of simulation methodology, an extremely complex model of the various commodity markets can be constructed which may represent real world behavior far more accurately than either the fixed demands or minimum demand structures used in interregional programming models. Consequently, the simulation format allows the economic behavior and environment relating to commodity marketing to contain far many more endogenous rather than exogenously specified variables. Second, the simulation methodology explicitly uses time as a variable when estimating the information necessary to analyze the effect of agricultural policies on agricultural production, resource use, and supply response. The simulation model is constructed to act in a recursive manner based upon the cobweb theorem of dichotomized production and marketing periods. This recursive property is exemplified by the movement of the model from an initial production period sequentially through a number of following production periods and finally to stop in a prespecified ending production period. Additionally, each production and related marketing period utilizes the information generated in preceding marketing and production periods to generate current production and marketing data.
But the simulation models also contain three distinct disadvantages that are three central advantages of the interregional programming models. First, simulation models are typically aggregate variables estimating models. Therefore, an aggregate crop acreage is estimated, rather than a spatial distribution of crop acreages. Consequently, the regional or local effects of national agricultural policies are very difficult to ascertain. Second, the econometric, regression equation response methodology does not easily lend itself to describing the competition among crops between and within regions for available resources. Usually, the assumption is made that real world limiting resources or inputs are in perfectly elastic supply in any particular production period. If a larger quantity of a resource, say land, is demanded by the acreage equations in the model, a complicated reallocation sector must be developed so that the resource use falls within prescribed limits. Third, the technical structure of production is only implicitly contained in the simulation model, whereas it is or can be explicitly defined in the programming models. For this reason, the difficulties of incorporating structural changes in agricultural production operations is extremely difficult. Regression analysis estimates variable coefficients and these coefficients reflect a particular historical production and response structure. Therefore, changes in the underlying structure of agriculture either through technological change or government programs provide a sharp argument
against the use of regression analysis for prediction purposes. An exception would occur in the short run when the historical structure can be assumed to continue.

Therefore, it seems reasonable in order to more adequately explain the dynamics and spatial distribution of agricultural activities, than is possible with a static interregional programming model or an aggregative and recursive econometric model, that a new type of modeling methodology was suggested. This methodology uses elements of both these analytical techniques, which has been referred to as recursive interactive programming. In essence, the simulation model provides the market information and dynamic properties needed by the interregional programming model. The interregional programming model provides, in return, the spatial distribution, resource use and underlying technical structure of production information and properties found lacking in the simulation model. Thus, each model can be strengthened by the presence of the other, especially if each model can draw on the other model for assistance in explaining or studying the effect of alternative agricultural policies for planning purposes.

Interfacing Specification

While simulation models and interregional programming models may conceptually complement each other's advantages and disadvantages, the problem remains of how best to concretely link or interface these two different modeling techniques. Three approaches were suggested to solve this problem with linear interregional programming models.
The first approach would feed the demands generated by a simulation model into a linear interregional programming model as minimum fixed demands. The linear programming model would then be solved for the regional acreage distribution and equilibrium costs/prices under cost minimization. But in this formulation, the information flow is one way, from the simulation model to the programming model. The second approach would be to use the acreage predictions from the simulation model in the programming model. The linear programming model would then be solved for equilibrium costs/prices and regional acreage distribution under cost minimization. Again, the information flow is only from the simulation model to the programming model.

Additionally, in both the above interfacing approaches, the solution of the linear programming model does not affect behavior of the simulation model. Both models would be predicting crop acreage levels or production levels respectively. Consequently, conceptual problems are created in trying to solve data generational conflicts, because the simulation and linear programming models remained essentially separate models. Thus, neither of these approaches were selected because neither approach produced the dynamic simulation and programming model, complete with interactions.

The third approach was the methodological approach chosen for the interfacing between the simulation and programming models. This approach would use the crop acreage and production predictions from an interregional profit maximizing linear programming model as acre-
age and production data in the simulation model. The simulation model would not predict its own crop acreages and production levels. Rather, it would use the data generated by the programming model to estimate aggregate resource use and the various market sector variables in year \( t \). This information and other pertinent information would then be used by the simulation model to rebuild or respecify the net returns and other objective function coefficients, resource availability, and the input-output matrix of the programming model in year \( t + 1 \). The programming model would then be solved for crop acreage and production levels of the year \( t + 1 \) and provide this information to the simulation model.

But an important problem referred to as the linearity problem, exists which must be eliminated before linear interregional programming models are used for crop acreage and production predictions. The linearity problem is a result of the mathematical specification of the programming algorithm, and the objective function. The algorithm maximizes the objective function, which is linear in terms of the coefficients. If a coefficient is positive and is larger than other coefficients, the algorithm will select that activity and increase its solution level until a resource restraint is reached. Thus, if a coefficient is negative one year, it may not enter the solution vector at all. If the same activity coefficient is positive the following year, it may enter the activity solution at a very high level.
In the real world, agricultural activities levels change, but not at the extremely high rate of change that the programming model might suggest. Thus, the linearity problem is essentially one of specifying allowable year to year upper and lower bounds on the allowable changes in the levels of activities from the preceding year is solution. These programming restraints are usually referred to as "flexibility restraints." The utilization of flexibility restraints respecifies the linear programming model as a recursive programming model [40]. Most often these flexibility restraints are the rates of change in activity levels based on time series data of past activity level changes. Therefore, in a recursive programming model the solution remains optimal but is optimal in a highly restrained sense and approximates a more predictive real world solution based on farmers' actual past observed production behavior.

In summary, then, this third interfacing approach would remove both the consistency problem of either two different crop acreage or production estimates mentioned in the two previous approaches, and the interaction problem or the one way information flow from the simulation model to the linear programming model. With this approach, price information and other variables used to estimate the flexibility restraints input-output matrix and the objective function of the yearly recursive programming model can be generated by the econometric simulation model. At the same time, the simula-
tation model can continue to estimate aggregate input use, prices, income, other market variables and other relevant economic information based on the recursive programming model's crop acreages and production levels predictions or estimations. Consequently, this methodological modeling format would be able to be used in a year to year, or period to period recursive dynamic analysis of the agricultural sector because the recursive programming model and the simulation model are interfaced both conceptually and methodologically. In effect, each model becomes a separate but equal sector in the larger recursive interactive programming model framework.

The Model Specification and Cycling Technique

The national recursive interactive programming model presented in this thesis study was developed to empirically illustrate the RIP methodology and analytical framework. Although the modeling framework of the RIP model interfaces a recursive programming model and a simulation model, in reality the description of the specification of the model and cycling technique considers the complete RIP model as containing four individual sectors. These four sectors are the recursive programming sector, the SUMMARY sector, the simulation sector, and the REVISE sector. Within each yearly cycle of the RIP model, these four individual sectors are sequentially linked so that economic information developed in each sector can be provided as needed to other sectors.
The recursive programming model is the initial sector solved in the RIP model. The solution of the recursive programming sector provides the predicted individual crop acreages and production levels in the RIP model. This average land class and average crop yield recursive programming model was developed primarily from an extremely complicated and comprehensive 105 producing area model with different land classes and representative yields of major crop and livestock activities presented by Wade [207] and documented by others [127]. Only 99 of these producing area regions were represented with production activities, and these activities only include barley, corn for grain, oats, sorghum for grain, soybeans, wheat, and cotton. Silage crops, the hays, other small grains, other crops and livestock production activities are not included in the specification of this sector. Additionally, 56 of these producing areas contain irrigated cropping activities. There are a total of 538 cropping activities, irrigated and dryland. The basic structure of the programming sector remained essentially the same as the Wade model with a nitrogen for fertilizer, a water supply, and irrigated crop land to dryland use, and crop activity subsectors, but with an important exception. Because crop and livestock demands for food and fiber were not included in the recursive programming model, a transportation sector was also not included in the model, but various local to national price ratios were used to calculate expected local prices to reflect differing region transportation costs.
The recursive programming sector model has many of its objective function and input-output coefficients changed every year by the REVISE sector. The REVISE sector will be discussed shortly. The changes in these coefficients reflect any changes in expected crop yields, costs of production, optimal nitrogen fertilization rate, and prices. Water use coefficients and prices remained constant throughout the various analyses. Revision of the land resource base available for the crop production activities also was allowed to occur in various years. These land resource bases were derived from various observed land use patterns from 1968 to 1973. Since at various times, the seven crops in this sector do not use all the available, allocated irrigated and nonirrigated land base, the land left unused by the programming sector was assumed to be used in other crop production activities. Because water availability was judged to be sufficient for crops in the model through 1980, water use in the different production areas was left unbounded, but the irrigated land base effectively limited unrealistic or an unbounded water use by the sector crops. The nitrogen buying sector was likewise left unbounded in this model.

Finally, even with carefully estimated upper and lower crop activity flexibility restraints, the recursive programming model will move to optimal solution of activities toward a most efficient, or largest net return locus of production activities by specializing in a few or one crop in each producing area if net relative returns
do not change sufficiently. Therefore, absolute upper and lower acreage limits or bounds were used to supersede the minimum or maximum estimated crop acreage flexibility restraints to prevent crop specialization.

After an optimal solution has been found in the recursive programming sector, the cycling procedure then moves to the SUMMARY sector, the second of the four sectors in the full RIP model.

The SUMMARY sector is a very important sector because it links the recursive programming sector with the simulation model, which is itself a sector. The SUMMARY sector is responsible for taking the recursive programming sector's solution data of individual crop acreages and regional production levels and summing them into national crop acreages and production levels. Once this is accomplished, this information is then transmitted to the simulation sector. The SUMMARY sector is necessary because the simulation sector is incapable of directly reading the recursive programming sector's solution and finding the relevant economic information it needs for its own calculations. After the SUMMARY sector has provided the relevant summed crop and production data and prepared it in a format which the simulation sector can use, the cycling mechanism then moves to the simulation sector, the third sector in the RIP model.

The simulation sector in the RIP model was constructed from an earlier national simulation model originally developed and re-
ported by Ray [160, 162] and modified by others, for forecasting purposes [93, 94]. The original simulation model was constructed with six submodels including one each for the feedgrains, cotton, wheat, soybeans, cotton, tobacco, and livestock. Each of these submodels was originally specified as a set of equations, estimated with data from 1930 to 1967, sequentially depicting the yearly production cycle of each of the agricultural commodities above. The revised livestock submodel used here was formulated to estimate the yearly equilibrium demand for livestock products and commercial feedgrain and soybean demands. The tobacco submodel was excluded entirely from the RIP simulation model.

In each commodity submodel, the equations can be categorized into three sections. The first submodel section is referred to as the pre-input section and calculated crop acreage, the stock of capital assets, machinery purchases, and land price. In the RIP simulation sector, these acreage equations were replaced by the acreage predictions from the recursive programming sector. The second submodel section is referred to as the input expenses and demands section. These various input demands fall into two categories and use information generated in the pre-input submodel. Single period inputs include fertilizer, seed, labor, and machinery operating expenses. Multiperiod inputs include machinery expenses, real estate expenses, interest on commodity stocks and real estate taxes. These input demand levels were then used to determine ex-
pected national crop yields and national production levels. Because these crop yields and production levels were determined in the REVISE sector and recursive programming sector, respectively, the commodity input and pre-input submodels of the simulation sector were not utilized in this study, and the various aggregate pre-input and input levels were not examined. Although the pre-input and input equation sections were not necessary for the formulation of the full RIP model, their econometric equations were left in the simulation sector for future research studies. In effect, the pre-input and input sections in each commodity submodel were dichotomized from the third and final set of equations, the output or market section. This section utilizes the summed crop production level information determined in the recursive programming and SUMMARY sectors with import and carryover inventory supplies to first estimate the commodity total supply. Afterwards, the commodity commercial, food, export, and industrial demands are calculated and summed to estimate total demand. Finally, the commodity price and any necessary revisions of ending year inventory or export levels are calculated for year t and the various relevant output variable levels are presented as an exogenous data set for the REVISE sector. Gross and net income equations were also left in the model, but these figures were not examined. In summary, the market sections were the only parts of the simulation model used in this research study.
After the simulation sector completes its calculations, the cycling mechanism moves the RIP model to its fourth and final sector, the REVISE sector. The REVISE sector was developed to change or update the recursive programming problem for the next $t + 1$th year in the analysis. The REVISE sector has been specified so that a great many different modeling variations for formulating the revisions in the new recursive programming sector's problem can occur. Consequently, this is the sector where most of the methodological experimentation with the RIP modeling format occurs. Different modeling specifications can define a purely recursive programming model, a one way flow of production and acreage information from the recursive programming sector to the simulation sector, or either a partial or full two way linkage between these two sectors. These different modeling variations are accomplished by using the REVISE sector in the context of different exogenously or endogenously determined data sets. For example, if the REVISE sector makes use of exogenously determined market information, the RIP model is effectively programmed as a recursive programming model. Additionally, within each of these larger model variations, a large number of further submodel variations were available for simulations. These further variations pertained to use of different types of data, e.g., actual, optimal or trend yields for the reformulation of the programming sector and have been described in Chapter III. Unfortunately many of these submodel variations could not be empirically tested due to lack of time and cost factor.
The structure of the REVISE sector is most easily explained in terms of two subsectors, the net return subsector and the flexibility restraint subsector. The net return subsector is utilized for a number of different coefficient calculations each period or year. The first calculations involve estimating the gross expected returns per acre for each crop activity by multiplying the expected crop price by the expected yield in each producing area. Crop production costs per acre, exclusive of nitrogen and water are then subtracted from the gross expected returns to provide the expected net returns per acre for each crop in the objective function. Nitrogen costs are also updated each year in the objective function. This subsector then chooses a particular set of expected crop yields for each activity, and their respective optimal nitrogen use coefficients in the input-output matrix. It is important to remember that the objective function, and to a lesser degree, the input-output matrix coefficients are all estimated as "expected values", although some of these values are known with certainty. Consequently, a large amount of built in error can arise from the possible misspecification of expected values of the various coefficients from year to year, especially in the objective function.

The flexibility restraint subsector is the second subsector in the REVISE sector and calculates the upper and lower crop activity bounds for the recursive programming sector in the t + 1th year. The flexibility restraint subsector first estimates upper and lower
flexibility coefficients by crops by states using econometrically estimated regression equations. These equations use government program and support price variables applicable for year \( t + 1 \), but use crop acreage levels, crop market prices, ending year inventories and export levels from year \( t \) as independent variables. These state flexibility coefficients are then weighted into the various producing areas by crops and then multiplied by their respective acreage levels in year \( t \). The resulting upper and lower crop activity flexibility restraints or upper and lower bounds limit the acreage changes for the individual cropping activities, thereby restricting the solution acres to a more "positive" supply response pattern. National acreage allotments for wheat and cotton crops, and absolute upper and lower acreage bounds to prevent crop specialization may be utilized to modify these flexibility restraints.

When the new programming problem coefficient calculations are finished in the REVISE sector, the RIP cycling mechanism then starts the four sector cycle again for the \( t + 1 \)th year. The recursive programming problem is revised, then solved, and the solution is summed into national figures from its component parts by the SUMMARY sector. The simulation sector then uses this information to calculate market information in year \( t + 1 \), and this data can then be used for the REVISE sector. Finally, the REVISE sector updates the recursive programming problem for year \( t + 2 \), and so on for as many years as specified by the economist.
Summary of Findings and Specification Problems

The explanatory ability of the prototype, national RIP model of U.S. agriculture constructed for this study was tested during two time periods. From 1969 to 1973, the model was examined for its adequacy to describe the observed land utilization patterns. During this period, five historical simulation runs were made to demonstrate not only some of the modeling variations available for this particular model, but also to try to validate this experimental model and its methodological design. The second time period in which the model was tested was from 1974 to 1980. This final predictive simulation served a double purpose. First, this simulation served to test the aggregate predictive crop acreage response behavior of the model from 1974 to 1976. Second, this predictive simulation was used to demonstrate the recursive, cobweb properties of the RIP model.

The first and second historical simulations utilized the RIP model as a national recursive programming model. The objective of these simulations was to try to accurately predict harvested crop acreage levels on a year to year basis based on actual observed market phenomena and the levels of various government programs. Consequently, the REVISE sector was specified to use an exogenously determined data set to rebuild the recursive programming sector's objective function, input-output matrix, and flexibility restraints rather than using the data provided by the simulation sector. These two simulations were made with almost the same model specifications.
except in one important area, the formulation of expected net returns. The objective function and crop activity expected net returns were calculated with expected optimal yields estimated with a Spillman trend yield production function in the first simulation. In the second simulation, OLS trend yield regression equations were made use of to estimate the yields utilized in the calculation of the expected net returns in the objective function. In both simulations, the yearly estimated flexibility restraints were calculated with the lagged observed acreage level of each cropping activity.

The empirical results of these simulations indicated that the RIP model when used as a recursive programming model explained the national land utilization pattern, the aggregate harvested acreage levels and supply response of the four feedgrains, wheat, soybean and cotton crops with reasonable accuracy. The estimated solution crop activity acreage results of the model were compared against their actual observed levels. In both simulations, the correct aggregate total turning point percentages were above 60 percent in all five years. In 1969, 1972, and 1973, the total correct number of turning points was over 66 percent. The national total aggregate Theil U coefficients were less than or equal to .080 in each of the five years, and were under .055 in 1970, 1971, and 1973. Thus, the prediction results of these two model variations show not only a close but also a similar correspondence to the actual, observed national crop spatial production patterns and supply responses.
The similarity and relative closeness of the national individual
disaggregate crop, aggregate crop and total aggregate summary statist­
cics do not clearly indicate whether the Spillman or OLS trend yield
variation is the more accurate predictive model. The aggregate
turning point figures showed that the Spillman yields were slightly
more accurate in three years, 1970, 1971, and 1973 but this slight
accuracy advantage was only one, two, or three more correct turning
points out of a total 538 possible turning points. On the other
hand, the OLS trend yield variation demonstrated a much higher accuracy
in 1969 and 1972. Therefore, the second simulation was judged a more
accurate predictor of turning points, or directional accuracy. The
aggregate Theil U coefficients indicated that both modeling vari­
tations were just about equally accurate in terms of relative error.
In three years, the Theil U statistics were within one thousandth of
each other, with the second simulation the lower coefficient. In the
remaining two showed the OLS simulation much lower in 1971, but much
higher in 1972. Thus, the second modeling variation with the OLS
trend yields used in the net return sector was judged to be a more
accurate predictor of both the national and spatial distribution of
crop acreages.

Although the overall predictive response of the first two recur­
sive programming variations can be considered close to actual ob­
served production behavior as most of the disaggregated and aggregated
crop acreages were estimated with an error of less then ten percent,
and many to within five percent, other crops were not estimated with the same precision. Moreover, the consistency of acreage errors, turning point percentages, and Theil U statistics for each crop varied by year. These uneven results for the various individual crops can be traced to four sources of error. These include estimation errors in the calculation of flexibility coefficients and flexibility restraints, incorrect expected net returns per acre for each crop because the naive price expectations model was inaccurate, use of harvested rather than planted acreages and the assumption of normal weather conditions and, a larger than necessary and inadequately specified land base from 1969 to 1973. Additionally, these sources of acreage estimation errors are additive. Consequently, an error in the solution acreage of one crop can cause discrepancies in the estimation of solution acreages by other crops. Finally, these sources of error were common to each of the historical simulations, and the predictive simulation.

The third historical simulation completed one of the interfacing steps needed for the full RIP model by using the simulation commodity market subsectors to generate market information for the REVISE sector. The OLS trend yields were used in the net return sector, and the actual crop yields were used in the input-output matrix. The yearly flexibility restraints were calculated by using the actual lagged crop activity acreages rather than using their endogenous solution values taken from the SUMMARY sector. Because
the market data was now being used in the REVISE sector to modify
the objective function net return coefficients, the nitrogen use
matrix coefficients, and the flexibility coefficients, it was hy­
pothesized that prediction errors in crop acreage levels, turning
points, and Theil U coefficients would be larger than in the first
two historical simulations.

However, this situation did not occur. The aggregate turning
point statistics showed that a lower percentage correct figure was
observed only in 1970. Also, the total aggregate Theil U coefficients
were almost identical in these three simulations in 1969, 1970, and
1972. The 1973 coefficient was much larger for the third simulation
but noticeable lower in 1971. In conclusion, the third historical
simulation linking the econometric sectors to the recursive programming
sector, but still keeping the activity acreages exogenous to the model,
could be regarded as at least as accurate as the first two simula­
tions through 1971. After 1971, as market variable estimation errors
accumulated, the model became progressively less accurate, as was
originally hypothesized.

The fourth and fifth historical simulation modeling variations
completed the interfacing or sector linkages in the RIP model. This
modeling variation was the same as specified for the third simulation,
except that the upper and lower flexibility restraints were calcu­
lated with the previous year's solution acreages from the recursive
programming sector. In the three previous simulations the use of
exogenous actual acreage levels served to correct any inaccurate crop activity solution levels in the previous year. Therefore, it was expected that the final set of model results in 1973 for both simulations would be considerably more erroneous than these three previous simulations, and especially the second simulation which had the least predictive errors. But it was also expected that these errors would be corrected through time as a result of the recursive properties of the model. The fourth simulation used the actual crop yields from 1969 to 1973 as the expected yields, and consequently was expected to simulate crop production behavior more accurately than the fifth simulation. The fifth simulation used OLS trend yields as the expected yields in the input-output matrix to test the full model's production response behavior under the "normal yield" scenario, and to try to gauge the extent of possible prediction behavior error over a five year period.

The ending year results of both simulations were fairly similar. After five years, considerable final acreage estimation errors occurred for the four feedgrains and soybeans. The aggregate 1973 soybeans, wheat, cotton, corn and barley harvested acreages were slightly more accurately estimated in the fifth simulation, but more acreage error was occurring for the grain sorghum and oats crops. In the fifth simulation these acreage errors were approximately -15, -8.4, 8.2, 17.4, -21, 46.28, and -36.8 percent, respectively, from their true acreage levels. Corn and sorghum acreages were the most overestimated
while barley and oats acreages were the most severely underestimated acreages in both simulations.

The aggregate number of turning points correctly estimated in these modeling variations fell substantially, and the total aggregate Theil U coefficients rose markedly from the results of the second historical simulation. These statistics indicated that the directional and relative acreage errors were increasing in these simulations, as was expected, although these statistics varied noticeably among the various crops. From 1970 to 1973, the aggregate turning point accuracy in these simulations ranged from only 46.3 to 56.7 percent. Additionally, the aggregate Theil U coefficients steadily increased from .063 in 1969 to over .12 in 1973, almost doubling the relative acreage accuracy error in five years. An examination of these two sets of different aggregate statistics, together with the individual crop statistics strongly suggests that a large amount of the RIP model's predictive error was attributable to movement toward crop specialization in many of the production areas of corn and sorghum at the expense of the other crops in the model.

This crop specialization was, in turn, a result of many factors, all of which were confounded, but were undoubtedly occurring, primarily, as a result of the recursive programming sector's cumulative interaction error with the simulation sector's market submodels, and the misspecification of the expected crop net returns subsector mentioned earlier. More specifically, in these two historical simulations, the
resulting simulation sector's market prices and other market variable estimation errors, especially in the feedgrain and soybean market submodels, were in large part due to inaccurate estimation of the crop solution acreages and production data in the recursive programming sector. The various market submodels in the simulation sector also demonstrated a noticeable inability to realistically cope with either low or high crop production surplus situations due to the fact they were estimated with market data only through 1967. Consequently, the REVISE sector was utilizing inaccurate solution acreage levels and market data to calculate the expected objective function net returns, and flexibility coefficients and restraints. These resulting errors, in turn, helped to increase the inaccuracy of the recursive programming sector. Finally, the cobweb, or recursive behavior characteristics expected by the feedgrain acreages and production levels, did not occur when the aggregate feedgrain price fell as a result of the large overhanging supplies. This happened because the support prices specified for corn and sorghum were higher than their respective production costs used in the model. Perhaps more accurate results would have occurred if only the loan rate had been used.

Nevertheless, although the RIP model's predicted crop production and supply response behavior was often in error with observed values and figures, this behavior reflected the endogenously determined
economic environment existing within the model. Consequently, the evaluation of the model's explanatory behavior should be viewed consistent with expected economic behavior, the methodological modeling framework and its prototype modeling specifications.

The final RIP model simulation was the predictive simulation from 1974 to 1980. This simulation was evaluated with respect to observed national price, acreage and production levels from 1974 to 1976, and as projected figures from 1977 to 1980 in a free market situation without government acreage or other production control constraints. Certain modifications in the RIP model specifications used for the historical simulations were made to try to correct many of the model specification problems occurring in the historical simulations and an initial predictive simulation run. These modifications included the development of three new land resource bases. Also, support prices were specified as loan rates, costs of production were revised to include a land ownership cost component, estimated commodity prices were multiplied by various ratios when ending year inventories were unusually low, or large, and any government inventories were assumed disposed of without affecting market behavior.

The predictive simulation results from 1974 to 1980 indicated that the modified RIP model is able to reflect the real world cobweb production and supply response of most of the crops in the model. From 1974 to 1976, corn and wheat acreages increased rapidly, though not as quickly as was actually observed in response to increases in their
respective crop prices. Part of the corn acreage underestimation could be attributable to the overestimated soybean acreages. Grain sorghum acreage also increased, but was overestimated. Cotton acreages fell during this period even though its price was rising, as did its actual supply response pattern. Soybean acreage was severely overestimated during this period, although its acreage declined as inventories built up and its price fell. The overestimated soybean acreage is probably responsible for much of the acreage underestimation of the other crops in the model, most noticeably those of oats and barley which would have been expected to have been increasing.

After 1976, the various crop supply responses appeared to realistically reflect changes in their respective market environments and relative prices, except for soybeans whose market sector had been misspecified. Corn and sorghum acreages peaked in 1977, and declined as did oats and barley acreages through 1980, as inventories were built up to more normal levels, and prices fell. It appeared that the absolute lower acreage bounds for barley and oats prevented a much further fall in their projected acreages. Wheat acreage fell for the same reasons, but started earlier in 1976, even though ending year inventories did not reach a billion bushels until 1978. Cotton acreage finally increased during this period in response to very high expected market prices and decreasing acreage competition from corn and soybeans whose prices had fallen substantially. The
falling soybean acreages and prices continued through 1979 when very low inventories triggered a large price increase. Consequently, the 1980 acreage increased substantially as the soybean sector seemed ready to start a new series of acreage increases in the early 1980s. Also, the feedgrain prices were also starting to increase in the late 1970s and 1980 presaging possible acreage increases in the early 1980s.

In summary, then, the results of the predictive simulation run suggest that modifications in the modeling specification formulation of the recursive interactive programming model resulted in a much more realistic representation of observed and projected crop response behavior to a changing economic environment. Additionally, these results strongly indicated that further model respecification and experimentation with different land resource bases, market sectors, or price expectation formulation for net return calculations with the various sectors would be necessary for the development of the RIP model presented in this thesis study as a truly realistic spatial and aggregate crop production response model that could be used for the accurate agricultural policy analysis needed for planning purposes.

Final Remarks and Future Research

The research presented in this thesis study has been concerned with developing a methodological formulation for and then constructing an empirical recursive simulation and linear programming model of some
major crops in U.S. agriculture. This particular methodological technique is referred to as recursive interactive programming because a national simulation model and a national recursive interregional linear programming model are interfaced to share market and production response information. Eventually, the development of this model and this methodological technique will permit a more detailed examination of the effects of different or alternative agricultural policies, and therefore as a planning tool to be used for the rapid analyses of the important economic variables governing the pricing and production of crops. The crops in this model include the four feedgrains, wheat, soybeans, and cotton. Within the model, a simulation sector including a national livestock subsector is interfaced with a 99 region linear programming sector using a yearly, cycling and linking mechanism. This new modeling technique is unique in the manner indicated as follows:

(a) it can be applied not only to a U.S. agriculture, but it can also be used for quantitative research in the fields of health care, transportation, economic development and energy policy and analyses;

(b) it includes a simulation sector containing an econometrically or quantitatively estimated set of behavioral response equations that estimate national input use, market and behavioral response relationships, input-output characteristics and production relationships. These relationships
are then used with the information generated within the linear programming sector to determine prices and related quantities yearly. Finally, this information in turn, is then used to regenerate the linear programming sector of the complete model for the following year within a recursive format and;

(c) it includes a recursive linear programming sector that optimizes resource allocation, using a profit maximization criteria, among cropping activities located within each of 99 production regions. The resulting acreages and production supplies are then transferred to and then used as information within the simulation sector.

The synthesis of a recursive, national simulation and linear programming model can allow basic historical and predictive quantitative research to be done on economic processes of adjustment through time using a wide variety of behavioral assumptions and production technologies. In addition, this modeling technique is capable of estimating yearly farm income, the spatial distribution of cropping activities and resource use, agricultural structure including farm numbers and sizes, the farm work force, the amount and distribution of capital investment and food costs in relation to grain inventory or export quantities, and other policy alternatives. Thus, the economic impacts of either given or proposed changes in regional or national agricultural policies, technological advances or behavioral changes can
be assessed for the formulation of regional or national policy guidelines based on these regional or national policy changes, technological advances or behavioral changes. Finally, a historical validation of the complete model can be made in comparison with actual data observations taken during the period upon which the time series regression or behavioral response equations are based.
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APPENDIX A. MISCELLANEOUS TABLES AND DATA
Table A.1. Crop activity codes and rotations in the linear programming sector.

<table>
<thead>
<tr>
<th>Crop Names</th>
<th>Rotation Code</th>
<th>Continuous Dryland</th>
<th>Continuous Irrigated</th>
<th>Dryland:Summerfallow Ratio: 1:1</th>
<th>1:2</th>
<th>1:3</th>
<th>1:6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td></td>
<td>GBA</td>
<td>IHA</td>
<td>GOA</td>
<td>GTA</td>
<td>GBA</td>
<td>LKA</td>
</tr>
<tr>
<td>Corn (for Grain)</td>
<td></td>
<td>OTB</td>
<td>ONB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td></td>
<td>BBA</td>
<td>BCA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oats</td>
<td></td>
<td>GCA</td>
<td>LGA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorghum (for Grain)</td>
<td></td>
<td>AEB</td>
<td>BHB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td></td>
<td>EEA</td>
<td>LHA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td>AXA</td>
<td>HIA</td>
<td>GRA</td>
<td>LNA</td>
<td>LMA</td>
<td>LLA</td>
</tr>
</tbody>
</table>
Table A.2. Cropping activities, historical flexibility coefficient ratios, and long run bounds used in linear programming sector.a

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity Name</th>
<th>Historical Flexibility Coefficients</th>
<th>Long Run Bounds (Thousand Acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R1GCA001</td>
<td>0.92</td>
<td>0.79</td>
</tr>
<tr>
<td>2</td>
<td>R1GCA006</td>
<td>0.84</td>
<td>0.68</td>
</tr>
<tr>
<td>3</td>
<td>R1AXA007</td>
<td>0.88</td>
<td>0.73</td>
</tr>
<tr>
<td>4</td>
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<td>0.74</td>
</tr>
<tr>
<td>532</td>
<td>R1IHA103</td>
<td>0.94</td>
<td>0.84</td>
</tr>
<tr>
<td>533</td>
<td>R1GTA104</td>
<td>0.87</td>
<td>0.74</td>
</tr>
<tr>
<td>534</td>
<td>R1LNA104</td>
<td>0.88</td>
<td>0.73</td>
</tr>
<tr>
<td>535</td>
<td>R1BGA104</td>
<td>0.92</td>
<td>0.84</td>
</tr>
<tr>
<td>536</td>
<td>R1BHB104</td>
<td>0.87</td>
<td>0.78</td>
</tr>
<tr>
<td>537</td>
<td>R1HIA104</td>
<td>0.63</td>
<td>0.51</td>
</tr>
<tr>
<td>538</td>
<td>R1IHA104</td>
<td>0.94</td>
<td>0.84</td>
</tr>
</tbody>
</table>
Table A.3. Historical data availability of yearly irrigated and harvested crop acreages for the 17 western states.\(^a\), \(^b\)

<table>
<thead>
<tr>
<th>State</th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybeans</th>
<th>Wheat</th>
</tr>
</thead>
</table>

\(^a\)Blank spaces indicate that irrigated and nonirrigated crop acreages could not be separated out from available state data.

\(^b\)The % dryland harvested was derived from the 1969 Agricultural Census.
Table A.3. (continued)

<table>
<thead>
<tr>
<th>State</th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybeans</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable Code Name</td>
<td>Definition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC</td>
<td>Acreage (million acres)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPUR</td>
<td>Livestock purchased by farmers (million 1947-49 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STK</td>
<td>Ending calendar year commodity stock on farms (million 1947-49 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STKAVE</td>
<td>Average of beginning and ending calendar year commodity stock on farms (million 1947-49 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPUR</td>
<td>Machinery purchases (million 1947-49 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSTK</td>
<td>Ending calendar year stock of machinery on farms (million 1947-49 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSTKAVE</td>
<td>Average of ending and beginning calendar year machinery stock on farms (million 1947-49)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRLA</td>
<td>Index of price of land and buildings per acre (index 1947-49=100)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VALA</td>
<td>Value of farmland and buildings (million 1947-49 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPA</td>
<td>Stock of physical assets defined as the sum of STKAVE, MSTKAVE and VALA (million 1947-49 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FERT</td>
<td>Fertilizer and lime expense (million 1947-49 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCTAF</td>
<td>Percent of crop acres which are fertilized</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEED</td>
<td>Purchased plus home-grown seed for individual crops (million 1947-49 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEED</td>
<td>Purchased livestock feed (million 1947-49 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^Prescripts on variable code names refer to commodity categories: livestock (L), feed grains (FG), wheat (W), soybeans (S), cotton (C), tobacco (T), other crops (O), and all commodities (US).
<table>
<thead>
<tr>
<th>Code Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>LABR</td>
<td>Man-hour requirements (million man-hours)</td>
</tr>
<tr>
<td>MACH</td>
<td>Machinery interest and depreciation (million 1947-49 dollars)</td>
</tr>
<tr>
<td>RE</td>
<td>Real estate expense including interest on land and farm buildings and depreciation, repairs and maintenance on farm buildings (million 1947-49 dollars)</td>
</tr>
<tr>
<td>FOR</td>
<td>Machinery fuel, oil and repairs expense (million 1947-49 dollars)</td>
</tr>
<tr>
<td>MISC</td>
<td>Miscellaneous expenses including pesticides, small hand tools, binding materials, electricity, telephone, etc. (million 1947-49 dollars)</td>
</tr>
<tr>
<td>INT</td>
<td>Interest on farmer held commodity inventories (million 1947-49 dollars)</td>
</tr>
<tr>
<td>RETX</td>
<td>Real estate taxes (million 1947-49 dollars)</td>
</tr>
<tr>
<td>Y</td>
<td>Crop yield per acre</td>
</tr>
<tr>
<td>PROD</td>
<td>Crop production (FG, million tons; W and S, million bushels; C million bales; and T, million pounds)</td>
</tr>
<tr>
<td>FU</td>
<td>Feed units in corn equivalent (million tons)</td>
</tr>
<tr>
<td>GCAU</td>
<td>Grain consuming animal units (million units)</td>
</tr>
<tr>
<td>SPY</td>
<td>Beginning crop year supplies defined as the sum of production, carry-in stocks and imports</td>
</tr>
<tr>
<td>PR</td>
<td>Average crop year price received by farmers deflated by the implicit GNP deflator. (L, index 1947-49=100: FG, dollars per ton; W and S, dollars per bushel; C and T, dollars per pound)</td>
</tr>
<tr>
<td>POP</td>
<td>Population (million people)</td>
</tr>
<tr>
<td>SD</td>
<td>Seed demand (same units as production)</td>
</tr>
<tr>
<td>Variable Code Name</td>
<td>Definition</td>
</tr>
<tr>
<td>--------------------</td>
<td>------------</td>
</tr>
<tr>
<td>CD</td>
<td>Total domestic crop year demand for all uses, except wheat in which only nonfood demand is included (same units as production)</td>
</tr>
<tr>
<td>FD</td>
<td>Crop year demand for wheat as food (million bushels)</td>
</tr>
<tr>
<td>FOOD</td>
<td>Crop year demand used for food (same units as production)</td>
</tr>
<tr>
<td>TD</td>
<td>Total demand (same units as production)</td>
</tr>
<tr>
<td>GINV</td>
<td>Government ending crop year inventory (same units as production)</td>
</tr>
<tr>
<td>CINV</td>
<td>Commercial ending crop year inventory (same units as production)</td>
</tr>
<tr>
<td>EXP</td>
<td>Crop year exports (same units as production)</td>
</tr>
<tr>
<td>GINC</td>
<td>Cash receipts and government payments deflated by the implicit GNP deflator (million 1947-49 dollars)</td>
</tr>
<tr>
<td>F.I.S. EX(_t)</td>
<td>Production expenses which correspond to the definition used in the Farm Income Situation</td>
</tr>
<tr>
<td>TXRT</td>
<td>Tax rate per dollar value of land and buildings</td>
</tr>
<tr>
<td>SPPR</td>
<td>Average support price levels deflated by the implicit GNP deflator (same units as price)</td>
</tr>
<tr>
<td>GPYT</td>
<td>Government payments deflated by the implicit GNP deflator (million 1947-49 dollars)</td>
</tr>
<tr>
<td>ACATDUMY</td>
<td>Acreage allotment dummy with 1.0's in years allotments were in effect</td>
</tr>
<tr>
<td>ACDIV</td>
<td>Acreage diverted from production (million acres)</td>
</tr>
<tr>
<td>SDPI</td>
<td>Index of seed prices deflated by the implicit GNP deflator (1947-49=100)</td>
</tr>
<tr>
<td>EQTY</td>
<td>Equity ratio defined as the value of real estate divided by mortgage debt on that real estate</td>
</tr>
</tbody>
</table>
Table A.4. (continued)

<table>
<thead>
<tr>
<th>Variable Code</th>
<th>Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMP</td>
<td></td>
<td>Crop year imports (same units as production)</td>
</tr>
<tr>
<td>MHPI</td>
<td></td>
<td>Index of machinery price deflated by GNP deflator (1947-49=100)</td>
</tr>
<tr>
<td>FTPI</td>
<td></td>
<td>Index of fertilizer price deflated by GNP deflator (1947-49=100)</td>
</tr>
<tr>
<td>MSPI</td>
<td></td>
<td>Index of motor supplies price deflated by GNP deflator (index 1947=100)</td>
</tr>
<tr>
<td>FSPI</td>
<td></td>
<td>Index of farm supplies price deflated by GNP deflator (index 1947=100)</td>
</tr>
<tr>
<td>PCDI</td>
<td></td>
<td>Per capita disposable income deflated by GNP deflator (1947-49 dollars)</td>
</tr>
<tr>
<td>TIME</td>
<td></td>
<td>Trend variable with 1930 = 1.0</td>
</tr>
<tr>
<td>LN(TIME)</td>
<td></td>
<td>Natural log of TIME variable with 1949 = 1.0</td>
</tr>
<tr>
<td>WARDUMY</td>
<td></td>
<td>Dummy variable for World War II with 1.0's for the years 1942-47</td>
</tr>
<tr>
<td>POSTWARDUMY</td>
<td></td>
<td>Dummy variable with 1.0's for years 1948-52</td>
</tr>
<tr>
<td>FRPD</td>
<td></td>
<td>Calendar year production of tobacco in all countries excluding the United States (million pounds)</td>
</tr>
</tbody>
</table>
Table A.5. Definitions of added variable code names used in Simulation and Linear Programming Model

<table>
<thead>
<tr>
<th>Var Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>States; 1-48</td>
</tr>
<tr>
<td>I</td>
<td>Producing Areas; 1-105</td>
</tr>
<tr>
<td>i</td>
<td>Main crop being estimated; Wheat(W), Corn(C), Sorghum (SG), Soybean(SB), Cotton(CT), Barley(B), Oats(O)</td>
</tr>
<tr>
<td>j</td>
<td>Main competitive crop for crop i; Wheat(W), Corn(C), Sorghum(SG), Soybean(SB), Cotton(CT), Barley(B), Oats(O)</td>
</tr>
<tr>
<td>t</td>
<td>Current year</td>
</tr>
<tr>
<td>t-1</td>
<td>Lagged year</td>
</tr>
<tr>
<td>PA(I)</td>
<td>Producing Area (I); I=1-105</td>
</tr>
<tr>
<td>i-Y(I)_t</td>
<td>Yield in PA(I) of crop i</td>
</tr>
<tr>
<td>i-YTR(I)_t</td>
<td>Trend yield in PA(I) of crop i</td>
</tr>
<tr>
<td>i-EXP-AC(I)_t</td>
<td>Trend cost per acre of crop i in PA(I)</td>
</tr>
<tr>
<td>i-PAAC(I)_t-l</td>
<td>Lagged PA acres in region (I) of crop i</td>
</tr>
<tr>
<td>j-PAAC(I)_t-l</td>
<td>Lagged PA acres in region (I) of competitive crop j</td>
</tr>
<tr>
<td>i-UPFLCOEF(I)_t</td>
<td>Upper flexibility coefficients allowing crop i acreage to change year to year in PA(I)</td>
</tr>
<tr>
<td>i-LOFLCOEF(I)_t</td>
<td>Lower flexibility coefficients allowing crop i acreage to change year to year in PA(I)</td>
</tr>
<tr>
<td>i-UBACPA(I)_t</td>
<td>Upper bound acreage in PA(I) allowed crop i</td>
</tr>
<tr>
<td>i-LBACPA(I)_t</td>
<td>Lower bound acreage in PA(I) allowed crop i</td>
</tr>
<tr>
<td>RHSAC(I)_t</td>
<td>Right hand side (resource constraint) acreage in PA(I)</td>
</tr>
<tr>
<td>RHSWT(I)_t</td>
<td>Right hand side (resource constraint) water in PA(I) where I=48-105</td>
</tr>
</tbody>
</table>
Table A.5. (continued)

<table>
<thead>
<tr>
<th>Var Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>i-ACREAGE(I)_{t}</td>
<td>Crop acreage in a PA(I) solved for by the LP</td>
</tr>
<tr>
<td>i-PROD(I)_{t}</td>
<td>Crop production in a PA(I) solved for by the LP</td>
</tr>
<tr>
<td>LP(i)-AC_{t}</td>
<td>Total national crop acreage solved for by the LP</td>
</tr>
<tr>
<td>LP(i)-PROD_{t}</td>
<td>Total national crop production solved for by the LP</td>
</tr>
<tr>
<td>i-GRET-AC(I)_{t}</td>
<td>Gross return per acre of crop i</td>
</tr>
<tr>
<td>i-NTRET-AC(I)_{t}</td>
<td>Net return per acre of crop i</td>
</tr>
<tr>
<td>i-PR(I)_{t-1}</td>
<td>Lagged price of crop i in PA(I)</td>
</tr>
<tr>
<td>j-PR(I)_{t-1}</td>
<td>Lagged price of competitive crop j in PA(I)</td>
</tr>
<tr>
<td>i-EXP_{t-1}</td>
<td>National exports of crop i</td>
</tr>
<tr>
<td>j-EXP_{t-1}</td>
<td>National exports of competitive crop j</td>
</tr>
<tr>
<td>i-INV_{t-1}</td>
<td>National inventory (GINV+CINV) of crop i</td>
</tr>
<tr>
<td>j-INV_{t-1}</td>
<td>National inventory (GINV+CINV) of competitive crop j</td>
</tr>
<tr>
<td>Time</td>
<td>Time trend variable; 1949=1</td>
</tr>
<tr>
<td>i-STAC(K)_{t-1}</td>
<td>Lagged state acreage of estimated crop i</td>
</tr>
<tr>
<td>j-STAC(K)_{t-1}</td>
<td>Lagged state acreage of estimated competitive crop j</td>
</tr>
<tr>
<td>i-GOV T_{t}</td>
<td>Government program and dummy variables</td>
</tr>
<tr>
<td>j-GOV T_{t}</td>
<td>Government program and dummy variables</td>
</tr>
<tr>
<td>i-SPPR(I)_{t}</td>
<td>PA support price of crop i</td>
</tr>
<tr>
<td>j-SPPR(I)_{t}</td>
<td>PA support price of competitive crop j</td>
</tr>
<tr>
<td>i-SPPR_{t}</td>
<td>Support price of crop i</td>
</tr>
<tr>
<td>j-SPPR_{t}</td>
<td>Support price of competitive crop j</td>
</tr>
<tr>
<td>i-UBABS(I)</td>
<td>Upper absolute acreage bound for crop i in PA(I)</td>
</tr>
</tbody>
</table>
Table A.5. (continued)

<table>
<thead>
<tr>
<th>Var Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>i-LBABS(I)</td>
<td>Lower absolute acreage bound for crop i in PA(I)</td>
</tr>
<tr>
<td>i-STUPFX(K)_{t}</td>
<td>State upper flexibility coefficient for crop i in state (I)</td>
</tr>
<tr>
<td>i-STLOFX(K)_{t}</td>
<td>State lower flexibility coefficient for crop i in state (K)</td>
</tr>
</tbody>
</table>
Table A.6. The main computer control program

Example of Control Program for a Predictive Run

```plaintext
PROGRAM ('ND')
INITIALZ
MOVE (XDATA,'REVMCC')
MOVE (XPBNAME,'PBFILE')
MOVE (XBOUND,'BND01973')
MOVE (XRHS,'RHSE9000')
MOVE (XOBJ,'OBJ00001')
MVADR(ALL1,RHS)
MVADR(ALL2,BD)
MVADR(ALL3,NNAME)
MVADR(ALL4,FF)
SETUP ('MAX')
RESTORE ('NAME',B1)
PRIMAL
SOLUTION ('FILE', 'FT09F001')
SOLUTION
SAVE ('NAME', BB)
FREECORE
KEN1
MORE
TALLY (COUNT, LOOP)
GOTO (OUT)
LOOP
SETUP ('MAX')
MOVE (SOLDNAME,'PBFILE')
REVISE ('FILE', 'FT20F001')
MVIND (XRHS, ALL1, 8)
MVIND (XBOUND, ALL2, 8)
MVIND (BNAME, ALL3, 8)
MVIND (FS, ALL4, 8)
SETUP ('MAX')
RESTORE ('NAME', BB)
PRIMAL
SAVE ('NAME', BNAME)
SAVE ('NAME', BB)
MVIND (BB, ALL3, 8)
SOLUTION ('FILE', FS)
SOLUTION
FREECORE
KEN1
MOVE (XDATA,'REVMCC')
ALL1=ALL1+8
ALL2=ALL2+8
```
Table A.6. (continued)

Example of Control Program for a Predictive Run

```
ALL3=ALL3+8
ALL4=ALL4+8
GOTO(MORE)
OUT EXIT
COUNT DC(7)
ALL1 DC(0)
ALL2 DC(0)
ALL3 DC(0)
ALL4 DC(0)
RHS DC('RHSE6800','RHSE6900','RHSE6900','RHSE7000','RHSE7000','RHSE7000','RHSE7000')
BD DC('BND01974','BND01975','BND01976','BND01977','BND01978','BND01979','BND01980')
BNAME DC('BASE1973')
FS DC('FT01F001')
BB DC('BAS21974')
B1 DC('BASE1')
FF DC('FT08F001','FT13F001','FT14F001','FT16F001','FT18F001','FT31F001','FT32F001')
PEND
```
Table A.7. Land base acreages in each producing area for the historical and predictive runs.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CLD01001</td>
<td>33.918</td>
<td>33.918</td>
<td>33.948</td>
<td>33.948</td>
<td>33.948</td>
</tr>
<tr>
<td>CLD01006</td>
<td>8.164</td>
<td>8.324</td>
<td>8.324</td>
<td>8.324</td>
<td>8.324</td>
</tr>
<tr>
<td>CLD01007</td>
<td>109.509</td>
<td>111.908</td>
<td>117.319</td>
<td>119.663</td>
<td>121.477</td>
</tr>
<tr>
<td>CLD01008</td>
<td>55.947</td>
<td>62.108</td>
<td>62.600</td>
<td>62.610</td>
<td>62.650</td>
</tr>
<tr>
<td>CLD01009</td>
<td>774.538</td>
<td>798.880</td>
<td>815.227</td>
<td>873.615</td>
<td>891.256</td>
</tr>
<tr>
<td>CLD01010</td>
<td>1096.984</td>
<td>1106.160</td>
<td>1217.272</td>
<td>1316.022</td>
<td>1321.355</td>
</tr>
<tr>
<td>CLD01011</td>
<td>1682.672</td>
<td>1794.563</td>
<td>1794.910</td>
<td>1831.555</td>
<td>1843.216</td>
</tr>
<tr>
<td>CLD01012</td>
<td>506.566</td>
<td>518.824</td>
<td>571.003</td>
<td>600.611</td>
<td>605.305</td>
</tr>
<tr>
<td>CLD01013</td>
<td>2657.292</td>
<td>2851.567</td>
<td>3026.022</td>
<td>3027.262</td>
<td>3028.595</td>
</tr>
<tr>
<td>CLD01014</td>
<td>2914.987</td>
<td>2915.369</td>
<td>3181.239</td>
<td>3185.408</td>
<td>3230.739</td>
</tr>
<tr>
<td>CLD01015</td>
<td>1635.191</td>
<td>1797.093</td>
<td>1841.197</td>
<td>1841.197</td>
<td>1841.196</td>
</tr>
<tr>
<td>CLD01016</td>
<td>539.021</td>
<td>564.108</td>
<td>764.337</td>
<td>770.329</td>
<td>779.478</td>
</tr>
<tr>
<td>CLD01018</td>
<td>1315.500</td>
<td>1350.301</td>
<td>1511.882</td>
<td>1571.347</td>
<td>1582.795</td>
</tr>
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Table A.9. Export levels of commodities in simulation sector.\textsuperscript{a}

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\textsuperscript{a}The export levels were compiled from U.S. Department of Agriculture published sources from 1968 to 1971 [198], and from various Economic Research Service publications during the period from 1972 to 1976 [51, 54, 55, 57]. After 1976, the average exports during the 1972 to 1976 period were used as projected values.
APPENDIX B. NATIONAL CROP THEIL U STATISTICS FOR THE HISTORICAL SIMULATIONS
Table B.1.1. National dryland and irrigated crop Theil U statistics for historical run number 1.

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<td>1970</td>
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<td>.042</td>
<td>.042</td>
<td>.077</td>
<td>.077</td>
</tr>
<tr>
<td>1971</td>
<td>.055</td>
<td>.047</td>
<td>.044</td>
<td>.073</td>
<td>.077</td>
</tr>
<tr>
<td>1972</td>
<td>.074</td>
<td>.080</td>
<td>.081</td>
<td>.113</td>
<td>.111</td>
</tr>
<tr>
<td>1973</td>
<td>.049</td>
<td>.048</td>
<td>.066</td>
<td>.125</td>
<td>.123</td>
</tr>
</tbody>
</table>
APPENDIX C. NATIONAL CROP ACREAGE AND TURNING POINT STATISTICS FOR THE HISTORICAL SIMULATIONS AND PREDICTIVE SIMULATION
Table C.1.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1969 in Historical Run Number 1.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>7777.50</td>
<td>50550.61</td>
<td>7925.26</td>
<td>17854.34</td>
<td>9737.16</td>
<td>40257.63</td>
<td>45521.53</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>8811.37</td>
<td>55972.28</td>
<td>7503.28</td>
<td>16360.06</td>
<td>10421.45</td>
<td>44154.14</td>
<td>48428.77</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>1033.87</td>
<td>5421.66</td>
<td>-421.98</td>
<td>-1494.27</td>
<td>684.28</td>
<td>3896.50</td>
<td>2907.24</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>13.29</td>
<td>10.73</td>
<td>-5.32</td>
<td>-8.37</td>
<td>7.03</td>
<td>9.68</td>
<td>6.39</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
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<tr>
<td>Estimated Turning Points</td>
<td>33</td>
<td>41</td>
<td>25</td>
<td>48</td>
<td>15</td>
<td>29</td>
<td>66</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-19</td>
<td>-20</td>
<td>-1</td>
<td>-30</td>
<td>-21</td>
<td>-18</td>
<td>-14</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>63.46</td>
<td>67.21</td>
<td>96.15</td>
<td>61.54</td>
<td>41.67</td>
<td>61.70</td>
<td>82.50</td>
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</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.1.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1969 in Historical Run Number 1.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage (^b)</td>
<td>1695.47</td>
<td>3016.45</td>
<td>3002.13</td>
<td>254.57</td>
<td>3622.03</td>
<td>213.70</td>
<td>2052.22</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>1838.29</td>
<td>3150.22</td>
<td>2675.08</td>
<td>197.27</td>
<td>4307.14</td>
<td>330.65</td>
<td>1957.94</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>142.82</td>
<td>133.77</td>
<td>-327.05</td>
<td>-57.30</td>
<td>685.12</td>
<td>116.95</td>
<td>-94.28</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>8.42</td>
<td>4.43</td>
<td>-10.89</td>
<td>-22.51</td>
<td>18.92</td>
<td>54.72</td>
<td>-4.59</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>31</td>
<td>24</td>
<td>18</td>
<td>15</td>
<td>27</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>19</td>
<td>9</td>
<td>17</td>
<td>13</td>
<td>23</td>
<td>5</td>
<td>24</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-12</td>
<td>-15</td>
<td>-1</td>
<td>-2</td>
<td>-4</td>
<td>0</td>
<td>-14</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>61.29</td>
<td>37.50</td>
<td>94.44</td>
<td>86.67</td>
<td>85.19</td>
<td>100.00</td>
<td>63.16</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.1.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1969 in Historical Run Number 1.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage(^b)</td>
<td>9472.97</td>
<td>53567.06</td>
<td>10927.39</td>
<td>18108.90</td>
<td>13359.20</td>
<td>40471.33</td>
<td>47573.75</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>10649.66</td>
<td>59122.50</td>
<td>10178.36</td>
<td>16557.33</td>
<td>14728.59</td>
<td>44484.79</td>
<td>50386.71</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>1176.69</td>
<td>5555.44</td>
<td>-749.04</td>
<td>-1551.57</td>
<td>1369.39</td>
<td>4013.45</td>
<td>2812.96</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>52</td>
<td>50</td>
<td>42</td>
<td>61</td>
<td>38</td>
<td>34</td>
<td>90</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>62.65</td>
<td>58.82</td>
<td>95.45</td>
<td>65.59</td>
<td>60.32</td>
<td>65.38</td>
<td>76.27</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.2.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1970 in Historical Run Number 1.a

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8030.64</td>
<td>52681.63</td>
<td>8034.13</td>
<td>18399.93</td>
<td>10036.64</td>
<td>41425.86</td>
<td>42127.67</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>9273.16</td>
<td>54483.59</td>
<td>8045.50</td>
<td>17109.46</td>
<td>11166.77</td>
<td>44781.30</td>
<td>42738.93</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>1242.52</td>
<td>1801.97</td>
<td>11.37</td>
<td>-1290.47</td>
<td>1130.13</td>
<td>3355.43</td>
<td>611.27</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>15.47</td>
<td>3.42</td>
<td>0.14</td>
<td>-7.01</td>
<td>11.26</td>
<td>8.10</td>
<td>1.45</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>25</td>
<td>23</td>
<td>23</td>
<td>52</td>
<td>24</td>
<td>15</td>
<td>49</td>
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<tr>
<td>Difference in Turning Points</td>
<td>-27</td>
<td>-38</td>
<td>-3</td>
<td>-26</td>
<td>-12</td>
<td>-32</td>
<td>-31</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>48.08</td>
<td>37.70</td>
<td>88.46</td>
<td>66.67</td>
<td>66.67</td>
<td>31.91</td>
<td>61.25</td>
</tr>
</tbody>
</table>

aCrop acreages are in thousand acres.

bDerived from AHCA data set.
Table C.2.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1970 in Historical Run Number 1.\(^{a}\)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
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<td>1737.12</td>
<td>-16.83</td>
<td>-0.96</td>
<td>31</td>
<td>23</td>
<td>-8</td>
<td>74.19</td>
</tr>
<tr>
<td>Corn</td>
<td>3588.73</td>
<td>3471.28</td>
<td>-117.44</td>
<td>-3.27</td>
<td>24</td>
<td>15</td>
<td>-9</td>
<td>62.50</td>
</tr>
<tr>
<td>Cotton</td>
<td>2986.51</td>
<td>2955.29</td>
<td>-31.22</td>
<td>-1.05</td>
<td>18</td>
<td>12</td>
<td>-6</td>
<td>66.67</td>
</tr>
<tr>
<td>Oats</td>
<td>254.23</td>
<td>216.20</td>
<td>-38.03</td>
<td>-14.96</td>
<td>15</td>
<td>7</td>
<td>-8</td>
<td>46.67</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3506.90</td>
<td>4216.66</td>
<td>709.76</td>
<td>20.24</td>
<td>27</td>
<td>23</td>
<td>-4</td>
<td>85.19</td>
</tr>
<tr>
<td>Soybean</td>
<td>159.50</td>
<td>278.03</td>
<td>118.53</td>
<td>74.31</td>
<td>5</td>
<td>2</td>
<td>-3</td>
<td>40.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>2001.09</td>
<td>1914.06</td>
<td>-87.03</td>
<td>-4.35</td>
<td>38</td>
<td>32</td>
<td>-6</td>
<td>84.21</td>
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</table>

\(^{a}\)Crop acreages are in thousand acres.

\(^{b}\)Derived from AWCAD data set.
<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>9784.59</td>
<td>11010.27</td>
<td>1225.68</td>
<td>12.53</td>
<td>83</td>
<td>48</td>
<td>-35</td>
<td>57.83</td>
</tr>
<tr>
<td>Corn</td>
<td>56270.35</td>
<td>57954.88</td>
<td>1684.52</td>
<td>2.99</td>
<td>85</td>
<td>38</td>
<td>-67</td>
<td>44.71</td>
</tr>
<tr>
<td>Cotton</td>
<td>11020.64</td>
<td>11000.79</td>
<td>-19.85</td>
<td>-0.18</td>
<td>44</td>
<td>35</td>
<td>-9</td>
<td>79.55</td>
</tr>
<tr>
<td>Oats</td>
<td>18654.16</td>
<td>17325.66</td>
<td>-1328.50</td>
<td>-7.12</td>
<td>93</td>
<td>59</td>
<td>-34</td>
<td>63.44</td>
</tr>
<tr>
<td>Sorghum</td>
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<td>15383.43</td>
<td>1839.89</td>
<td>13.59</td>
<td>63</td>
<td>47</td>
<td>-16</td>
<td>74.60</td>
</tr>
<tr>
<td>Soybean</td>
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<td>45059.32</td>
<td>3473.96</td>
<td>8.35</td>
<td>52</td>
<td>17</td>
<td>-35</td>
<td>32.69</td>
</tr>
<tr>
<td>Wheat</td>
<td>44128.76</td>
<td>44652.99</td>
<td>524.23</td>
<td>1.19</td>
<td>118</td>
<td>81</td>
<td>-37</td>
<td>68.64</td>
</tr>
</tbody>
</table>

*aCrop acreages are in thousand acres.

*bDerived from AHCA data set.
Table C.3.1. National Summary of Dryland Crop Acreage and Turning Point Statistics
for 1971 in Historical Run Number 1.

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8502.32</td>
<td>58605.45</td>
<td>8139.21</td>
<td>15475.11</td>
<td>12295.77</td>
<td>42205.96</td>
<td>45669.48</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>7999.52</td>
<td>58215.20</td>
<td>9582.08</td>
<td>15819.55</td>
<td>11292.64</td>
<td>44022.96</td>
<td>44681.30</td>
</tr>
<tr>
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<td>-502.80</td>
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<td>1442.86</td>
<td>344.44</td>
<td>-1003.13</td>
<td>1816.99</td>
<td>-988.17</td>
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<td>-5.91</td>
<td>-0.67</td>
<td>17.73</td>
<td>2.23</td>
<td>-8.16</td>
<td>4.31</td>
<td>-2.16</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>26</td>
<td>39</td>
<td>12</td>
<td>49</td>
<td>29</td>
<td>26</td>
<td>56</td>
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<td>-24</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>50.00</td>
<td>63.93</td>
<td>46.15</td>
<td>62.82</td>
<td>80.56</td>
<td>55.32</td>
<td>70.00</td>
</tr>
</tbody>
</table>

Note:

a Crop acreages are in thousand acres.
b Derived from AHCA data set.
Table C.3.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1971 in Historical Run Number 1.a

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>1657.98</td>
<td>1622.39</td>
<td>-35.59</td>
<td>-2.15</td>
<td>31</td>
<td>19</td>
<td>-12</td>
<td>61.29</td>
</tr>
<tr>
<td>Corn</td>
<td>4094.48</td>
<td>4173.76</td>
<td>79.28</td>
<td>1.94</td>
<td>24</td>
<td>11</td>
<td>-13</td>
<td>45.83</td>
</tr>
<tr>
<td>Cotton</td>
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<td>3446.68</td>
<td>274.62</td>
<td>8.66</td>
<td>18</td>
<td>9</td>
<td>-9</td>
<td>50.00</td>
</tr>
<tr>
<td>Oats</td>
<td>196.26</td>
<td>191.45</td>
<td>-4.82</td>
<td>-2.45</td>
<td>15</td>
<td>11</td>
<td>-4</td>
<td>73.33</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3924.50</td>
<td>3688.57</td>
<td>-235.92</td>
<td>-6.01</td>
<td>27</td>
<td>16</td>
<td>-11</td>
<td>59.26</td>
</tr>
<tr>
<td>Soybean</td>
<td>92.98</td>
<td>124.23</td>
<td>31.25</td>
<td>33.61</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>100.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>2045.53</td>
<td>2041.00</td>
<td>-4.53</td>
<td>-0.22</td>
<td>38</td>
<td>19</td>
<td>-19</td>
<td>50.00</td>
</tr>
</tbody>
</table>

aCrop acreages are in thousand acres.

bDerived from AHCA data set.
Table C.3.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1971 in Historical Run Number 1.

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage^b</td>
<td>10160.29</td>
<td>62699.93</td>
<td>11311.27</td>
<td>15671.37</td>
<td>16220.26</td>
<td>42298.93</td>
<td>47715.01</td>
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<tr>
<td>Predicted Acreage</td>
<td>9621.91</td>
<td>62388.96</td>
<td>13028.75</td>
<td>16011.00</td>
<td>14981.21</td>
<td>44147.18</td>
<td>46722.30</td>
</tr>
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<td>339.63</td>
<td>-1239.05</td>
<td>1848.25</td>
<td>-992.71</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-5.30</td>
<td>-0.50</td>
<td>15.18</td>
<td>2.17</td>
<td>-7.64</td>
<td>4.37</td>
<td>-2.08</td>
</tr>
</tbody>
</table>

|                    |           |           |           |           |           |           |           |
| Real Turning Points| 83        | 85        | 44        | 93        | 63        | 52        | 118       |
| Estimated Turning Points | 45    | 50        | 21        | 60        | 45        | 31        | 75        |
| Difference in Turning Points | -38  | -35       | -23       | -33       | -18       | -21       | -43       |
| Percent Correct   | 54.22     | 58.82     | 47.73     | 64.52     | 71.43     | 59.62     | 63.56     |

^Crop acreages are in thousand acres.

^bDerived from AHCA data set.
Table C.4.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1972 in Historical Run Number 1.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8053.89</td>
<td>52450.84</td>
<td>9448.77</td>
<td>13286.54</td>
<td>10024.97</td>
<td>44975.82</td>
<td>45336.42</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>7730.68</td>
<td>60828.44</td>
<td>9612.43</td>
<td>13175.16</td>
<td>12019.49</td>
<td>43016.14</td>
<td>45396.99</td>
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<td>Acreage Difference</td>
<td>-323.21</td>
<td>8377.58</td>
<td>163.66</td>
<td>-111.38</td>
<td>1994.51</td>
<td>-1959.68</td>
<td>60.56</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-4.01</td>
<td>15.97</td>
<td>1.73</td>
<td>-0.84</td>
<td>19.90</td>
<td>-4.36</td>
<td>0.13</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>32</td>
<td>49</td>
<td>12</td>
<td>48</td>
<td>26</td>
<td>28</td>
<td>66</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-20</td>
<td>-12</td>
<td>-14</td>
<td>-30</td>
<td>-10</td>
<td>-19</td>
<td>-14</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>61.54</td>
<td>80.33</td>
<td>46.15</td>
<td>61.54</td>
<td>72.22</td>
<td>59.57</td>
<td>82.50</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
### Table C.4.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1972 in Historical Run Number 1.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>1632.22</td>
<td>1616.94</td>
<td>-15.27</td>
<td>0.94</td>
<td>31</td>
<td>16</td>
<td>-15</td>
<td>51.61</td>
</tr>
<tr>
<td>Corn</td>
<td>4001.98</td>
<td>4262.95</td>
<td>260.97</td>
<td>6.52</td>
<td>24</td>
<td>20</td>
<td>-4</td>
<td>83.33</td>
</tr>
<tr>
<td>Cotton</td>
<td>3307.50</td>
<td>3620.98</td>
<td>313.48</td>
<td>9.48</td>
<td>18</td>
<td>15</td>
<td>-10</td>
<td>44.44</td>
</tr>
<tr>
<td>Oats</td>
<td>183.35</td>
<td>168.63</td>
<td>-14.72</td>
<td>-8.03</td>
<td>15</td>
<td>9</td>
<td>-6</td>
<td>60.00</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3374.54</td>
<td>3802.64</td>
<td>428.10</td>
<td>12.69</td>
<td>27</td>
<td>21</td>
<td>0</td>
<td>77.78</td>
</tr>
<tr>
<td>Soybean</td>
<td>172.65</td>
<td>68.20</td>
<td>-104.45</td>
<td>-60.50</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>100.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>1872.23</td>
<td>1720.48</td>
<td>-151.76</td>
<td>-8.11</td>
<td>38</td>
<td>24</td>
<td>-14</td>
<td>63.16</td>
</tr>
</tbody>
</table>

^Crop acreages are in thousand acres.

^Derived from AHCA data set.
Table C.4.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1972 in Historical Run Number 1.

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>9686.10</td>
<td>56452.82</td>
<td>12756.27</td>
<td>13469.88</td>
<td>13399.51</td>
<td>45148.48</td>
<td>47208.65</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>9347.63</td>
<td>65091.38</td>
<td>13233.41</td>
<td>13343.79</td>
<td>15822.13</td>
<td>43084.34</td>
<td>47117.46</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-338.48</td>
<td>8638.57</td>
<td>477.14</td>
<td>-126.09</td>
<td>2422.62</td>
<td>-2064.14</td>
<td>-91.18</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-3.49</td>
<td>15.30</td>
<td>3.74</td>
<td>-0.94</td>
<td>18.08</td>
<td>-4.57</td>
<td>-0.19</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>48</td>
<td>69</td>
<td>20</td>
<td>57</td>
<td>47</td>
<td>33</td>
<td>90</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-35</td>
<td>-16</td>
<td>-24</td>
<td>-36</td>
<td>-16</td>
<td>-19</td>
<td>-28</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>57.83</td>
<td>81.18</td>
<td>45.45</td>
<td>61.29</td>
<td>74.60</td>
<td>63.46</td>
<td>76.27</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.5.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 1.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8863.45</td>
<td>56362.93</td>
<td>8463.53</td>
<td>13864.37</td>
<td>12215.02</td>
<td>55312.02</td>
<td>51278.89</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>8625.01</td>
<td>58100.48</td>
<td>10680.45</td>
<td>12041.30</td>
<td>12438.15</td>
<td>50596.58</td>
<td>52171.40</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-238.43</td>
<td>1737.55</td>
<td>2216.92</td>
<td>-1823.06</td>
<td>223.13</td>
<td>-4715.42</td>
<td>892.50</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>37</td>
<td>37</td>
<td>21</td>
<td>57</td>
<td>18</td>
<td>44</td>
<td>49</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-15</td>
<td>-24</td>
<td>-5</td>
<td>-21</td>
<td>-18</td>
<td>-3</td>
<td>-31</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>71.15</td>
<td>60.66</td>
<td>80.77</td>
<td>73.08</td>
<td>50.00</td>
<td>93.62</td>
<td>61.25</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.5.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 1.a

<table>
<thead>
<tr>
<th>Crop</th>
<th>Irrigated Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>1670.50</td>
<td>1612.93</td>
<td>-57.57</td>
<td>-3.45</td>
<td>31</td>
<td>18</td>
<td>-13</td>
<td>58.06</td>
</tr>
<tr>
<td>Corn</td>
<td>4456.24</td>
<td>4454.70</td>
<td>-1.55</td>
<td>-0.03</td>
<td>24</td>
<td>10</td>
<td>-14</td>
<td>41.67</td>
</tr>
<tr>
<td>Cotton</td>
<td>3397.28</td>
<td>3779.68</td>
<td>382.40</td>
<td>11.26</td>
<td>18</td>
<td>7</td>
<td>-11</td>
<td>38.89</td>
</tr>
<tr>
<td>Oats</td>
<td>193.16</td>
<td>153.15</td>
<td>-40.01</td>
<td>-20.71</td>
<td>15</td>
<td>12</td>
<td>-3</td>
<td>80.00</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3637.83</td>
<td>3811.13</td>
<td>173.30</td>
<td>4.76</td>
<td>27</td>
<td>22</td>
<td>-5</td>
<td>81.48</td>
</tr>
<tr>
<td>Soybean</td>
<td>363.90</td>
<td>295.77</td>
<td>-68.12</td>
<td>-18.72</td>
<td>5</td>
<td>4</td>
<td>-1</td>
<td>80.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>2599.07</td>
<td>2188.60</td>
<td>-410.47</td>
<td>-15.79</td>
<td>38</td>
<td>24</td>
<td>-14</td>
<td>63.16</td>
</tr>
</tbody>
</table>

^Crop acreages are in thousand acres.

^Derived from AHCA data set.
Table C.5.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 1.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actual Acreage\textsuperscript{b}</strong></td>
<td>10533.94</td>
<td>60819.17</td>
<td>11860.81</td>
<td>14057.53</td>
<td>15852.85</td>
<td>55675.91</td>
<td>53877.96</td>
</tr>
<tr>
<td><strong>Predicted Acreage</strong></td>
<td>10237.94</td>
<td>62555.18</td>
<td>14460.13</td>
<td>12194.46</td>
<td>16249.28</td>
<td>50892.36</td>
<td>54360.00</td>
</tr>
<tr>
<td><strong>Acreage Difference</strong></td>
<td>-296.00</td>
<td>1736.01</td>
<td>2599.32</td>
<td>-1863.07</td>
<td>396.43</td>
<td>-4783.55</td>
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<td>-2.81</td>
<td>2.85</td>
<td>21.92</td>
<td>-13.25</td>
<td>2.50</td>
<td>-8.59</td>
<td>0.89</td>
</tr>
<tr>
<td><strong>Real Turning Points</strong></td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td><strong>Estimated Turning Points</strong></td>
<td>55</td>
<td>47</td>
<td>28</td>
<td>69</td>
<td>40</td>
<td>48</td>
<td>73</td>
</tr>
<tr>
<td><strong>Difference in Turning Points</strong></td>
<td>-28</td>
<td>-38</td>
<td>-16</td>
<td>-24</td>
<td>-23</td>
<td>-4</td>
<td>-45</td>
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<tr>
<td><strong>Percent Correct</strong></td>
<td>66.27</td>
<td>55.29</td>
<td>63.64</td>
<td>74.19</td>
<td>63.49</td>
<td>92.31</td>
<td>61.86</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from AHCA data set.
Table C.6.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1969 in Historical Run Number 2.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>7777.50</td>
<td>50550.61</td>
<td>7925.26</td>
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<td>9737.16</td>
<td>40257.63</td>
<td>45521.53</td>
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<tr>
<td>Predicted Acreage</td>
<td>8732.99</td>
<td>56246.22</td>
<td>7479.50</td>
<td>16007.50</td>
<td>10848.96</td>
<td>43863.82</td>
<td>48025.29</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>955.49</td>
<td>5695.59</td>
<td>-445.76</td>
<td>-1846.83</td>
<td>1111.80</td>
<td>3606.17</td>
<td>2503.75</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>12.29</td>
<td>11.27</td>
<td>-5.62</td>
<td>-10.34</td>
<td>11.42</td>
<td>8.96</td>
<td>5.50</td>
</tr>
<tr>
<td>Real Turning</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Points</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated Turning</td>
<td>34</td>
<td>45</td>
<td>21</td>
<td>52</td>
<td>18</td>
<td>28</td>
<td>65</td>
</tr>
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<td>Points</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Difference in</td>
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<td>-16</td>
<td>-5</td>
<td>-26</td>
<td>-18</td>
<td>-19</td>
<td>-15</td>
</tr>
<tr>
<td>Turning Points</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent Correct</td>
<td>65.38</td>
<td>73.77</td>
<td>80.77</td>
<td>66.67</td>
<td>50.00</td>
<td>59.57</td>
<td>81.25</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.6.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1969 in Historical Run Number 2.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>1695.47</td>
<td>3016.45</td>
<td>3002.13</td>
<td>254.57</td>
<td>3622.03</td>
<td>213.70</td>
<td>2052.22</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>1873.32</td>
<td>3080.90</td>
<td>2667.18</td>
<td>197.27</td>
<td>4244.84</td>
<td>360.21</td>
<td>1941.47</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>177.84</td>
<td>64.45</td>
<td>-334.95</td>
<td>-57.30</td>
<td>622.81</td>
<td>146.51</td>
<td>-110.75</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>10.49</td>
<td>2.14</td>
<td>-11.16</td>
<td>-22.51</td>
<td>17.19</td>
<td>68.56</td>
<td>-5.40</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>31</td>
<td>24</td>
<td>18</td>
<td>15</td>
<td>27</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>20</td>
<td>13</td>
<td>17</td>
<td>13</td>
<td>24</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-11</td>
<td>-11</td>
<td>-1</td>
<td>-2</td>
<td>-3</td>
<td>0</td>
<td>-13</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>64.52</td>
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<td>86.67</td>
<td>88.89</td>
<td>100.00</td>
<td>65.79</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from AMCA data set.
Table C.6.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1969 in Historical Run Number 2.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage\textsuperscript{b}</td>
<td>9472.97</td>
<td>53567.06</td>
<td>10927.39</td>
<td>18108.90</td>
<td>13359.20</td>
<td>40471.33</td>
<td>47573.75</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>10606.30</td>
<td>59327.12</td>
<td>10146.69</td>
<td>16204.77</td>
<td>15093.79</td>
<td>44224.03</td>
<td>49966.76</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>1133.33</td>
<td>5760.06</td>
<td>-780.71</td>
<td>-1904.13</td>
<td>1734.60</td>
<td>3752.70</td>
<td>2393.01</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>11.96</td>
<td>10.75</td>
<td>-7.14</td>
<td>-10.51</td>
<td>12.98</td>
<td>9.27</td>
<td>5.03</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
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<tr>
<td>Estimated Turning Points</td>
<td>54</td>
<td>58</td>
<td>38</td>
<td>65</td>
<td>42</td>
<td>33</td>
<td>90</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-29</td>
<td>-27</td>
<td>-6</td>
<td>-28</td>
<td>-21</td>
<td>-19</td>
<td>-28</td>
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<tr>
<td>Percent Correct</td>
<td>65.06</td>
<td>68.24</td>
<td>86.36</td>
<td>69.89</td>
<td>66.67</td>
<td>63.46</td>
<td>76.27</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from AHCA data set.
Table C.7.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1970 in Historical Run Number 2.a

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage b</td>
<td>8030.64</td>
<td>52681.63</td>
<td>8034.13</td>
<td>18399.93</td>
<td>10036.64</td>
<td>41425.86</td>
<td>42127.67</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>9247.42</td>
<td>54964.41</td>
<td>7865.97</td>
<td>16914.72</td>
<td>11500.84</td>
<td>44757.25</td>
<td>42931.27</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>1216.77</td>
<td>2282.79</td>
<td>-168.17</td>
<td>-1485.22</td>
<td>1464.20</td>
<td>3331.39</td>
<td>803.61</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>15.15</td>
<td>4.33</td>
<td>-2.09</td>
<td>-8.07</td>
<td>14.59</td>
<td>8.04</td>
<td>1.91</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>31</td>
<td>23</td>
<td>20</td>
<td>54</td>
<td>23</td>
<td>15</td>
<td>50</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-21</td>
<td>-38</td>
<td>-6</td>
<td>-24</td>
<td>-13</td>
<td>-32</td>
<td>-30</td>
</tr>
<tr>
<td>Percent Correct</td>
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<td>37.70</td>
<td>76.92</td>
<td>69.23</td>
<td>63.89</td>
<td>31.91</td>
<td>62.50</td>
</tr>
</tbody>
</table>

a Crop acreages are in thousand acres.

b Derived from AHCA data set.
Table C.7.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1970 in Historical Run Number 2.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>1753.95</td>
<td>3588.73</td>
<td>2986.51</td>
<td>254.23</td>
<td>3506.90</td>
<td>159.50</td>
<td>2001.09</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>1760.37</td>
<td>3417.84</td>
<td>2879.53</td>
<td>210.91</td>
<td>4201.98</td>
<td>306.92</td>
<td>1937.00</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>6.43</td>
<td>-170.89</td>
<td>-106.98</td>
<td>-43.32</td>
<td>695.09</td>
<td>147.42</td>
<td>-64.10</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>0.37</td>
<td>-4.76</td>
<td>-3.58</td>
<td>-17.04</td>
<td>19.82</td>
<td>92.43</td>
<td>-3.20</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>31</td>
<td>24</td>
<td>18</td>
<td>15</td>
<td>27</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>21</td>
<td>11</td>
<td>13</td>
<td>7</td>
<td>23</td>
<td>2</td>
<td>31</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-10</td>
<td>-13</td>
<td>-5</td>
<td>-8</td>
<td>-4</td>
<td>-3</td>
<td>-7</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>67.74</td>
<td>45.83</td>
<td>72.22</td>
<td>46.67</td>
<td>85.19</td>
<td>40.00</td>
<td>81.58</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHICA data set.
Table C.7.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1970 in Historical Run Number 2.

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>9784.59</td>
<td>56270.35</td>
<td>11020.64</td>
<td>18654.16</td>
<td>13543.54</td>
<td>41585.36</td>
<td>44128.76</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>11007.79</td>
<td>58382.25</td>
<td>10745.50</td>
<td>17125.62</td>
<td>15702.82</td>
<td>45064.18</td>
<td>44868.27</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>1223.20</td>
<td>2111.89</td>
<td>-275.14</td>
<td>-1528.54</td>
<td>2159.28</td>
<td>3478.81</td>
<td>739.50</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>12.50</td>
<td>3.75</td>
<td>-2.50</td>
<td>-8.19</td>
<td>15.94</td>
<td>8.37</td>
<td>1.68</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
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<tr>
<td>Estimated Turning Points</td>
<td>52</td>
<td>34</td>
<td>33</td>
<td>61</td>
<td>46</td>
<td>17</td>
<td>81</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-31</td>
<td>-51</td>
<td>-11</td>
<td>-32</td>
<td>-17</td>
<td>-35</td>
<td>-37</td>
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<tr>
<td>Percent Correct</td>
<td>62.65</td>
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<td>75.00</td>
<td>65.59</td>
<td>73.02</td>
<td>32.69</td>
<td>68.64</td>
</tr>
</tbody>
</table>

^aCrop acreages are in thousand acres.

^bDerived from AHCA data set.
Table C.8.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1971 in Historical Run Number 2.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8502.32</td>
<td>58605.45</td>
<td>8139.21</td>
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<td>12295.77</td>
<td>42205.96</td>
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<td>8011.67</td>
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<td>9397.53</td>
<td>14740.53</td>
<td>11979.28</td>
<td>43518.11</td>
<td>44574.87</td>
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<td>-734.58</td>
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<td>1312.14</td>
<td>-1094.59</td>
</tr>
<tr>
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<td>-5.77</td>
<td>0.22</td>
<td>15.46</td>
<td>-4.75</td>
<td>-2.57</td>
<td>3.11</td>
<td>-2.40</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>27</td>
<td>35</td>
<td>14</td>
<td>45</td>
<td>30</td>
<td>30</td>
<td>56</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-25</td>
<td>-26</td>
<td>-12</td>
<td>-33</td>
<td>-6</td>
<td>-17</td>
<td>-24</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>51.92</td>
<td>57.38</td>
<td>53.85</td>
<td>57.69</td>
<td>83.33</td>
<td>63.83</td>
<td>70.00</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
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<td>1616.94</td>
<td>-41.03</td>
<td>-2.47</td>
<td>31</td>
<td>22</td>
<td>-9</td>
<td>70.97</td>
</tr>
<tr>
<td>Corn</td>
<td>4094.48</td>
<td>4122.89</td>
<td>28.40</td>
<td>0.69</td>
<td>24</td>
<td>7</td>
<td>-17</td>
<td>29.17</td>
</tr>
<tr>
<td>Cotton</td>
<td>3172.06</td>
<td>3223.88</td>
<td>51.82</td>
<td>1.63</td>
<td>18</td>
<td>12</td>
<td>-6</td>
<td>66.67</td>
</tr>
<tr>
<td>Oats</td>
<td>196.26</td>
<td>191.45</td>
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<td>-2.45</td>
<td>15</td>
<td>11</td>
<td>-4</td>
<td>73.33</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3924.50</td>
<td>3910.27</td>
<td>-14.23</td>
<td>-0.36</td>
<td>27</td>
<td>12</td>
<td>-15</td>
<td>44.44</td>
</tr>
<tr>
<td>Soybean</td>
<td>92.98</td>
<td>124.23</td>
<td>31.25</td>
<td>33.61</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>100.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>2045.53</td>
<td>2068.52</td>
<td>22.98</td>
<td>1.12</td>
<td>38</td>
<td>19</td>
<td>-19</td>
<td>50.00</td>
</tr>
</tbody>
</table>

a Crop acreages are in thousand acres.

b Derived from AHCA data set.
Table C.8.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1971 in Historical Run Number 2.{a}

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>10160.29</td>
<td>62699.93</td>
<td>11311.27</td>
<td>15671.37</td>
<td>16220.26</td>
<td>42298.93</td>
<td>47715.01</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>9628.61</td>
<td>62856.73</td>
<td>12621.40</td>
<td>14931.97</td>
<td>15889.55</td>
<td>43642.33</td>
<td>46643.39</td>
</tr>
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<td>-330.71</td>
<td>1343.40</td>
<td>-1071.62</td>
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<td>0.25</td>
<td>11.58</td>
<td>-4.72</td>
<td>-2.04</td>
<td>3.18</td>
<td>-2.25</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
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<td>-43</td>
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<tr>
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<td>59.04</td>
<td>49.41</td>
<td>59.09</td>
<td>60.22</td>
<td>66.67</td>
<td>67.31</td>
<td>63.56</td>
</tr>
</tbody>
</table>

{a}Crop acreages are in thousand acres.

{b}Derived from AHCA data set.
Table C.9.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1972 in Historical Run Number 2.a

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8053.89</td>
<td>52450.84</td>
<td>9448.77</td>
<td>13286.54</td>
<td>10024.97</td>
<td>44975.82</td>
<td>45336.42</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>7234.27</td>
<td>61507.43</td>
<td>9410.60</td>
<td>12992.22</td>
<td>13780.89</td>
<td>41794.15</td>
<td>45141.97</td>
</tr>
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<td>9056.56</td>
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<td>-294.31</td>
<td>3755.92</td>
<td>-3181.67</td>
<td>-194.45</td>
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<tr>
<td>Percent Difference</td>
<td>-10.18</td>
<td>17.27</td>
<td>-0.40</td>
<td>-2.22</td>
<td>37.47</td>
<td>-7.07</td>
<td>-0.43</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
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<td>33</td>
<td>49</td>
<td>15</td>
<td>52</td>
<td>27</td>
<td>33</td>
<td>64</td>
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<tr>
<td>Difference in Turning Points</td>
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<td>-11</td>
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<td>-16</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>63.46</td>
<td>80.33</td>
<td>57.69</td>
<td>66.67</td>
<td>75.00</td>
<td>70.21</td>
<td>80.00</td>
</tr>
</tbody>
</table>

a Crop acreages are in thousand acres.

b Derived from AHCA data set.
Table C.9.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1972 in Historical Run Number 2.a

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>1632.22</td>
<td>4001.98</td>
<td>3307.50</td>
<td>183.35</td>
<td>3374.54</td>
<td>172.65</td>
<td>1872.23</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>1574.87</td>
<td>4215.06</td>
<td>3264.45</td>
<td>168.63</td>
<td>4169.30</td>
<td>68.20</td>
<td>1800.58</td>
</tr>
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<td>213.09</td>
<td>-43.05</td>
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<td>-104.45</td>
<td>-71.66</td>
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<td>23.55</td>
<td>-60.50</td>
<td>-3.83</td>
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<tr>
<td>Real Turning Points</td>
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<td>24</td>
<td>18</td>
<td>15</td>
<td>27</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>19</td>
<td>16</td>
<td>3</td>
<td>9</td>
<td>21</td>
<td>5</td>
<td>26</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-12</td>
<td>-8</td>
<td>-15</td>
<td>-6</td>
<td>-6</td>
<td>0</td>
<td>-12</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>61.29</td>
<td>66.67</td>
<td>16.67</td>
<td>60.00</td>
<td>77.78</td>
<td>100.00</td>
<td>68.42</td>
</tr>
</tbody>
</table>

^Crop acreages are in thousand acres.

^Derived from AHCA data set.
<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>9686.10</td>
<td>56452.82</td>
<td>12756.27</td>
<td>13469.88</td>
<td>13399.51</td>
<td>45148.48</td>
<td>47208.65</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>8809.14</td>
<td>65722.44</td>
<td>12675.04</td>
<td>13160.85</td>
<td>17950.19</td>
<td>41862.34</td>
<td>46942.55</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-876.96</td>
<td>9269.62</td>
<td>-81.22</td>
<td>-309.03</td>
<td>4550.60</td>
<td>-3286.13</td>
<td>-266.10</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-9.05</td>
<td>16.42</td>
<td>-0.64</td>
<td>-2.29</td>
<td>33.96</td>
<td>-7.28</td>
<td>-0.56</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>52</td>
<td>65</td>
<td>18</td>
<td>61</td>
<td>48</td>
<td>38</td>
<td>90</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-31</td>
<td>-20</td>
<td>-26</td>
<td>-32</td>
<td>-15</td>
<td>-14</td>
<td>-28</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>62.65</td>
<td>76.47</td>
<td>40.91</td>
<td>65.59</td>
<td>76.19</td>
<td>73.08</td>
<td>76.27</td>
</tr>
</tbody>
</table>

*aCrop acreages are in thousand acres.

bDerived from AHCA data set.
Table C.10.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 2. a

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8863.45</td>
<td>56362.93</td>
<td>8463.53</td>
<td>13864.37</td>
<td>12215.02</td>
<td>55312.02</td>
<td>51278.89</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>8746.52</td>
<td>58203.62</td>
<td>10358.50</td>
<td>11541.28</td>
<td>12644.18</td>
<td>50651.05</td>
<td>51868.08</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-116.92</td>
<td>1840.68</td>
<td>1894.97</td>
<td>-2323.08</td>
<td>429.16</td>
<td>-4660.96</td>
<td>589.19</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-1.32</td>
<td>3.27</td>
<td>22.39</td>
<td>-16.76</td>
<td>3.51</td>
<td>-8.43</td>
<td>1.15</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>35</td>
<td>37</td>
<td>23</td>
<td>56</td>
<td>17</td>
<td>44</td>
<td>44</td>
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<tr>
<td>Difference in Turning Points</td>
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<td>-36</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>67.31</td>
<td>60.66</td>
<td>88.46</td>
<td>71.79</td>
<td>47.22</td>
<td>93.62</td>
<td>55.00</td>
</tr>
</tbody>
</table>

a Crop acreages are in thousand acres.

b Derived from AHCA data set.
Table C.10.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 2.\(^a\)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>1670.50</td>
<td>1633.22</td>
<td>-37.27</td>
<td>-2.23</td>
<td>31</td>
<td>19</td>
<td>-12</td>
<td>61.29</td>
</tr>
<tr>
<td>Corn</td>
<td>4456.24</td>
<td>4408.17</td>
<td>-48.08</td>
<td>-1.08</td>
<td>24</td>
<td>11</td>
<td>-13</td>
<td>45.83</td>
</tr>
<tr>
<td>Cotton</td>
<td>3397.28</td>
<td>3705.53</td>
<td>308.25</td>
<td>9.07</td>
<td>18</td>
<td>9</td>
<td>-9</td>
<td>50.00</td>
</tr>
<tr>
<td>Oats</td>
<td>193.16</td>
<td>152.85</td>
<td>-40.31</td>
<td>-20.87</td>
<td>15</td>
<td>12</td>
<td>-3</td>
<td>80.00</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3637.83</td>
<td>3816.80</td>
<td>178.97</td>
<td>4.92</td>
<td>27</td>
<td>21</td>
<td>-6</td>
<td>77.78</td>
</tr>
<tr>
<td>Soybean</td>
<td>363.90</td>
<td>319.39</td>
<td>-44.51</td>
<td>-44.51</td>
<td>5</td>
<td>4</td>
<td>-1</td>
<td>80.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>2599.07</td>
<td>2216.30</td>
<td>-382.78</td>
<td>-14.73</td>
<td>38</td>
<td>25</td>
<td>13</td>
<td>65.79</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actual Acreage</strong></td>
<td>10533.94</td>
<td>60819.17</td>
<td>11860.81</td>
<td>14057.53</td>
<td>15852.85</td>
<td>55675.91</td>
<td>53877.96</td>
</tr>
<tr>
<td><strong>Predicted Acreage</strong></td>
<td>10379.74</td>
<td>62611.79</td>
<td>14064.02</td>
<td>11694.13</td>
<td>16460.98</td>
<td>50970.44</td>
<td>54084.38</td>
</tr>
<tr>
<td><strong>Acreage Difference</strong></td>
<td>-154.20</td>
<td>1792.62</td>
<td>2203.21</td>
<td>-2363.39</td>
<td>608.14</td>
<td>-4705.47</td>
<td>206.41</td>
</tr>
<tr>
<td><strong>Percent Difference</strong></td>
<td>-1.46</td>
<td>2.95</td>
<td>18.58</td>
<td>-16.81</td>
<td>3.84</td>
<td>-8.45</td>
<td>0.38</td>
</tr>
<tr>
<td><strong>Real Turning Points</strong></td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td><strong>Estimated Turning Points</strong></td>
<td>54</td>
<td>48</td>
<td>32</td>
<td>68</td>
<td>38</td>
<td>48</td>
<td>69</td>
</tr>
<tr>
<td><strong>Difference in Turning Points</strong></td>
<td>-29</td>
<td>-37</td>
<td>-12</td>
<td>-25</td>
<td>-25</td>
<td>-4</td>
<td>-49</td>
</tr>
<tr>
<td><strong>Percent Correct</strong></td>
<td>65.06</td>
<td>56.47</td>
<td>72.73</td>
<td>73.12</td>
<td>60.32</td>
<td>92.31</td>
<td>58.47</td>
</tr>
</tbody>
</table>

*Crop acreages are in thousand acres.*
*Derived from AHCA data set.*
Table C.11.1. National Summary of Dryland Crop Acreage and Turning Point Statistics
for 1969 in Historical Run Number 3.\(^a\)

<table>
<thead>
<tr>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>7777.50</td>
<td>50550.61</td>
<td>7925.26</td>
<td>17854.34</td>
<td>9737.16</td>
<td>40257.63</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>8431.91</td>
<td>55256.45</td>
<td>7298.09</td>
<td>16331.46</td>
<td>12187.57</td>
<td>44470.48</td>
</tr>
<tr>
<td>Acreage Difference</td>
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<td>4705.82</td>
<td>-627.17</td>
<td>-1522.87</td>
<td>2450.41</td>
<td>4212.84</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>8.41</td>
<td>9.31</td>
<td>-7.91</td>
<td>-8.53</td>
<td>25.17</td>
<td>10.46</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>42</td>
<td>45</td>
<td>21</td>
<td>50</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-10</td>
<td>-16</td>
<td>-5</td>
<td>-28</td>
<td>-14</td>
<td>-23</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>80.77</td>
<td>73.77</td>
<td>80.77</td>
<td>64.10</td>
<td>61.11</td>
<td>51.06</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
### Table C.11.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1969 in Historical Run Number 3.\(^a\)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>1695.47</td>
<td>1887.53</td>
<td>192.06</td>
<td>11.33</td>
<td>31</td>
<td>19</td>
<td>-12</td>
<td>61.29</td>
</tr>
<tr>
<td>Corn</td>
<td>3016.45</td>
<td>3095.81</td>
<td>79.36</td>
<td>2.63</td>
<td>24</td>
<td>13</td>
<td>-11</td>
<td>54.17</td>
</tr>
<tr>
<td>Cotton</td>
<td>3002.13</td>
<td>2659.04</td>
<td>-343.10</td>
<td>-11.43</td>
<td>18</td>
<td>16</td>
<td>-2</td>
<td>88.89</td>
</tr>
<tr>
<td>Oats</td>
<td>254.57</td>
<td>199.10</td>
<td>-55.47</td>
<td>-21.79</td>
<td>15</td>
<td>13</td>
<td>-2</td>
<td>86.67</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3622.03</td>
<td>4407.96</td>
<td>785.93</td>
<td>21.70</td>
<td>27</td>
<td>24</td>
<td>-3</td>
<td>88.89</td>
</tr>
<tr>
<td>Soybean</td>
<td>213.70</td>
<td>372.45</td>
<td>158.75</td>
<td>74.29</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>100.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>2052.22</td>
<td>1904.68</td>
<td>-147.54</td>
<td>-7.19</td>
<td>38</td>
<td>24</td>
<td>-14</td>
<td>63.16</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.11.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1969 in Historical Run Number 3.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>9472.97</td>
<td>53567.06</td>
<td>10927.39</td>
<td>18108.90</td>
<td>13359.20</td>
<td>40471.33</td>
<td>47573.75</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>10319.44</td>
<td>58352.26</td>
<td>9957.13</td>
<td>16530.55</td>
<td>16595.54</td>
<td>44842.93</td>
<td>49512.51</td>
</tr>
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<td>846.47</td>
<td>4785.20</td>
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<td>-1578.35</td>
<td>3236.34</td>
<td>4371.59</td>
<td>1938.77</td>
</tr>
<tr>
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<td>8.93</td>
<td>-8.88</td>
<td>-8.72</td>
<td>24.23</td>
<td>10.80</td>
<td>4.08</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
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<tr>
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<td>61</td>
<td>58</td>
<td>37</td>
<td>63</td>
<td>46</td>
<td>29</td>
<td>88</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-22</td>
<td>-27</td>
<td>-7</td>
<td>-30</td>
<td>-17</td>
<td>-23</td>
<td>-30</td>
</tr>
<tr>
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<td>68.24</td>
<td>84.09</td>
<td>67.74</td>
<td>73.02</td>
<td>55.77</td>
<td>74.58</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from AHC\textsuperscript{a} data set.
Table C.12.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1970 in Historical Run Number 3.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage\textsuperscript{b}</td>
<td>8030.64</td>
<td>52681.63</td>
<td>8034.13</td>
<td>18399.93</td>
<td>10036.64</td>
<td>41425.86</td>
<td>42127.67</td>
</tr>
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<td>Predicted Acreage</td>
<td>9089.78</td>
<td>54440.93</td>
<td>7865.88</td>
<td>17476.29</td>
<td>11804.48</td>
<td>45128.94</td>
<td>42672.65</td>
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<td>1767.84</td>
<td>3703.07</td>
<td>544.99</td>
</tr>
<tr>
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<td>3.34</td>
<td>-2.09</td>
<td>-5.02</td>
<td>17.61</td>
<td>8.94</td>
<td>1.29</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>31</td>
<td>21</td>
<td>19</td>
<td>56</td>
<td>23</td>
<td>15</td>
<td>44</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-21</td>
<td>-40</td>
<td>-7</td>
<td>-22</td>
<td>-13</td>
<td>-32</td>
<td>-36</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>59.62</td>
<td>34.43</td>
<td>73.08</td>
<td>71.79</td>
<td>63.89</td>
<td>31.91</td>
<td>55.00</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from AHCA data set.
<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-0.46</td>
<td>-0.03</td>
<td>31</td>
<td>20</td>
<td>-11</td>
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</tr>
<tr>
<td>Corn</td>
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<td>-147.35</td>
<td>-4.11</td>
<td>24</td>
<td>10</td>
<td>-14</td>
<td>41.67</td>
</tr>
<tr>
<td>Cotton</td>
<td>2986.51</td>
<td>2891.69</td>
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<td>-3.17</td>
<td>18</td>
<td>13</td>
<td>-5</td>
<td>72.22</td>
</tr>
<tr>
<td>Oats</td>
<td>254.23</td>
<td>205.18</td>
<td>-49.05</td>
<td>-19.29</td>
<td>15</td>
<td>8</td>
<td>-7</td>
<td>53.33</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3506.90</td>
<td>4138.54</td>
<td>631.64</td>
<td>18.01</td>
<td>27</td>
<td>24</td>
<td>18</td>
<td>88.89</td>
</tr>
<tr>
<td>Soybean</td>
<td>159.50</td>
<td>326.89</td>
<td>167.39</td>
<td>104.94</td>
<td>5</td>
<td>5</td>
<td>140.71</td>
<td>40.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>2001.09</td>
<td>1860.38</td>
<td>-140.71</td>
<td>-7.03</td>
<td>38</td>
<td>31</td>
<td></td>
<td>81.58</td>
</tr>
</tbody>
</table>

^Crop acreages are in thousand acres.

^Derived from AHCA data set.
Table C.12.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1970 in Historical Run Number 3.a

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>9784.59</td>
<td>56270.35</td>
<td>11020.64</td>
<td>18654.16</td>
<td>13543.54</td>
<td>41585.36</td>
<td>44128.76</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>10843.26</td>
<td>57882.31</td>
<td>10757.56</td>
<td>17681.48</td>
<td>15943.02</td>
<td>45455.82</td>
<td>44533.04</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>1058.67</td>
<td>1611.96</td>
<td>-263.07</td>
<td>-972.68</td>
<td>2399.48</td>
<td>3870.46</td>
<td>404.27</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>10.82</td>
<td>2.86</td>
<td>-2.39</td>
<td>-5.21</td>
<td>17.72</td>
<td>9.31</td>
<td>0.92</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>51</td>
<td>31</td>
<td>32</td>
<td>64</td>
<td>47</td>
<td>17</td>
<td>75</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-32</td>
<td>-54</td>
<td>-12</td>
<td>-29</td>
<td>-16</td>
<td>-35</td>
<td>-43</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>61.45</td>
<td>36.47</td>
<td>72.73</td>
<td>68.82</td>
<td>74.60</td>
<td>32.69</td>
<td>63.56</td>
</tr>
</tbody>
</table>

aCrop acreages are in thousand acres.

bDerived from AHCA data set.
Table C.13.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1971 in Historical Run Number 3.

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8502.32</td>
<td>58605.45</td>
<td>8139.21</td>
<td>15475.11</td>
<td>12295.77</td>
<td>42205.96</td>
<td>45669.48</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>8475.22</td>
<td>58554.05</td>
<td>9233.46</td>
<td>15683.88</td>
<td>12006.40</td>
<td>43269.23</td>
<td>44359.61</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-27.11</td>
<td>-51.40</td>
<td>1094.25</td>
<td>208.77</td>
<td>-289.36</td>
<td>1063.26</td>
<td>-1309.86</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-0.32</td>
<td>-0.09</td>
<td>13.44</td>
<td>1.35</td>
<td>-2.35</td>
<td>2.52</td>
<td>-2.87</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>37</td>
<td>38</td>
<td>15</td>
<td>48</td>
<td>29</td>
<td>30</td>
<td>57</td>
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<tr>
<td>Difference in Turning Points</td>
<td>-15</td>
<td>-23</td>
<td>-11</td>
<td>-30</td>
<td>-7</td>
<td>-17</td>
<td>-23</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>71.15</td>
<td>62.30</td>
<td>57.69</td>
<td>61.54</td>
<td>80.56</td>
<td>63.83</td>
<td>71.25</td>
</tr>
</tbody>
</table>

\(^{a}\)Crop acreages are in thousand acres.

\(^{b}\)Derived from AHCA data set.
Table C.13.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1971 in Historical Run Number 3.a

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigated Barley</td>
<td>1657.98</td>
<td>4094.48</td>
<td>3172.06</td>
<td>196.26</td>
<td>3924.50</td>
<td>92.98</td>
<td>2045.53</td>
</tr>
<tr>
<td></td>
<td>Irrigated Corn</td>
<td>1688.78</td>
<td>4108.55</td>
<td>3183.20</td>
<td>192.10</td>
<td>3897.98</td>
<td>126.03</td>
<td>2068.04</td>
</tr>
<tr>
<td></td>
<td>Irrigated Cotton</td>
<td>30.80</td>
<td>14.07</td>
<td>11.14</td>
<td>-4.16</td>
<td>-26.52</td>
<td>33.05</td>
<td>22.51</td>
</tr>
<tr>
<td></td>
<td>Irrigated Oats</td>
<td>1.86</td>
<td>0.34</td>
<td>0.35</td>
<td>-2.12</td>
<td>-0.68</td>
<td>35.55</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>Irrigated Sorghum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Irrigated Soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Irrigated Wheat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Crop acreages are in thousand acres.

a Derived from AHCA data set.
Table C.13.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1971 in Historical Run Number 3.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage(^b)</td>
<td>10160.29</td>
<td>62699.93</td>
<td>11311.27</td>
<td>15671.37</td>
<td>16220.26</td>
<td>42298.93</td>
<td>47715.01</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>10164.00</td>
<td>62662.61</td>
<td>12416.66</td>
<td>15875.98</td>
<td>15904.38</td>
<td>43395.26</td>
<td>46427.65</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>3.71</td>
<td>-37.33</td>
<td>1105.39</td>
<td>204.61</td>
<td>-315.89</td>
<td>1096.32</td>
<td>-1287.36</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>0.04</td>
<td>-0.06</td>
<td>9.77</td>
<td>1.31</td>
<td>-1.95</td>
<td>2.59</td>
<td>-2.70</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>61</td>
<td>45</td>
<td>26</td>
<td>58</td>
<td>41</td>
<td>35</td>
<td>77</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-22</td>
<td>-40</td>
<td>-18</td>
<td>-35</td>
<td>-22</td>
<td>-17</td>
<td>-41</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>73.49</td>
<td>52.94</td>
<td>59.09</td>
<td>62.37</td>
<td>65.08</td>
<td>67.31</td>
<td>65.25</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.14.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1972 in Historical Run Number 3.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8053.89</td>
<td>52450.84</td>
<td>9448.77</td>
<td>13286.54</td>
<td>10024.97</td>
<td>44975.82</td>
<td>45336.42</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>7518.14</td>
<td>61576.68</td>
<td>9095.14</td>
<td>13034.83</td>
<td>13473.52</td>
<td>41603.62</td>
<td>45706.12</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-535.75</td>
<td>9125.82</td>
<td>-353.63</td>
<td>-251.70</td>
<td>3448.56</td>
<td>-3372.19</td>
<td>369.70</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-6.65</td>
<td>17.40</td>
<td>-3.74</td>
<td>-1.89</td>
<td>34.40</td>
<td>-7.50</td>
<td>0.82</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>37</td>
<td>51</td>
<td>17</td>
<td>52</td>
<td>28</td>
<td>30</td>
<td>63</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-15</td>
<td>-10</td>
<td>-9</td>
<td>-26</td>
<td>-8</td>
<td>-17</td>
<td>-17</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>71.15</td>
<td>83.61</td>
<td>65.38</td>
<td>66.67</td>
<td>77.78</td>
<td>63.83</td>
<td>78.75</td>
</tr>
</tbody>
</table>

*Crop acreages are in thousand acres.

*Derived from AHCA data set.*
Table C.14.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1972 in Historical Run Number 3.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>1632.22</td>
<td>4001.98</td>
<td>3307.50</td>
<td>183.35</td>
<td>3374.54</td>
<td>172.65</td>
<td>1872.23</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>1585.75</td>
<td>4205.82</td>
<td>3257.49</td>
<td>168.44</td>
<td>4158.84</td>
<td>81.18</td>
<td>1849.53</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-46.47</td>
<td>203.84</td>
<td>-50.01</td>
<td>-14.91</td>
<td>784.30</td>
<td>-91.47</td>
<td>-22.70</td>
</tr>
<tr>
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<td>5.09</td>
<td>-1.51</td>
<td>-8.13</td>
<td>23.24</td>
<td>-52.98</td>
<td>-1.21</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>31</td>
<td>24</td>
<td>18</td>
<td>15</td>
<td>27</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
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<td>16</td>
<td>4</td>
<td>9</td>
<td>23</td>
<td>5</td>
<td>26</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-12</td>
<td>-8</td>
<td>-14</td>
<td>-6</td>
<td>-4</td>
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<td>-12</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>61.29</td>
<td>66.67</td>
<td>22.22</td>
<td>60.00</td>
<td>85.19</td>
<td>100.00</td>
<td>68.42</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AMCA data set.
Table C.14.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1972 in Historical Run Number 3.

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage^b</td>
<td>9686.10</td>
<td>56452.82</td>
<td>12756.27</td>
<td>13469.88</td>
<td>13399.51</td>
<td>45148.48</td>
<td>47208.65</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>9103.89</td>
<td>65782.44</td>
<td>12352.63</td>
<td>13203.27</td>
<td>17632.36</td>
<td>41684.80</td>
<td>47555.65</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-582.21</td>
<td>9329.62</td>
<td>-403.64</td>
<td>-266.62</td>
<td>4232.85</td>
<td>-3463.68</td>
<td>347.00</td>
</tr>
<tr>
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<td>16.53</td>
<td>-3.16</td>
<td>-1.98</td>
<td>31.59</td>
<td>-7.67</td>
<td>0.74</td>
</tr>
<tr>
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<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>56</td>
<td>67</td>
<td>21</td>
<td>61</td>
<td>51</td>
<td>35</td>
<td>89</td>
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<td>Difference in Turning Points</td>
<td>-27</td>
<td>-18</td>
<td>-23</td>
<td>-32</td>
<td>-12</td>
<td>-17</td>
<td>-29</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>67.47</td>
<td>78.82</td>
<td>47.73</td>
<td>65.59</td>
<td>80.95</td>
<td>67.31</td>
<td>75.42</td>
</tr>
</tbody>
</table>

^Crop acreages are in thousand acres.

Derived from AHCA data set.
### Table C.15.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 3.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8863.45</td>
<td>56362.93</td>
<td>8463.53</td>
<td>13864.37</td>
<td>12215.02</td>
<td>55312.02</td>
<td>51278.89</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>8278.56</td>
<td>59613.35</td>
<td>10195.63</td>
<td>11270.43</td>
<td>12033.98</td>
<td>48298.30</td>
<td>51263.41</td>
</tr>
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<td>3250.42</td>
<td>1732.10</td>
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<td>-181.03</td>
<td>-7013.71</td>
<td>-15.48</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-6.60</td>
<td>5.77</td>
<td>20.47</td>
<td>-18.71</td>
<td>-1.48</td>
<td>-12.68</td>
<td>-0.03</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>36</td>
<td>39</td>
<td>23</td>
<td>60</td>
<td>20</td>
<td>42</td>
<td>44</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-16</td>
<td>-22</td>
<td>-3</td>
<td>-18</td>
<td>-16</td>
<td>-5</td>
<td>-36</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>69.23</td>
<td>63.93</td>
<td>88.46</td>
<td>76.92</td>
<td>55.56</td>
<td>89.36</td>
<td>55.00</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.15.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 3.

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage b</td>
<td>1670.50</td>
<td>4456.24</td>
<td>3397.28</td>
<td>193.16</td>
<td>3637.83</td>
<td>363.90</td>
<td>2599.07</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>1605.37</td>
<td>4401.37</td>
<td>3710.32</td>
<td>157.31</td>
<td>3718.92</td>
<td>333.02</td>
<td>2193.74</td>
</tr>
<tr>
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<td>313.05</td>
<td>-35.85</td>
<td>81.09</td>
<td>-30.88</td>
<td>-405.34</td>
</tr>
<tr>
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<td>-1.23</td>
<td>9.21</td>
<td>-18.56</td>
<td>2.23</td>
<td>-8.48</td>
<td>-15.60</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>31</td>
<td>24</td>
<td>18</td>
<td>15</td>
<td>27</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>18</td>
<td>11</td>
<td>8</td>
<td>12</td>
<td>26</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-13</td>
<td>-13</td>
<td>-10</td>
<td>-3</td>
<td>-1</td>
<td>-2</td>
<td>-13</td>
</tr>
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<td>58.06</td>
<td>45.83</td>
<td>44.44</td>
<td>80.00</td>
<td>96.30</td>
<td>60.00</td>
<td>65.79</td>
</tr>
</tbody>
</table>

a Crop acreages are in thousand acres.
b Derived from AHCA data set.
Table C.15.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 3, a

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage b</td>
<td>10533.94</td>
<td>60819.17</td>
<td>11860.81</td>
<td>14057.53</td>
<td>15852.85</td>
<td>55675.91</td>
<td>53877.96</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>9883.92</td>
<td>64014.72</td>
<td>13905.95</td>
<td>11427.74</td>
<td>15752.89</td>
<td>48631.32</td>
<td>53457.14</td>
</tr>
<tr>
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<td>3195.55</td>
<td>2045.14</td>
<td>-2629.79</td>
<td>-99.95</td>
<td>-7044.59</td>
<td>-420.82</td>
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<td>-6.17</td>
<td>5.25</td>
<td>17.24</td>
<td>-18.71</td>
<td>-0.63</td>
<td>-12.65</td>
<td>-0.78</td>
</tr>
<tr>
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<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
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<td>54</td>
<td>50</td>
<td>31</td>
<td>72</td>
<td>46</td>
<td>45</td>
<td>69</td>
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<tr>
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<td>-35</td>
<td>-13</td>
<td>-21</td>
<td>-17</td>
<td>-7</td>
<td>-49</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>65.06</td>
<td>58.82</td>
<td>70.45</td>
<td>77.42</td>
<td>73.02</td>
<td>86.54</td>
<td>58.47</td>
</tr>
</tbody>
</table>

a Crop acreages are in thousand acres.

b Derived from AHCA data set.
<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actual Acreage</strong></td>
<td>7777.50</td>
<td>50550.61</td>
<td>7925.26</td>
<td>17854.34</td>
<td>9737.16</td>
<td>40257.63</td>
<td>45521.53</td>
</tr>
<tr>
<td><strong>Predicted Acreage</strong></td>
<td>8431.91</td>
<td>55256.45</td>
<td>7298.09</td>
<td>16331.46</td>
<td>12187.57</td>
<td>44470.48</td>
<td>47607.84</td>
</tr>
<tr>
<td><strong>Acreage Difference</strong></td>
<td>654.40</td>
<td>4705.82</td>
<td>-627.17</td>
<td>-1522.87</td>
<td>2450.41</td>
<td>4212.84</td>
<td>2086.30</td>
</tr>
<tr>
<td><strong>Percent Difference</strong></td>
<td>8.41</td>
<td>9.31</td>
<td>-7.91</td>
<td>-8.53</td>
<td>25.17</td>
<td>10.46</td>
<td>4.58</td>
</tr>
<tr>
<td><strong>Real Turning Points</strong></td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td><strong>Estimated Turning Points</strong></td>
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<td>45</td>
<td>21</td>
<td>50</td>
<td>22</td>
<td>24</td>
<td>64</td>
</tr>
<tr>
<td><strong>Difference in Turning Points</strong></td>
<td>-10</td>
<td>-16</td>
<td>-5</td>
<td>-28</td>
<td>-14</td>
<td>-23</td>
<td>-16</td>
</tr>
<tr>
<td><strong>Percent Correct</strong></td>
<td>80.77</td>
<td>73.77</td>
<td>80.77</td>
<td>64.10</td>
<td>61.11</td>
<td>51.06</td>
<td>80.00</td>
</tr>
</tbody>
</table>

\*Crop acreages are in thousand acres.

\*Derived from AHCA data set.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>1695.47</td>
<td>1887.53</td>
<td>192.06</td>
<td>11.33</td>
<td>31</td>
<td>19</td>
<td>-12</td>
<td>61.29</td>
</tr>
<tr>
<td>Corn</td>
<td>3016.45</td>
<td>3095.81</td>
<td>79.36</td>
<td>2.63</td>
<td>24</td>
<td>13</td>
<td>-11</td>
<td>54.17</td>
</tr>
<tr>
<td>Cotton</td>
<td>3002.13</td>
<td>2700.57</td>
<td>-301.56</td>
<td>-10.04</td>
<td>18</td>
<td>17</td>
<td>-1</td>
<td>94.44</td>
</tr>
<tr>
<td>Oats</td>
<td>254.57</td>
<td>199.10</td>
<td>-55.47</td>
<td>-21.79</td>
<td>15</td>
<td>13</td>
<td>-2</td>
<td>86.67</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3622.03</td>
<td>4378.17</td>
<td>756.14</td>
<td>20.88</td>
<td>27</td>
<td>24</td>
<td>-3</td>
<td>88.89</td>
</tr>
<tr>
<td>Soybean</td>
<td>213.70</td>
<td>372.45</td>
<td>158.75</td>
<td>74.29</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>100.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>2052.22</td>
<td>1904.68</td>
<td>-147.54</td>
<td>-7.19</td>
<td>38</td>
<td>24</td>
<td>-14</td>
<td>63.16</td>
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</tbody>
</table>

*Crop acreages are in thousand acres.

*Derived from AHCA data set.*
Table C.16.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1969 in Historical Run Number 4.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>9472.97</td>
<td>53567.06</td>
<td>10927.39</td>
<td>18108.90</td>
<td>13359.20</td>
<td>40471.33</td>
<td>47573.75</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>10319.44</td>
<td>58352.26</td>
<td>9998.66</td>
<td>16530.55</td>
<td>16565.75</td>
<td>44842.93</td>
<td>49512.51</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>846.47</td>
<td>4785.20</td>
<td>-928.73</td>
<td>-1578.35</td>
<td>3206.55</td>
<td>4371.59</td>
<td>1938.77</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>8.94</td>
<td>8.93</td>
<td>-8.50</td>
<td>-8.72</td>
<td>24.00</td>
<td>10.80</td>
<td>4.08</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>61</td>
<td>58</td>
<td>38</td>
<td>63</td>
<td>46</td>
<td>29</td>
<td>88</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-22</td>
<td>-27</td>
<td>-6</td>
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<td>-17</td>
<td>-23</td>
<td>-30</td>
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<tr>
<td>Percent Correct</td>
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<td>68.24</td>
<td>86.36</td>
<td>67.74</td>
<td>73.02</td>
<td>55.77</td>
<td>74.58</td>
</tr>
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</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from AHCA data set.
Table C.17.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1970 in Historical Run Number 4.<sup>a</sup>

<table>
<thead>
<tr>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage &lt;sup&gt;b&lt;/sup&gt;</td>
<td>8030.64</td>
<td>52681.63</td>
<td>8034.13</td>
<td>18399.93</td>
<td>10036.64</td>
<td>41425.86</td>
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<td>9429.20</td>
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<td>7273.35</td>
<td>14519.76</td>
<td>13800.16</td>
<td>45857.15</td>
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<td>-760.79</td>
<td>-3880.17</td>
<td>3763.53</td>
<td>4431.29</td>
</tr>
<tr>
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<td>17.42</td>
<td>10.29</td>
<td>-9.47</td>
<td>-21.09</td>
<td>37.50</td>
<td>10.70</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>38</td>
<td>18</td>
<td>19</td>
<td>54</td>
<td>24</td>
<td>17</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-14</td>
<td>-43</td>
<td>-7</td>
<td>-24</td>
<td>-12</td>
<td>-30</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>73.08</td>
<td>29.51</td>
<td>73.08</td>
<td>69.23</td>
<td>66.67</td>
<td>36.17</td>
</tr>
</tbody>
</table>

<sup>a</sup>Crop acreages are in thousand acres.

<sup>b</sup>Derived from AHCA data set.
<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
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<td>1853.81</td>
<td>99.86</td>
<td>5.69</td>
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<td>14</td>
<td>-17</td>
<td>45.16</td>
</tr>
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<td>3563.62</td>
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<td>-0.70</td>
<td>24</td>
<td>5</td>
<td>-19</td>
<td>20.83</td>
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<td>13</td>
<td>-5</td>
<td>72.22</td>
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<tr>
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<td>5</td>
<td>-10</td>
<td>33.33</td>
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<td>27</td>
<td>22</td>
<td>-5</td>
<td>81.48</td>
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<td>Soybean</td>
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<td>343.01</td>
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<td>22</td>
<td>-3</td>
<td>40.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>2001.09</td>
<td>1747.59</td>
<td>-253.50</td>
<td>-12.67</td>
<td>38</td>
<td>23</td>
<td>-15</td>
<td>60.53</td>
</tr>
</tbody>
</table>

^Crop acreages are in thousand acres.

^Derived from AHCA data set.
<table>
<thead>
<tr>
<th>Crop Acreage</th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
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<td>13543.54</td>
<td>41585.36</td>
<td>44128.76</td>
</tr>
<tr>
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<td>11283.00</td>
<td>61664.84</td>
<td>9877.62</td>
<td>14683.86</td>
<td>18263.10</td>
<td>46359.67</td>
<td>43239.28</td>
</tr>
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<td>5394.51</td>
<td>-1143.02</td>
<td>-3970.30</td>
<td>4719.56</td>
<td>4774.30</td>
<td>-889.48</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>15.31</td>
<td>9.59</td>
<td>-10.37</td>
<td>-21.28</td>
<td>34.85</td>
<td>11.48</td>
<td>-2.02</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
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<td>52</td>
<td>118</td>
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<tr>
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<td>23</td>
<td>32</td>
<td>59</td>
<td>46</td>
<td>19</td>
<td>54</td>
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<td>Difference in Turning Points</td>
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<td>-62</td>
<td>-12</td>
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<td>-17</td>
<td>-33</td>
<td>-64</td>
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<td>Percent Correct</td>
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<td>27.06</td>
<td>72.73</td>
<td>63.44</td>
<td>73.02</td>
<td>36.54</td>
<td>45.76</td>
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</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8502.32</td>
<td>58605.45</td>
<td>8139.21</td>
<td>15475.11</td>
<td>12295.77</td>
<td>42205.96</td>
<td>45669.48</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>8971.91</td>
<td>61142.02</td>
<td>8413.30</td>
<td>12122.23</td>
<td>14883.65</td>
<td>44493.42</td>
<td>42759.23</td>
</tr>
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<td>274.08</td>
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<td>2587.89</td>
<td>2287.46</td>
<td>-2910.24</td>
</tr>
<tr>
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<td>5.52</td>
<td>4.33</td>
<td>3.37</td>
<td>-21.67</td>
<td>21.05</td>
<td>5.42</td>
<td>-6.37</td>
</tr>
<tr>
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<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
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<td>4</td>
<td>23</td>
<td>29</td>
<td>27</td>
<td>45</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
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<td>-22</td>
<td>-55</td>
<td>-7</td>
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<td>-35</td>
</tr>
<tr>
<td>Percent Correct</td>
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<td>36.07</td>
<td>15.38</td>
<td>29.49</td>
<td>80.56</td>
<td>57.45</td>
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</table>

*Crop acreages are in thousand acres.

b Derived from AHCA data set.
Table C.18.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1971 in Historical Run Number 4.\(^{a}\)

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage (^{b})</td>
<td>1657.98</td>
<td>4094.48</td>
<td>3172.06</td>
<td>196.26</td>
<td>3924.50</td>
<td>92.98</td>
<td>2045.53</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>1674.46</td>
<td>3958.03</td>
<td>2987.34</td>
<td>132.32</td>
<td>4390.08</td>
<td>345.02</td>
<td>1663.63</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>16.49</td>
<td>-136.45</td>
<td>-184.72</td>
<td>-63.94</td>
<td>465.58</td>
<td>252.04</td>
<td>-381.90</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>0.99</td>
<td>-3.33</td>
<td>-5.82</td>
<td>-32.58</td>
<td>11.86</td>
<td>271.07</td>
<td>-18.67</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>31</td>
<td>24</td>
<td>18</td>
<td>15</td>
<td>27</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>21</td>
<td>8</td>
<td>12</td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-10</td>
<td>-16</td>
<td>-6</td>
<td>-14</td>
<td>-21</td>
<td>0</td>
<td>-18</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>67.74</td>
<td>33.33</td>
<td>66.67</td>
<td>6.67</td>
<td>22.22</td>
<td>100.00</td>
<td>52.63</td>
</tr>
</tbody>
</table>

\(^{a}\)Crop acreages are in thousand acres.

\(^{b}\)Derived from AHCA data set.
### Table C.18.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1971 in Historical Run Number 4.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actual Acreage</strong>(^b)</td>
<td>10160.29</td>
<td>62699.93</td>
<td>11311.27</td>
<td>15671.37</td>
<td>16220.26</td>
<td>42298.93</td>
<td>47715.01</td>
</tr>
<tr>
<td><strong>Predicted Acreage</strong></td>
<td>10646.37</td>
<td>65100.05</td>
<td>11400.63</td>
<td>12254.55</td>
<td>19273.73</td>
<td>44838.44</td>
<td>44422.86</td>
</tr>
<tr>
<td><strong>Acreage Difference</strong></td>
<td>486.08</td>
<td>2400.12</td>
<td>89.36</td>
<td>-3416.82</td>
<td>3053.47</td>
<td>2539.50</td>
<td>-3292.15</td>
</tr>
<tr>
<td><strong>Percent Difference</strong></td>
<td>4.78</td>
<td>3.83</td>
<td>0.79</td>
<td>-21.80</td>
<td>18.83</td>
<td>6.00</td>
<td>-6.90</td>
</tr>
<tr>
<td><strong>Real Turning Points</strong></td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td><strong>Estimated Turning Points</strong></td>
<td>47</td>
<td>30</td>
<td>16</td>
<td>24</td>
<td>35</td>
<td>32</td>
<td>65</td>
</tr>
<tr>
<td><strong>Percent Correct</strong></td>
<td>56.63</td>
<td>35.29</td>
<td>36.36</td>
<td>25.81</td>
<td>55.56</td>
<td>61.54</td>
<td>55.08</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.19.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1972 in Historical Run Number 4.¹

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8053.89</td>
<td>52450.84</td>
<td>9448.77</td>
<td>13286.54</td>
<td>10024.97</td>
<td>44975.82</td>
<td>45336.42</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>7770.29</td>
<td>63838.02</td>
<td>9300.46</td>
<td>10259.28</td>
<td>16239.67</td>
<td>43380.38</td>
<td>42577.37</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-283.60</td>
<td>11387.17</td>
<td>-148.31</td>
<td>-3027.27</td>
<td>614.79</td>
<td>-1595.44</td>
<td>-2759.06</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-3.52</td>
<td>21.71</td>
<td>-1.57</td>
<td>-22.78</td>
<td>61.99</td>
<td>-3.55</td>
<td>-6.09</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>19</td>
<td>33</td>
<td>16</td>
<td>27</td>
<td>11</td>
<td>28</td>
<td>56</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>36.54</td>
<td>54.10</td>
<td>61.54</td>
<td>34.62</td>
<td>30.56</td>
<td>59.57</td>
<td>70.00</td>
</tr>
</tbody>
</table>

¹Crop acreages are in thousand acres.

²Derived from AHCA data set.
Table C.19.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1972 in Historical Run Number 4.a

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>1632.22</td>
<td>1558.95</td>
<td>-73.26</td>
<td>-4.49</td>
<td>31</td>
<td>21</td>
<td>-10</td>
<td>67.74</td>
</tr>
<tr>
<td>Corn</td>
<td>4001.98</td>
<td>4090.56</td>
<td>88.59</td>
<td>2.21</td>
<td>24</td>
<td>16</td>
<td>-8</td>
<td>66.67</td>
</tr>
<tr>
<td>Cotton</td>
<td>3307.50</td>
<td>3102.70</td>
<td>-204.79</td>
<td>-6.19</td>
<td>18</td>
<td>3</td>
<td>-15</td>
<td>66.67</td>
</tr>
<tr>
<td>Oats</td>
<td>183.35</td>
<td>113.63</td>
<td>-69.72</td>
<td>-38.03</td>
<td>15</td>
<td>4</td>
<td>-11</td>
<td>26.67</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3374.54</td>
<td>4537.48</td>
<td>1162.95</td>
<td>34.46</td>
<td>27</td>
<td>20</td>
<td>-7</td>
<td>74.07</td>
</tr>
<tr>
<td>Soybean</td>
<td>172.65</td>
<td>241.57</td>
<td>68.91</td>
<td>39.91</td>
<td>5</td>
<td>3</td>
<td>-2</td>
<td>60.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>1872.23</td>
<td>1522.46</td>
<td>-349.78</td>
<td>-18.68</td>
<td>38</td>
<td>21</td>
<td>-17</td>
<td>55.26</td>
</tr>
</tbody>
</table>

a Crop acreages are in thousand acres.

b Derived from AHCA data set.
Table C.19.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1972 in Historical Run Number 4.

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage b</td>
<td>9686.10</td>
<td>56452.82</td>
<td>12756.27</td>
<td>13469.88</td>
<td>13399.51</td>
<td>45148.48</td>
<td>47208.65</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>9329.23</td>
<td>67928.56</td>
<td>12403.16</td>
<td>10372.91</td>
<td>20777.15</td>
<td>43621.95</td>
<td>44099.82</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-356.87</td>
<td>11475.75</td>
<td>-353.11</td>
<td>-3096.97</td>
<td>7377.64</td>
<td>-1526.53</td>
<td>-3108.82</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-3.68</td>
<td>20.33</td>
<td>-2.77</td>
<td>-22.99</td>
<td>55.06</td>
<td>-3.38</td>
<td>-6.59</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>40</td>
<td>49</td>
<td>19</td>
<td>31</td>
<td>31</td>
<td>31</td>
<td>77</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>48.19</td>
<td>57.65</td>
<td>43.18</td>
<td>33.33</td>
<td>49.21</td>
<td>59.62</td>
<td>65.25</td>
</tr>
</tbody>
</table>

a Crop acreages are in thousand acres.

b Derived from AHCA data set.
Table C.20.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 4.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage \textsuperscript{b}</td>
<td>8863.45</td>
<td>56362.93</td>
<td>8463.53</td>
<td>13864.37</td>
<td>12215.02</td>
<td>55312.02</td>
<td>51278.89</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>6850.70</td>
<td>67211.63</td>
<td>9940.23</td>
<td>8831.84</td>
<td>17922.42</td>
<td>46588.34</td>
<td>47064.70</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-2012.74</td>
<td>10848.84</td>
<td>1476.70</td>
<td>-5032.51</td>
<td>5707.41</td>
<td>-8723.66</td>
<td>-4214.18</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-22.71</td>
<td>19.25</td>
<td>17.45</td>
<td>-36.30</td>
<td>46.72</td>
<td>-15.77</td>
<td>-8.22</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>30</td>
<td>32</td>
<td>21</td>
<td>54</td>
<td>14</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-22</td>
<td>-29</td>
<td>-5</td>
<td>-24</td>
<td>-22</td>
<td>-14</td>
<td>-48</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>57.69</td>
<td>52.46</td>
<td>80.77</td>
<td>69.23</td>
<td>38.89</td>
<td>70.21</td>
<td>40.00</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop areages are in thousand acres.

\textsuperscript{b}Derived from AHCA data set.
Table C.20.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 4,\(^a\)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>1670.50</td>
<td>1447.61</td>
<td>-222.89</td>
<td>-13.34</td>
<td>31</td>
<td>21</td>
<td>-10</td>
<td>67.74</td>
</tr>
<tr>
<td>Corn</td>
<td>4456.24</td>
<td>3485.16</td>
<td>90.46</td>
<td>2.03</td>
<td>24</td>
<td>18</td>
<td>-15</td>
<td>37.50</td>
</tr>
<tr>
<td>Cotton</td>
<td>3397.28</td>
<td>3485.16</td>
<td>87.88</td>
<td>2.59</td>
<td>18</td>
<td>15</td>
<td>-3</td>
<td>83.33</td>
</tr>
<tr>
<td>Oats</td>
<td>193.16</td>
<td>98.57</td>
<td>-94.59</td>
<td>-48.97</td>
<td>15</td>
<td>11</td>
<td>-4</td>
<td>73.33</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3637.83</td>
<td>4759.13</td>
<td>1121.31</td>
<td>30.82</td>
<td>27</td>
<td>8</td>
<td>-19</td>
<td>29.63</td>
</tr>
<tr>
<td>Soybean</td>
<td>363.90</td>
<td>276.46</td>
<td>-87.44</td>
<td>-24.03</td>
<td>5</td>
<td>4</td>
<td>-1</td>
<td>80.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>2599.07</td>
<td>1630.65</td>
<td>-968.43</td>
<td>-37.26</td>
<td>38</td>
<td>21</td>
<td>-17</td>
<td>55.26</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AMCA data set.
Table C.20.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 4.\(^a\)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage(^b)</td>
<td>10533.94</td>
<td>60619.17</td>
<td>11860.81</td>
<td>14057.53</td>
<td>15852.85</td>
<td>55675.91</td>
<td>53877.96</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>8298.31</td>
<td>71758.31</td>
<td>13425.39</td>
<td>8930.40</td>
<td>22681.55</td>
<td>46864.80</td>
<td>48695.34</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-2235.63</td>
<td>10939.14</td>
<td>1564.59</td>
<td>-5127.13</td>
<td>6828.70</td>
<td>-8811.11</td>
<td>-5182.62</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>51</td>
<td>41</td>
<td>36</td>
<td>65</td>
<td>22</td>
<td>37</td>
<td>53</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-32</td>
<td>-44</td>
<td>-8</td>
<td>-28</td>
<td>-41</td>
<td>-15</td>
<td>-65</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>61.45</td>
<td>48.24</td>
<td>81.82</td>
<td>69.89</td>
<td>34.92</td>
<td>71.15</td>
<td>44.92</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.21.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1969 in Historical Run Number 5.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>7777.50</td>
<td>50550.61</td>
<td>7925.26</td>
<td>17854.34</td>
<td>9737.16</td>
<td>40257.63</td>
<td>45521.53</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>8431.91</td>
<td>55256.45</td>
<td>7298.09</td>
<td>16331.46</td>
<td>12187.57</td>
<td>44470.48</td>
<td>47607.84</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>654.40</td>
<td>4705.82</td>
<td>-627.17</td>
<td>-1522.87</td>
<td>2450.41</td>
<td>4212.84</td>
<td>2086.30</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>8.41</td>
<td>9.31</td>
<td>-7.91</td>
<td>-8.53</td>
<td>25.17</td>
<td>10.46</td>
<td>4.58</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning</td>
<td>42</td>
<td>45</td>
<td>21</td>
<td>50</td>
<td>22</td>
<td>24</td>
<td>64</td>
</tr>
<tr>
<td>Points Difference</td>
<td>-10</td>
<td>-16</td>
<td>-5</td>
<td>-28</td>
<td>-14</td>
<td>-23</td>
<td>-16</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>80.77</td>
<td>73.77</td>
<td>80.77</td>
<td>64.10</td>
<td>61.11</td>
<td>51.06</td>
<td>80.00</td>
</tr>
</tbody>
</table>

\(^a\) Crop acreages are in thousand acres.

\(^b\) Derived from AHCA data set.
Table C.21.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1969 in Historical Run Number 5.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>1695.47</td>
<td>1887.53</td>
<td>192.06</td>
<td>11.33</td>
<td>31</td>
<td>19</td>
<td>-12</td>
<td>61.29</td>
</tr>
<tr>
<td>Corn</td>
<td>3016.45</td>
<td>3095.81</td>
<td>79.36</td>
<td>2.63</td>
<td>24</td>
<td>13</td>
<td>-11</td>
<td>54.17</td>
</tr>
<tr>
<td>Cotton</td>
<td>3002.13</td>
<td>2700.57</td>
<td>-301.56</td>
<td>-10.04</td>
<td>18</td>
<td>17</td>
<td>-1</td>
<td>94.44</td>
</tr>
<tr>
<td>Oats</td>
<td>254.57</td>
<td>199.10</td>
<td>-55.47</td>
<td>-21.79</td>
<td>15</td>
<td>13</td>
<td>-2</td>
<td>86.67</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3622.03</td>
<td>4378.17</td>
<td>756.14</td>
<td>20.88</td>
<td>27</td>
<td>24</td>
<td>-3</td>
<td>88.89</td>
</tr>
<tr>
<td>Soybean</td>
<td>213.70</td>
<td>372.45</td>
<td>158.75</td>
<td>74.29</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>100.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>2052.22</td>
<td>1904.68</td>
<td>-147.54</td>
<td>-7.19</td>
<td>38</td>
<td>24</td>
<td>-14</td>
<td>63.16</td>
</tr>
</tbody>
</table>

aCrop acreages are in thousand acres.

bDerived from AHCA data set.
Table C.21.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1969 in Historical Run Number 5.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actual Acreage</strong>(^b)</td>
<td>9472.97</td>
<td>53567.06</td>
<td>10927.39</td>
<td>18108.90</td>
<td>13359.20</td>
<td>40471.33</td>
<td>47573.75</td>
</tr>
<tr>
<td><strong>Predicted Acreage</strong></td>
<td>10319.44</td>
<td>58352.26</td>
<td>9998.66</td>
<td>16530.55</td>
<td>16565.75</td>
<td>44842.93</td>
<td>49512.51</td>
</tr>
<tr>
<td><strong>Acreage Difference</strong></td>
<td>846.47</td>
<td>4785.20</td>
<td>-928.74</td>
<td>-1578.35</td>
<td>3206.55</td>
<td>4371.59</td>
<td>1938.77</td>
</tr>
<tr>
<td><strong>Percent Difference</strong></td>
<td>8.94</td>
<td>8.93</td>
<td>-8.50</td>
<td>-8.72</td>
<td>24.00</td>
<td>10.80</td>
<td>4.08</td>
</tr>
<tr>
<td><strong>Real Turning Points</strong></td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td><strong>Estimated Turning Points</strong></td>
<td>61</td>
<td>58</td>
<td>38</td>
<td>63</td>
<td>46</td>
<td>29</td>
<td>88</td>
</tr>
<tr>
<td><strong>Difference in Turning Points</strong></td>
<td>-22</td>
<td>-27</td>
<td>-6</td>
<td>-30</td>
<td>-17</td>
<td>-23</td>
<td>-30</td>
</tr>
<tr>
<td><strong>Percent Correct</strong></td>
<td>73.49</td>
<td>68.24</td>
<td>86.36</td>
<td>67.74</td>
<td>73.02</td>
<td>55.77</td>
<td>74.58</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.22.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1970 in Historical Run Number 5.a

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreageb</td>
<td>8030.64</td>
<td>52681.63</td>
<td>8034.13</td>
<td>18399.93</td>
<td>10036.64</td>
<td>41425.86</td>
<td>42127.67</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>9405.40</td>
<td>58008.49</td>
<td>7266.73</td>
<td>14571.70</td>
<td>13866.13</td>
<td>45900.50</td>
<td>41518.73</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>1374.77</td>
<td>5326.86</td>
<td>-767.39</td>
<td>-3828.24</td>
<td>3829.49</td>
<td>4474.63</td>
<td>-608.93</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>17.12</td>
<td>10.11</td>
<td>-9.55</td>
<td>-20.81</td>
<td>38.16</td>
<td>10.80</td>
<td>-1.45</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>38</td>
<td>19</td>
<td>19</td>
<td>53</td>
<td>24</td>
<td>18</td>
<td>31</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-14</td>
<td>-42</td>
<td>-7</td>
<td>-25</td>
<td>-12</td>
<td>-29</td>
<td>-49</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>73.08</td>
<td>31.15</td>
<td>73.08</td>
<td>67.95</td>
<td>66.67</td>
<td>38.30</td>
<td>38.75</td>
</tr>
</tbody>
</table>

aCrop acreages are in thousand acres.

bDerived from AHCA data set.
Table C.22.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1970 in Historical Run Number 5.a

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>1753.95</td>
<td>3588.73</td>
<td>2986.51</td>
<td>254.23</td>
<td>3506.90</td>
<td>159.50</td>
<td>2001.09</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>1857.43</td>
<td>3566.95</td>
<td>2603.17</td>
<td>170.06</td>
<td>4497.39</td>
<td>494.53</td>
<td>1734.13</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>103.48</td>
<td>-21.78</td>
<td>-383.34</td>
<td>-84.17</td>
<td>990.50</td>
<td>335.02</td>
<td>-266.96</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>5.90</td>
<td>-0.61</td>
<td>-12.84</td>
<td>-33.11</td>
<td>28.24</td>
<td>210.04</td>
<td>-13.34</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>31</td>
<td>24</td>
<td>18</td>
<td>15</td>
<td>22</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>15</td>
<td>5</td>
<td>12</td>
<td>5</td>
<td>22</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-16</td>
<td>-19</td>
<td>-6</td>
<td>-10</td>
<td>-5</td>
<td>-3</td>
<td>-15</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>48.39</td>
<td>20.83</td>
<td>66.67</td>
<td>33.33</td>
<td>81.48</td>
<td>40.00</td>
<td>60.53</td>
</tr>
</tbody>
</table>

a Crop acreages are in thousand acres.

b Derived from AHCA data set.
Table C.22.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1970 in Historical Run Number 5.a

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>9784.59</td>
<td>56270.35</td>
<td>11020.64</td>
<td>18654.16</td>
<td>13543.54</td>
<td>41585.36</td>
<td>44128.76</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>11262.83</td>
<td>61575.44</td>
<td>9869.90</td>
<td>14741.75</td>
<td>18363.53</td>
<td>46395.02</td>
<td>43252.86</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>1478.24</td>
<td>5305.09</td>
<td>-1150.73</td>
<td>-3912.40</td>
<td>4819.99</td>
<td>4809.66</td>
<td>-875.90</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>15.11%</td>
<td>9.43%</td>
<td>-10.44%</td>
<td>-20.97%</td>
<td>35.59%</td>
<td>11.57%</td>
<td>-1.98%</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>53</td>
<td>24</td>
<td>31</td>
<td>58</td>
<td>46</td>
<td>20</td>
<td>54</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-30</td>
<td>-61</td>
<td>-13</td>
<td>-35</td>
<td>-17</td>
<td>-32</td>
<td>-64</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>63.86%</td>
<td>28.24%</td>
<td>70.45%</td>
<td>62.37%</td>
<td>73.02%</td>
<td>38.46%</td>
<td>45.76%</td>
</tr>
</tbody>
</table>

a Crop acreages are in thousand acres
b Derived from AHCA data set.
Table C.23.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1971 in Historical Run Number 5.\(^a\)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage(^b)</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>8502.32</td>
<td>8665.07</td>
<td>162.76</td>
<td>1.91</td>
<td>52</td>
<td>22</td>
<td>-30</td>
<td>42.31</td>
</tr>
<tr>
<td>Corn</td>
<td>58605.45</td>
<td>60935.52</td>
<td>2330.07</td>
<td>3.98</td>
<td>61</td>
<td>24</td>
<td>-37</td>
<td>39.34</td>
</tr>
<tr>
<td>Cotton</td>
<td>8139.21</td>
<td>8416.46</td>
<td>277.24</td>
<td>3.41</td>
<td>26</td>
<td>4</td>
<td>-22</td>
<td>15.38</td>
</tr>
<tr>
<td>Oats</td>
<td>15475.11</td>
<td>12058.48</td>
<td>-3416.63</td>
<td>-22.08</td>
<td>78</td>
<td>24</td>
<td>-54</td>
<td>30.77</td>
</tr>
<tr>
<td>Sorghum</td>
<td>12295.77</td>
<td>14606.18</td>
<td>2310.42</td>
<td>18.79</td>
<td>36</td>
<td>29</td>
<td>-7</td>
<td>80.56</td>
</tr>
<tr>
<td>Soybean</td>
<td>42205.96</td>
<td>44780.57</td>
<td>2574.61</td>
<td>6.10</td>
<td>47</td>
<td>29</td>
<td>-18</td>
<td>61.70</td>
</tr>
<tr>
<td>Wheat</td>
<td>45669.48</td>
<td>43136.85</td>
<td>-2532.62</td>
<td>-5.55</td>
<td>80</td>
<td>46</td>
<td>-34</td>
<td>57.50</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.23.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1971 in Historical Run Number 5.

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acreage</td>
<td>1657.98</td>
<td>4094.48</td>
<td>3172.06</td>
<td>196.26</td>
<td>3924.50</td>
<td>92.98</td>
<td>2045.53</td>
</tr>
<tr>
<td>Predicted</td>
<td>1620.12</td>
<td>3963.90</td>
<td>2799.43</td>
<td>137.73</td>
<td>4586.64</td>
<td>389.69</td>
<td>1656.57</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-2.28</td>
<td>-3.19</td>
<td>-11.75</td>
<td>-29.82</td>
<td>16.87</td>
<td>319.11</td>
<td>-19.02</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>31</td>
<td>24</td>
<td>18</td>
<td>15</td>
<td>27</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>20</td>
<td>9</td>
<td>13</td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-11</td>
<td>-15</td>
<td>-5</td>
<td>-14</td>
<td>-21</td>
<td>0</td>
<td>-18</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>64.52</td>
<td>37.50</td>
<td>72.22</td>
<td>6.67</td>
<td>22.22</td>
<td>100.00</td>
<td>52.63</td>
</tr>
</tbody>
</table>

^Crop acreages are in thousand acres.

bDerived from AHCA data set.
Table C.23.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1971 in Historical Run Number 5.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actual Acreage</strong>\textsuperscript{b}</td>
<td>10160.29</td>
<td>62699.93</td>
<td>11311.27</td>
<td>15671.37</td>
<td>16220.26</td>
<td>42298.93</td>
<td>47715.01</td>
</tr>
<tr>
<td><strong>Predicted Acreage</strong></td>
<td>10285.19</td>
<td>64899.42</td>
<td>12115.89</td>
<td>12196.21</td>
<td>19192.82</td>
<td>45170.25</td>
<td>44793.42</td>
</tr>
<tr>
<td><strong>Acreage Difference</strong></td>
<td>124.90</td>
<td>2199.48</td>
<td>-95.38</td>
<td>-3475.16</td>
<td>2972.55</td>
<td>2871.32</td>
<td>-2921.59</td>
</tr>
<tr>
<td><strong>Percent Difference</strong></td>
<td>1.23</td>
<td>3.51</td>
<td>-0.84</td>
<td>-22.18</td>
<td>18.33</td>
<td>6.79</td>
<td>-6.12</td>
</tr>
<tr>
<td><strong>Real Turning Points</strong></td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td><strong>Estimated Turning Points</strong></td>
<td>42</td>
<td>33</td>
<td>17</td>
<td>25</td>
<td>35</td>
<td>34</td>
<td>66</td>
</tr>
<tr>
<td><strong>Percent Correct</strong></td>
<td>50.60</td>
<td>38.82</td>
<td>38.64</td>
<td>26.88</td>
<td>55.56</td>
<td>65.38</td>
<td>55.93</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop, acreages are in thousand acres.

\textsuperscript{b}Derived from AHCA data set.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>8053.89</td>
<td>52450.84</td>
<td>9448.77</td>
<td>13286.43</td>
<td>10024.97</td>
<td>44975.82</td>
<td>45336.42</td>
</tr>
<tr>
<td>Predicted Acreage</td>
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<td>63474.69</td>
<td>9086.15</td>
<td>10184.83</td>
<td>16210.82</td>
<td>43788.12</td>
<td>42971.49</td>
</tr>
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<td>-313.41</td>
<td>11023.83</td>
<td>-362.61</td>
<td>-3101.71</td>
<td>6185.85</td>
<td>-1187.70</td>
<td>-2364.92</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-3.89</td>
<td>21.02</td>
<td>-3.84</td>
<td>-23.34</td>
<td>61.70</td>
<td>-2.64</td>
<td>-5.22</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>52</td>
<td>61</td>
<td>26</td>
<td>78</td>
<td>36</td>
<td>47</td>
<td>80</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>13</td>
<td>32</td>
<td>16</td>
<td>26</td>
<td>10</td>
<td>25</td>
<td>55</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-39</td>
<td>-29</td>
<td>-10</td>
<td>-52</td>
<td>-26</td>
<td>-22</td>
<td>-25</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>25.00</td>
<td>52.46</td>
<td>61.54</td>
<td>33.33</td>
<td>27.78</td>
<td>53.19</td>
<td>68.75</td>
</tr>
</tbody>
</table>

*Crop acreages are in thousand acres.

*Derived from AHCA data set.*
<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>1632.22</td>
<td>1526.26</td>
<td>-105.95</td>
<td>-6.49</td>
<td>31</td>
<td>21</td>
<td>-10</td>
<td>67.74</td>
</tr>
<tr>
<td>Corn</td>
<td>4001.98</td>
<td>3307.50</td>
<td>-644.48</td>
<td>-18.51</td>
<td>24</td>
<td>17</td>
<td>-7</td>
<td>70.83</td>
</tr>
<tr>
<td>Cotton</td>
<td>3374.54</td>
<td>3876.32</td>
<td>501.78</td>
<td>14.36</td>
<td>18</td>
<td>16</td>
<td>-2</td>
<td>11.11</td>
</tr>
<tr>
<td>Oats</td>
<td>272.65</td>
<td>172.83</td>
<td>99.82</td>
<td>57.89</td>
<td>5</td>
<td>3</td>
<td>-16</td>
<td>26.67</td>
</tr>
<tr>
<td>Sorghum</td>
<td>1872.23</td>
<td>1535.69</td>
<td>336.54</td>
<td>21.84</td>
<td>38</td>
<td>22</td>
<td>0</td>
<td>74.07</td>
</tr>
<tr>
<td>Soybean</td>
<td>172.65</td>
<td>100.18</td>
<td>72.47</td>
<td>42.10</td>
<td>3</td>
<td>2</td>
<td>-16</td>
<td>60.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>1872.23</td>
<td>1535.69</td>
<td>336.54</td>
<td>21.84</td>
<td>38</td>
<td>22</td>
<td>0</td>
<td>74.07</td>
</tr>
</tbody>
</table>
Table C.24.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1972 in Historical Run Number 5.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>9686.10</td>
<td>56452.82</td>
<td>12756.27</td>
<td>13469.88</td>
<td>13399.51</td>
<td>45148.48</td>
<td>47208.65</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>9266.74</td>
<td>67569.81</td>
<td>11962.47</td>
<td>10302.69</td>
<td>20965.64</td>
<td>44060.95</td>
<td>44507.18</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-419.36</td>
<td>11117.00</td>
<td>-793.80</td>
<td>-3167.20</td>
<td>7566.13</td>
<td>-1087.52</td>
<td>-2701.47</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-4.33</td>
<td>19.69</td>
<td>-6.22</td>
<td>-23.51</td>
<td>56.47</td>
<td>-2.41</td>
<td>-5.72</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>34</td>
<td>49</td>
<td>18</td>
<td>30</td>
<td>30</td>
<td>28</td>
<td>77</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-49</td>
<td>-36</td>
<td>-26</td>
<td>-63</td>
<td>-33</td>
<td>-24</td>
<td>-41</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>40.96</td>
<td>57.65</td>
<td>40.91</td>
<td>32.26</td>
<td>47.62</td>
<td>53.85</td>
<td>65.25</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AllCA data set.
Table C.25.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 5.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage</th>
<th>Predicted Acreage</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
<th>Real Turning Points</th>
<th>Estimated Turning Points</th>
<th>Difference in Turning Points</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>8863.45</td>
<td>6882.33</td>
<td>-1981.11</td>
<td>-22.35</td>
<td>52</td>
<td>31</td>
<td>-21</td>
<td>59.62</td>
</tr>
<tr>
<td>Corn</td>
<td>56362.93</td>
<td>66920.75</td>
<td>10558.04</td>
<td>18.73</td>
<td>61</td>
<td>30</td>
<td>-31</td>
<td>49.18</td>
</tr>
<tr>
<td>Cotton</td>
<td>8463.53</td>
<td>9652.90</td>
<td>1189.37</td>
<td>14.05</td>
<td>26</td>
<td>21</td>
<td>-5</td>
<td>80.77</td>
</tr>
<tr>
<td>Oats</td>
<td>13864.37</td>
<td>8779.12</td>
<td>-5085.23</td>
<td>-36.68</td>
<td>78</td>
<td>53</td>
<td>-25</td>
<td>67.95</td>
</tr>
<tr>
<td>Sorghum</td>
<td>12215.02</td>
<td>18169.64</td>
<td>5954.62</td>
<td>48.75</td>
<td>36</td>
<td>14</td>
<td>-22</td>
<td>38.89</td>
</tr>
<tr>
<td>Soybean</td>
<td>55312.02</td>
<td>47023.67</td>
<td>-8288.32</td>
<td>-14.98</td>
<td>47</td>
<td>32</td>
<td>-15</td>
<td>68.09</td>
</tr>
<tr>
<td>Wheat</td>
<td>51278.89</td>
<td>47670.07</td>
<td>-6391.18</td>
<td>-7.04</td>
<td>80</td>
<td>31</td>
<td>-49</td>
<td>38.75</td>
</tr>
</tbody>
</table>

Crop acreages are in thousand acres.

Derived from AHCA data set.
Table C.25.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 5.

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>1670.50</td>
<td>4456.24</td>
<td>3397.28</td>
<td>193.16</td>
<td>3637.83</td>
<td>363.90</td>
<td>2599.07</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>1431.78</td>
<td>4484.50</td>
<td>3181.78</td>
<td>101.88</td>
<td>5020.05</td>
<td>320.60</td>
<td>1706.01</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-238.72</td>
<td>28.25</td>
<td>-215.50</td>
<td>-91.28</td>
<td>1382.23</td>
<td>-43.30</td>
<td>-893.06</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-14.29</td>
<td>0.63</td>
<td>-6.34</td>
<td>-47.26</td>
<td>38.00</td>
<td>-11.90</td>
<td>-34.36</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>31</td>
<td>24</td>
<td>18</td>
<td>15</td>
<td>27</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>22</td>
<td>8</td>
<td>13</td>
<td>11</td>
<td>6</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-9</td>
<td>-16</td>
<td>-5</td>
<td>-4</td>
<td>-21</td>
<td>-1</td>
<td>-16</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>70.97</td>
<td>33.33</td>
<td>72.22</td>
<td>73.33</td>
<td>22.22</td>
<td>80.00</td>
<td>57.89</td>
</tr>
</tbody>
</table>

^Crop acreages are in thousand acres.

bDerived from AHCA data set.
Table C.25.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1973 in Historical Run Number 5.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage (^b)</td>
<td>10533.94</td>
<td>60819.17</td>
<td>11860.81</td>
<td>14057.53</td>
<td>15852.85</td>
<td>55675.91</td>
<td>53877.96</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>8314.11</td>
<td>71405.25</td>
<td>12834.67</td>
<td>8881.00</td>
<td>23189.69</td>
<td>47344.27</td>
<td>49376.07</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-2219.84</td>
<td>10586.08</td>
<td>973.86</td>
<td>-5176.53</td>
<td>7336.84</td>
<td>-8331.64</td>
<td>-4501.89</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-21.07</td>
<td>17.41</td>
<td>8.21</td>
<td>-36.82</td>
<td>46.28</td>
<td>-14.96</td>
<td>-8.36</td>
</tr>
<tr>
<td>Real Turning Points</td>
<td>83</td>
<td>85</td>
<td>44</td>
<td>93</td>
<td>63</td>
<td>52</td>
<td>118</td>
</tr>
<tr>
<td>Estimated Turning Points</td>
<td>53</td>
<td>38</td>
<td>34</td>
<td>64</td>
<td>20</td>
<td>36</td>
<td>53</td>
</tr>
<tr>
<td>Difference in Turning Points</td>
<td>-30</td>
<td>-47</td>
<td>-10</td>
<td>-29</td>
<td>-43</td>
<td>-16</td>
<td>-65</td>
</tr>
<tr>
<td>Percent Correct</td>
<td>63.86</td>
<td>44.71</td>
<td>77.27</td>
<td>68.82</td>
<td>31.75</td>
<td>69.23</td>
<td>44.92</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.26.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1974 in the Predictive Run.a

<table>
<thead>
<tr>
<th>Crop</th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in 1973</td>
<td>8863.45</td>
<td>56362.93</td>
<td>8463.53</td>
<td>13864.37</td>
<td>12215.02</td>
<td>55312.02</td>
<td>51278.89</td>
</tr>
<tr>
<td>Predicted Acreage</td>
<td>7465.43</td>
<td>54008.13</td>
<td>6699.23</td>
<td>11489.04</td>
<td>12988.67</td>
<td>60426.15</td>
<td>56646.65</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-1398.01</td>
<td>-2354.80</td>
<td>-1764.30</td>
<td>-2375.33</td>
<td>773.65</td>
<td>5114.13</td>
<td>5367.73</td>
</tr>
</tbody>
</table>

aCrop acreages are in thousand acres.

bDerived from AHCA data set.
Table C.26.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1974 in the Predictive Run.\(^a\)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage in 1973</th>
<th>Predicted Acreage for 1974</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>1670.50</td>
<td>1463.55</td>
<td>-206.95</td>
<td>-12.39</td>
</tr>
<tr>
<td>Corn</td>
<td>4456.24</td>
<td>4220.84</td>
<td>-235.41</td>
<td>-5.28</td>
</tr>
<tr>
<td>Cotton</td>
<td>3397.28</td>
<td>3091.99</td>
<td>-305.29</td>
<td>-8.99</td>
</tr>
<tr>
<td>Oats</td>
<td>193.16</td>
<td>163.36</td>
<td>-29.80</td>
<td>-15.43</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3637.83</td>
<td>3295.99</td>
<td>-341.83</td>
<td>-9.40</td>
</tr>
<tr>
<td>Soybean</td>
<td>363.90</td>
<td>701.24</td>
<td>337.34</td>
<td>92.70</td>
</tr>
<tr>
<td>Wheat</td>
<td>2599.07</td>
<td>2885.01</td>
<td>285.94</td>
<td>11.00</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.26.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1974 in the Predictive Run.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage(^b) in 1973</td>
<td>10533.94</td>
<td>60819.17</td>
<td>11860.81</td>
<td>14057.53</td>
<td>15852.85</td>
<td>55675.91</td>
<td>53877.96</td>
</tr>
<tr>
<td>Predicted Acreage for 1974</td>
<td>8928.98</td>
<td>58228.97</td>
<td>9791.21</td>
<td>11652.40</td>
<td>16284.66</td>
<td>61127.38</td>
<td>59531.66</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-1604.96</td>
<td>-2590.20</td>
<td>-2069.59</td>
<td>-2405.13</td>
<td>431.82</td>
<td>5451.47</td>
<td>5653.70</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-15.24</td>
<td>-4.26</td>
<td>-17.45</td>
<td>-17.11</td>
<td>2.72</td>
<td>9.79</td>
<td>10.49</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.27.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1975 in the Predictive Run.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage\textsuperscript{b} in 1973</td>
<td>8863.45</td>
<td>56362.93</td>
<td>8463.53</td>
<td>13864.37</td>
<td>12215.02</td>
<td>55312.02</td>
<td>51278.89</td>
</tr>
<tr>
<td>Predicted Acreage for 1975</td>
<td>6403.38</td>
<td>56811.22</td>
<td>5208.60</td>
<td>9987.13</td>
<td>15801.05</td>
<td>58944.89</td>
<td>61515.39</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-2460.06</td>
<td>448.29</td>
<td>-3254.93</td>
<td>-3877.23</td>
<td>3586.03</td>
<td>3632.87</td>
<td>10236.46</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-27.76</td>
<td>0.80</td>
<td>-38.46</td>
<td>-27.97</td>
<td>29.36</td>
<td>6.57</td>
<td>19.96</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from AHCA data set.
Table C.27.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1975 in the Predictive Run.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actual Acreage</strong> (^b) in 1973</td>
<td>1670.50</td>
<td>4456.24</td>
<td>3397.28</td>
<td>193.16</td>
<td>3637.83</td>
<td>363.90</td>
<td>2599.07</td>
</tr>
<tr>
<td><strong>Predicted Acreage</strong> for 1975</td>
<td>1279.98</td>
<td>4517.59</td>
<td>2819.42</td>
<td>141.15</td>
<td>3139.45</td>
<td>885.98</td>
<td>2896.61</td>
</tr>
<tr>
<td><strong>Acreage Difference</strong></td>
<td>-390.52</td>
<td>61.35</td>
<td>-577.86</td>
<td>-52.01</td>
<td>-498.38</td>
<td>522.08</td>
<td>297.53</td>
</tr>
<tr>
<td><strong>Percent Difference</strong></td>
<td>-23.38</td>
<td>1.38</td>
<td>-17.01</td>
<td>-26.93</td>
<td>-13.70</td>
<td>143.47</td>
<td>11.45</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.27.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1975 in the Predictive Run.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage</td>
<td>10533.94</td>
<td>60819.17</td>
<td>11860.81</td>
<td>14057.53</td>
<td>15852.85</td>
<td>55675.91</td>
<td>53877.96</td>
</tr>
<tr>
<td>in 1973</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predicted Acre</td>
<td>7683.35</td>
<td>61328.81</td>
<td>8028.02</td>
<td>10128.28</td>
<td>18940.50</td>
<td>59830.87</td>
<td>64412.00</td>
</tr>
<tr>
<td>age for 1975</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acreage Diff</td>
<td>-2850.59</td>
<td>509.64</td>
<td>-3832.79</td>
<td>-3929.25</td>
<td>3087.65</td>
<td>4154.96</td>
<td>10534.03</td>
</tr>
<tr>
<td>Percent Diff</td>
<td>-27.06</td>
<td>0.84</td>
<td>-32.31</td>
<td>-27.95</td>
<td>19.48</td>
<td>7.46</td>
<td>19.55</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.28.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1976 in the Predictive Run.a

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage in 1973</td>
<td>8863.45</td>
<td>56362.93</td>
<td>8463.53</td>
<td>13864.37</td>
<td>12215.02</td>
<td>55312.02</td>
<td>51278.89</td>
</tr>
<tr>
<td>Predicted Acreage for 1976</td>
<td>5647.72</td>
<td>61102.36</td>
<td>4946.62</td>
<td>8781.81</td>
<td>17771.97</td>
<td>53722.82</td>
<td>62095.89</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-3215.72</td>
<td>4739.42</td>
<td>-3516.92</td>
<td>-5082.54</td>
<td>5556.95</td>
<td>-1589.20</td>
<td>10816.98</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-36.28</td>
<td>8.41</td>
<td>-41.55</td>
<td>-36.66</td>
<td>45.49</td>
<td>-2.87</td>
<td>21.09</td>
</tr>
</tbody>
</table>

aCrop acreages are in thousand acres.

bDerived from AHCA data set.
Table C.28.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1976 in the Predictive Run.a

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage b in 1973</td>
<td>1670.50</td>
<td>4456.24</td>
<td>3397.28</td>
<td>193.16</td>
<td>3637.83</td>
<td>363.90</td>
<td>2599.07</td>
</tr>
<tr>
<td>Predicted Acreage for 1976</td>
<td>1141.53</td>
<td>4701.13</td>
<td>2837.75</td>
<td>120.27</td>
<td>3094.12</td>
<td>638.85</td>
<td>2916.40</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-528.97</td>
<td>244.88</td>
<td>-559.53</td>
<td>-72.89</td>
<td>-543.71</td>
<td>274.95</td>
<td>317.33</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-31.67</td>
<td>5.50</td>
<td>-16.47</td>
<td>-37.73</td>
<td>-14.95</td>
<td>75.56</td>
<td>12.21</td>
</tr>
</tbody>
</table>

aCrop acreages are in thousand acres.
bDerived from AIICA data set.
### Table C.28.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1976 in the Predictive Run.\(^a\)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage(^b) in 1973</th>
<th>Predicted Acreage for 1976</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>10533.94</td>
<td>6789.25</td>
<td>-3744.70</td>
<td>-35.55</td>
</tr>
<tr>
<td>Corn</td>
<td>60819.17</td>
<td>65803.44</td>
<td>4984.27</td>
<td>8.20</td>
</tr>
<tr>
<td>Cotton</td>
<td>11860.81</td>
<td>7784.36</td>
<td>-4076.45</td>
<td>-34.37</td>
</tr>
<tr>
<td>Oats</td>
<td>14057.53</td>
<td>8902.08</td>
<td>-5155.45</td>
<td>-36.67</td>
</tr>
<tr>
<td>Sorghum</td>
<td>15852.85</td>
<td>20866.09</td>
<td>5013.24</td>
<td>31.62</td>
</tr>
<tr>
<td>Soybean</td>
<td>55675.91</td>
<td>54361.66</td>
<td>-1314.25</td>
<td>-2.36</td>
</tr>
<tr>
<td>Wheat</td>
<td>53877.96</td>
<td>65012.29</td>
<td>11134.33</td>
<td>20.67</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.29.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1977 in the Predictive Run.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Crop</th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage \textsuperscript{b} in 1973</td>
<td>8863.45</td>
<td>56362.93</td>
<td>8463.53</td>
<td>13864.37</td>
<td>12215.02</td>
<td>55312.02</td>
<td>51278.89</td>
</tr>
<tr>
<td>Predicted Acreage for 1977</td>
<td>5448.69</td>
<td>66206.19</td>
<td>6340.32</td>
<td>7853.89</td>
<td>18804.52</td>
<td>49059.68</td>
<td>62071.89</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-3414.75</td>
<td>9843.35</td>
<td>-2123.21</td>
<td>-6010.45</td>
<td>6589.50</td>
<td>-6252.34</td>
<td>10792.97</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-38.53</td>
<td>17.46</td>
<td>-25.09</td>
<td>-43.35</td>
<td>53.95</td>
<td>-11.30</td>
<td>21.05</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from AHCA data set.
Table C.29.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1977 in the Predictive Run.\(^a\)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage in 1973</th>
<th>Predicted Acreage for 1977</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>1670.50</td>
<td>1057.68</td>
<td>-612.81</td>
<td>-36.68</td>
</tr>
<tr>
<td>Corn</td>
<td>4456.24</td>
<td>4840.43</td>
<td>384.19</td>
<td>8.62</td>
</tr>
<tr>
<td>Cotton</td>
<td>3397.28</td>
<td>3117.46</td>
<td>-279.82</td>
<td>-8.24</td>
</tr>
<tr>
<td>Oats</td>
<td>193.16</td>
<td>104.06</td>
<td>-89.10</td>
<td>-46.13</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3637.83</td>
<td>3527.50</td>
<td>-110.32</td>
<td>-3.03</td>
</tr>
<tr>
<td>Soybean</td>
<td>363.90</td>
<td>432.25</td>
<td>68.35</td>
<td>18.78</td>
</tr>
<tr>
<td>Wheat</td>
<td>2599.07</td>
<td>2551.37</td>
<td>-47.70</td>
<td>-1.84</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.29.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1977 in the Predictive Run.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage in 1973</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>10533.94</td>
<td>60819.17</td>
<td>11860.81</td>
<td>14057.53</td>
<td>15852.85</td>
<td>55675.91</td>
<td>53877.96</td>
</tr>
<tr>
<td>Corn</td>
<td>6506.37</td>
<td>71046.56</td>
<td>9457.78</td>
<td>7957.95</td>
<td>22332.02</td>
<td>49491.93</td>
<td>64623.26</td>
</tr>
<tr>
<td>Cotton</td>
<td>-4027.57</td>
<td>10227.39</td>
<td>-2403.03</td>
<td>-6099.58</td>
<td>6479.17</td>
<td>-6183.98</td>
<td>10745.29</td>
</tr>
<tr>
<td>Oats</td>
<td>-38.23</td>
<td>16.82</td>
<td>-20.26</td>
<td>-43.39</td>
<td>40.87</td>
<td>-11.11</td>
<td>19.94</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCA data set.
Table C.30.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1978 in the Predictive Run.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage\textsuperscript{b} in 1973</th>
<th>Predicted Acreage for 1978</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>8863.45</td>
<td>5144.19</td>
<td>-3719.25</td>
<td>-41.96</td>
</tr>
<tr>
<td>Corn</td>
<td>56362.93</td>
<td>64194.33</td>
<td>7831.39</td>
<td>13.89</td>
</tr>
<tr>
<td>Cotton</td>
<td>8463.53</td>
<td>8143.59</td>
<td>-319.94</td>
<td>-3.78</td>
</tr>
<tr>
<td>Oats</td>
<td>13864.37</td>
<td>7457.12</td>
<td>-6407.23</td>
<td>-46.21</td>
</tr>
<tr>
<td>Sorghum</td>
<td>12215.02</td>
<td>18708.70</td>
<td>6493.68</td>
<td>53.16</td>
</tr>
<tr>
<td>Soybean</td>
<td>55312.02</td>
<td>45319.72</td>
<td>-9992.26</td>
<td>-18.07</td>
</tr>
<tr>
<td>Wheat</td>
<td>51278.89</td>
<td>60386.70</td>
<td>9107.79</td>
<td>17.76</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from ANCA data set.
Table C.30.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1978 in the Predictive Run.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actual Acreage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in 1973</td>
<td>1670.50</td>
<td>4456.24</td>
<td>3397.28</td>
<td>193.16</td>
<td>3637.83</td>
<td>363.90</td>
<td>2599.07</td>
</tr>
<tr>
<td><strong>Predicted Acreage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>for 1978</td>
<td>972.01</td>
<td>4578.17</td>
<td>3596.14</td>
<td>92.20</td>
<td>3207.99</td>
<td>305.93</td>
<td>2244.35</td>
</tr>
<tr>
<td><strong>Acreage Difference</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>-698.49</td>
<td>121.93</td>
<td>198.86</td>
<td>-100.96</td>
<td>-429.83</td>
<td>-57.96</td>
<td>-354.72</td>
</tr>
<tr>
<td><strong>Percent Difference</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>-41.81</td>
<td>2.74</td>
<td>5.85</td>
<td>-52.27</td>
<td>-11.82</td>
<td>-15.93</td>
<td>-13.65</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from AHCA data set.
Table C.30.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1978 in the Predictive Run.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actual Acreage(^b)</strong> in 1973</td>
<td>10533.94</td>
<td>60819.17</td>
<td>11860.81</td>
<td>14057.53</td>
<td>15852.85</td>
<td>55675.91</td>
<td>53877.96</td>
</tr>
<tr>
<td><strong>Predicted Acreage for 1978</strong></td>
<td>6116.19</td>
<td>68772.50</td>
<td>11739.73</td>
<td>7594.32</td>
<td>21916.69</td>
<td>45625.66</td>
<td>62631.05</td>
</tr>
<tr>
<td><strong>Acreage Difference</strong></td>
<td>-4417.75</td>
<td>7953.33</td>
<td>-121.08</td>
<td>-6508.21</td>
<td>6063.84</td>
<td>-10050.25</td>
<td>8753.09</td>
</tr>
<tr>
<td><strong>Percent Difference</strong></td>
<td>-41.94</td>
<td>13.08</td>
<td>-1.02</td>
<td>-46.30</td>
<td>38.25</td>
<td>-18.05</td>
<td>16.25</td>
</tr>
</tbody>
</table>

\(^a\) Crop acreages are in thousand acres.

\(^b\) Derived from ALICA data set.
Table C.31.1. National Summary of Dryland Crop Acreage and Turning Point Statistics for 1979 in the Predictive Run.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage(^b) in 1973</td>
<td>8863.45</td>
<td>56362.93</td>
<td>8463.53</td>
<td>13864.37</td>
<td>12215.02</td>
<td>55312.02</td>
<td>51278.89</td>
</tr>
<tr>
<td>Predicted Acreage for 1979</td>
<td>4980.57</td>
<td>57893.08</td>
<td>10318.22</td>
<td>7269.19</td>
<td>17540.92</td>
<td>42420.03</td>
<td>53356.87</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-3882.87</td>
<td>1530.15</td>
<td>1854.70</td>
<td>-6595.15</td>
<td>5325.90</td>
<td>-12891.98</td>
<td>2077.96</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-43.81</td>
<td>2.71</td>
<td>21.91</td>
<td>-47.57</td>
<td>43.60</td>
<td>-23.31</td>
<td>4.05</td>
</tr>
</tbody>
</table>

\(^a\) Crop acreages are in thousand acres.

\(^b\) Derived from AHCA data set.
Table C.31.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1979 in the Predictive Run.a

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage in 1973</th>
<th>Predicted Acreage for 1979</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated Barley</td>
<td>1670.50</td>
<td>899.55</td>
<td>-770.94</td>
<td>-46.15</td>
</tr>
<tr>
<td>Irrigated Corn</td>
<td>4456.24</td>
<td>4053.84</td>
<td>-402.41</td>
<td>-9.03</td>
</tr>
<tr>
<td>Irrigated Cotton</td>
<td>3397.28</td>
<td>4108.28</td>
<td>711.00</td>
<td>20.93</td>
</tr>
<tr>
<td>Irrigated Oats</td>
<td>193.16</td>
<td>79.94</td>
<td>-113.22</td>
<td>-58.61</td>
</tr>
<tr>
<td>Irrigated Sorghum</td>
<td>3637.83</td>
<td>2934.32</td>
<td>-703.51</td>
<td>-19.34</td>
</tr>
<tr>
<td>Irrigated Soybean</td>
<td>363.90</td>
<td>219.05</td>
<td>-144.85</td>
<td>-39.80</td>
</tr>
<tr>
<td>Irrigated Wheat</td>
<td>2599.07</td>
<td>1980.93</td>
<td>-618.14</td>
<td>-23.78</td>
</tr>
</tbody>
</table>

^Crop acreages are in thousand acres.

^Derived from AllCA data set.
Table C.31.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1979 in the Predictive Run.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage (b) in 1973</td>
<td>10533.94</td>
<td>60819.17</td>
<td>11860.81</td>
<td>14057.53</td>
<td>15852.85</td>
<td>55675.91</td>
<td>53877.96</td>
</tr>
<tr>
<td>Predicted Acreage for 1979</td>
<td>5880.12</td>
<td>61946.92</td>
<td>14426.50</td>
<td>7349.13</td>
<td>20475.23</td>
<td>42639.07</td>
<td>55337.79</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-4653.82</td>
<td>1127.75</td>
<td>2565.70</td>
<td>-6708.39</td>
<td>4622.38</td>
<td>-13036.84</td>
<td>1459.83</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-44.18</td>
<td>1.85</td>
<td>21.63</td>
<td>-47.72</td>
<td>29.16</td>
<td>-23.42</td>
<td>2.71</td>
</tr>
</tbody>
</table>

\(^a\)Crop acreages are in thousand acres.

\(^b\)Derived from AHCRA data set.
Table C.32.1. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1980 in the Predictive Run.\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Barley</th>
<th>Corn</th>
<th>Cotton</th>
<th>Oats</th>
<th>Sorghum</th>
<th>Soybean</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage\textsuperscript{b} in 1973</td>
<td>8863.45</td>
<td>56362.93</td>
<td>8463.53</td>
<td>13864.37</td>
<td>12215.02</td>
<td>55312.02</td>
<td>51278.89</td>
</tr>
<tr>
<td>Predicted Acreage for 1980</td>
<td>4927.63</td>
<td>56008.12</td>
<td>11269.30</td>
<td>7140.04</td>
<td>16659.88</td>
<td>46462.57</td>
<td>46386.37</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-3935.81</td>
<td>-354.81</td>
<td>2805.77</td>
<td>-6724.30</td>
<td>4444.86</td>
<td>-8849.54</td>
<td>-4892.51</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>-44.40</td>
<td>-0.63</td>
<td>33.15</td>
<td>-48.50</td>
<td>36.39</td>
<td>-16.00</td>
<td>-9.54</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from AHCA data set.
Table C.32.2. National Summary of Irrigated Crop Acreage and Turning Point Statistics for 1980 in the Predictive Run.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Crop Acreage</th>
<th>Irrigated Barley</th>
<th>Irrigated Corn</th>
<th>Irrigated Cotton</th>
<th>Irrigated Oats</th>
<th>Irrigated Sorghum</th>
<th>Irrigated Soybean</th>
<th>Irrigated Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Acreage \textsuperscript{b} in 1973</td>
<td>1670.50</td>
<td>4456.24</td>
<td>3397.28</td>
<td>193.16</td>
<td>3637.83</td>
<td>363.90</td>
<td>2599.07</td>
</tr>
<tr>
<td>Predicted Acreage for 1980</td>
<td>854.75</td>
<td>3674.13</td>
<td>4599.99</td>
<td>69.51</td>
<td>2661.82</td>
<td>170.44</td>
<td>1769.43</td>
</tr>
<tr>
<td>Acreage Difference</td>
<td>-815.75</td>
<td>-782.12</td>
<td>1202.71</td>
<td>-123.65</td>
<td>-976.01</td>
<td>-193.46</td>
<td>-829.64</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from AWCA data set.
Table C.32.3. National Summary of Aggregate Crop Acreage and Turning Point Statistics for 1980 in the Predictive Run.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Crop</th>
<th>Actual Acreage\textsuperscript{b} in 1973</th>
<th>Predicted Acreage for 1980</th>
<th>Acreage Difference</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>10533.94</td>
<td>5782.38</td>
<td>-4751.56</td>
<td>-45.11</td>
</tr>
<tr>
<td>Corn</td>
<td>60819.17</td>
<td>59682.25</td>
<td>-1136.92</td>
<td>-1.87</td>
</tr>
<tr>
<td>Cotton</td>
<td>11860.81</td>
<td>15869.29</td>
<td>4008.48</td>
<td>33.80</td>
</tr>
<tr>
<td>Oats</td>
<td>14057.53</td>
<td>7209.55</td>
<td>-6847.97</td>
<td>-48.71</td>
</tr>
<tr>
<td>Sorghum</td>
<td>15852.85</td>
<td>19321.70</td>
<td>3468.85</td>
<td>21.88</td>
</tr>
<tr>
<td>Soybean</td>
<td>55675.91</td>
<td>46632.90</td>
<td>-9043.01</td>
<td>-16.24</td>
</tr>
<tr>
<td>Wheat</td>
<td>53877.96</td>
<td>48155.80</td>
<td>-5722.17</td>
<td>-10.62</td>
</tr>
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</table>

\textsuperscript{a}Crop acreages are in thousand acres.

\textsuperscript{b}Derived from AHCA data set.
Table C.33. National Total of Correct Turning Point Percentages for the Historical Runs.

<table>
<thead>
<tr>
<th>Year</th>
<th>No. 1</th>
<th>No. 2</th>
<th>No. 3</th>
<th>No. 4</th>
<th>No. 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969</td>
<td>68.2</td>
<td>70.6</td>
<td>71.2</td>
<td>71.2</td>
<td>71.2</td>
</tr>
<tr>
<td>1970</td>
<td>60.4</td>
<td>60.2</td>
<td>58.9</td>
<td>53.0</td>
<td>53.2</td>
</tr>
<tr>
<td>1971</td>
<td>60.8</td>
<td>60.4</td>
<td>63.8</td>
<td>46.3</td>
<td>46.8</td>
</tr>
<tr>
<td>1972</td>
<td>67.7</td>
<td>69.1</td>
<td>70.6</td>
<td>51.7</td>
<td>49.4</td>
</tr>
<tr>
<td>1973</td>
<td>66.9</td>
<td>66.4</td>
<td>68.2</td>
<td>56.7</td>
<td>55.4</td>
</tr>
</tbody>
</table>
APPENDIX D. ACTUAL AND PREDICTED ACREAGE AND SELECTED MARKET STATISTICS FOR HISTORICAL SIMULATION NUMBER 3 TO NUMBER 5, AND THE PREDICTIVE SIMULATION

<table>
<thead>
<tr>
<th>Year</th>
<th>Actual Market Statistics</th>
<th>Historical Run No. 3 Market Statistics</th>
<th>Historical Run No. 4 Market Statistics</th>
<th>Historical Run No. 5 Market Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Harvested Acreage(^a)</td>
<td>Production (Mil. tons)</td>
<td>Ending Season Inventory Price(^b)</td>
<td>Harvested Acreage (Mil. Ac.)</td>
</tr>
<tr>
<td></td>
<td>(Mil. Ac.)</td>
<td>(Mil. tons)</td>
<td>(Mil. tons)</td>
<td>(Per ton)</td>
</tr>
<tr>
<td>1968</td>
<td>97.31</td>
<td>170.50</td>
<td>50.2</td>
<td>24.02</td>
</tr>
<tr>
<td>1969</td>
<td>96.54</td>
<td>177.49</td>
<td>48.6</td>
<td>24.36</td>
</tr>
<tr>
<td>1970</td>
<td>99.30</td>
<td>160.10</td>
<td>33.2</td>
<td>26.04</td>
</tr>
<tr>
<td>1971</td>
<td>106.27</td>
<td>207.70</td>
<td>48.4</td>
<td>21.18</td>
</tr>
<tr>
<td>1972</td>
<td>94.03</td>
<td>199.90</td>
<td>32.4</td>
<td>28.91</td>
</tr>
<tr>
<td>1973</td>
<td>102.26</td>
<td>205.00</td>
<td>22.2</td>
<td>42.16</td>
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</tbody>
</table>

\(^a\)From U.S. Department of Agriculture published sources [198].

\(^b\)Estimated from individual feedgrain market statistics in 1948 dollars [198].

<table>
<thead>
<tr>
<th>Year</th>
<th>Actual Acreage</th>
<th>Production</th>
<th>Ending Inventory</th>
<th>Season Price</th>
<th>Loan Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Mil. Ac.)</td>
<td>(Mil. Bu.)</td>
<td>(Mil. Bu.)</td>
<td>(Per Bu.)</td>
<td></td>
</tr>
<tr>
<td>1968</td>
<td>54.77</td>
<td>1556.64</td>
<td>816.70</td>
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</tr>
<tr>
<td>1969</td>
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<td>1442.68</td>
<td>884.90</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>1970</td>
<td>43.56</td>
<td>1351.56</td>
<td>731.50</td>
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<td>1.25</td>
</tr>
<tr>
<td>1971</td>
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<td>1617.80</td>
<td>863.1</td>
<td>1.34</td>
<td>1.25</td>
</tr>
<tr>
<td>1972</td>
<td>47.28</td>
<td>1544.94</td>
<td>438.4</td>
<td>1.76</td>
<td>1.25</td>
</tr>
<tr>
<td>1973</td>
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<table>
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<th>Historical Run No. 3 Market Statistics</th>
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<td>Harvested Acreage</td>
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<td>(Mil. Ac.)</td>
</tr>
<tr>
<td>1968</td>
</tr>
<tr>
<td>1969</td>
</tr>
<tr>
<td>1970</td>
</tr>
<tr>
<td>1971</td>
</tr>
<tr>
<td>1972</td>
</tr>
<tr>
<td>1973</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Historical Run No. 4 Market Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvested Acreage</td>
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<tr>
<td>(Mil. Ac.)</td>
</tr>
<tr>
<td>1968</td>
</tr>
<tr>
<td>1969</td>
</tr>
<tr>
<td>1970</td>
</tr>
<tr>
<td>1971</td>
</tr>
<tr>
<td>1972</td>
</tr>
<tr>
<td>1973</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Historical Run No. 5 Market Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvested Acreage</td>
</tr>
<tr>
<td>(Mil. Ac.)</td>
</tr>
<tr>
<td>1968</td>
</tr>
<tr>
<td>1969</td>
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<tr>
<td>1970</td>
</tr>
<tr>
<td>1971</td>
</tr>
<tr>
<td>1972</td>
</tr>
<tr>
<td>1973</td>
</tr>
</tbody>
</table>

^aFrom U.S. Department of Agriculture published sources [198].

^bFrom U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service [200].

<table>
<thead>
<tr>
<th>Year</th>
<th>Harvested Acreage (Mil. Ac.)</th>
<th>Production (Mil. Bu.)</th>
<th>Ending Season Inventory (Mil. Bu.)</th>
<th>Support Price (Per Bu.)</th>
<th>Historical Run No. 3 Market Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968</td>
<td>41.39</td>
<td>1106.96</td>
<td>326.84</td>
<td>2.43</td>
<td>40.53</td>
</tr>
<tr>
<td>1969</td>
<td>41.33</td>
<td>1133.12</td>
<td>229.84</td>
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<td>44.84</td>
</tr>
<tr>
<td>1970</td>
<td>42.25</td>
<td>1127.10</td>
<td>98.78</td>
<td>2.85</td>
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</tr>
<tr>
<td>1971</td>
<td>42.70</td>
<td>1175.99</td>
<td>71.96</td>
<td>3.03</td>
<td>43.40</td>
</tr>
<tr>
<td>1972</td>
<td>45.70</td>
<td>1270.63</td>
<td>59.64</td>
<td>4.37</td>
<td>41.68</td>
</tr>
<tr>
<td>1973</td>
<td>55.80</td>
<td>1547.17</td>
<td>170.88</td>
<td>5.68</td>
<td>48.63</td>
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<table>
<thead>
<tr>
<th>Year</th>
<th>Historical Run No. 4 Market Statistics</th>
</tr>
</thead>
<tbody>
<tr>
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<td>40.53</td>
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<td>1969</td>
<td>44.84</td>
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<td>1970</td>
<td>46.36</td>
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<tr>
<td>1971</td>
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</tr>
<tr>
<td>1973</td>
<td>46.86</td>
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From U.S. Department of Agriculture published sources [198].

<table>
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<th>Year</th>
<th>Actual Market Statistics</th>
<th>Historical Run No. 3 Market Statistics</th>
<th>Historical Run No. 4 Market Statistics</th>
<th>Historical Run No. 5 Market Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Harvested Acreage (Mil. Ac.)</td>
<td>Production (Mil. Bl.)</td>
<td>Ending Inventory (Mil. Bl.)</td>
<td>Season Price (Per lb.)</td>
</tr>
<tr>
<td>1968</td>
<td>10.16</td>
<td>10.93</td>
<td>6.52</td>
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</tr>
<tr>
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<td>11.05</td>
<td>9.99</td>
<td>5.76</td>
<td>22.00</td>
</tr>
<tr>
<td>1970</td>
<td>11.16</td>
<td>10.19</td>
<td>4.25</td>
<td>22.93</td>
</tr>
<tr>
<td>1971</td>
<td>11.47</td>
<td>10.48</td>
<td>3.23</td>
<td>28.23</td>
</tr>
<tr>
<td>1972</td>
<td>12.98</td>
<td>13.70</td>
<td>3.93</td>
<td>27.30</td>
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<tr>
<td>1973</td>
<td>11.97</td>
<td>12.97</td>
<td>3.74</td>
<td>44.60</td>
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</tbody>
</table>

*aFrom U.S. Department of Agriculture published sources [198].
Table D.1.5. National actual and predicted barley harvested acreage and prices from 1968 to 1973.

<table>
<thead>
<tr>
<th>Year</th>
<th>Harvested Acreage</th>
<th>Season Price</th>
<th>Support Price</th>
<th>Historical Run No. 3</th>
<th>Historical Run No. 4</th>
<th>Historical Run No. 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Mil. Ac.)</td>
<td>(Per Bu.)</td>
<td>(Per Bu.)</td>
<td>Harvested Acreage</td>
<td>Season Price</td>
<td>Harvested Acreage</td>
</tr>
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<td>(Mil. Ac.)</td>
<td>(Per Bu.)</td>
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<td>10.32</td>
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<td>1.03</td>
<td>10.84</td>
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<td>1.15</td>
<td>9.10</td>
<td>1.03</td>
<td>9.33</td>
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<td>1973</td>
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<td>2.13</td>
<td>1.34</td>
<td>9.88</td>
<td>1.29</td>
<td>8.30</td>
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</tbody>
</table>

\(^{a}\)From U.S. Department of Agriculture published sources [198].

<table>
<thead>
<tr>
<th>Year</th>
<th>Harvested Acreage (Mil. Ac.)</th>
<th>Season Price (Per Bu.)</th>
<th>Support Price (Per Bu.)</th>
<th>Historical Run No. 3</th>
<th>Harvested Acreage (Mil. Ac.)</th>
<th>Season Price (Per Bu.)</th>
<th>Historical Run No. 4</th>
<th>Harvested Acreage (Mil. Ac.)</th>
<th>Season Price (Per Bu.)</th>
<th>Historical Run No. 5</th>
<th>Harvested Acreage (Mil. Ac.)</th>
<th>Season Price (Per Bu.)</th>
</tr>
</thead>
<tbody>
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<td>1968</td>
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<td>55.69</td>
<td>1.34</td>
<td>55.69</td>
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<td>1969</td>
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<td>58.35</td>
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<td>58.35</td>
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<td>1970</td>
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<td>57.88</td>
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<td>61.66</td>
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<tr>
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<td>62.66</td>
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<td>65.01</td>
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<td>0.91</td>
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<td>1973</td>
<td>61.89</td>
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<td>1.37</td>
<td>64.01</td>
<td>1.65</td>
<td>71.75</td>
<td>0.97</td>
<td>71.40</td>
<td>0.74</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

\(^a\)From U.S. Department of Agriculture published sources [198].

\(^b\)From U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service [200], loan rate plus diversion payment.

<table>
<thead>
<tr>
<th>Year</th>
<th>Actual Harvested Acreage (Mil. Ac.)</th>
<th>Season Price (Per Bu.)</th>
<th>Actual Support Season Price (Per Bu.)</th>
<th>Historical Run No. 3 Harvested Acreage (Mil. Ac.)</th>
<th>Season Price (Per Bu.)</th>
<th>Historical Run No. 4 Harvested Acreage (Mil. Ac.)</th>
<th>Season Price (Per Bu.)</th>
<th>Historical Run No. 5 Harvested Acreage (Mil. Ac.)</th>
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*From U.S. Department of Agriculture published sources [198].

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<td>Season Price (Per Bu.)</td>
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^From U.S. Department of Agriculture published sources [198].

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<th>Production (Mil. Tons)</th>
<th>Ending Inventory (Mil. Tons)</th>
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\( ^a \) From Economic Research Service published sources [55].

\( ^b \) In 1948 dollars.

\( ^c \) Minimum allowable inventory.

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<th>Actual Market Statistics</th>
<th>Predictive Run Market Statistics</th>
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<td>Production (Mil. Bu.)</td>
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*aFrom Economic Research Service published sources [50, 58].
Table D.2.3. National actual and predicted soybean harvested acreage and market statistics from 1973 to 1980.

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<tr>
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^aFrom Economic Research Service published source [54].

^bPrice support not authorized for 1975 crop.

^cFrom U.S.D.A. news bulletin [199].

^dMinimum allowable inventory.

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<sup>a</sup>From Economic Research Service published source [51].

<sup>b</sup>From U.S.D.A. published sources [198].

<sup>c</sup>From Economic Research Service published source [50].

<sup>d</sup>Minimum allowable inventory.
Table D.2.5. National actual and predicted corn, sorghum, barley and oat harvested acreage and market statistics from 1974 to 1980.

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<sup>a</sup>From Economic Research Service published sources [55].

<sup>b</sup>From U.S.D.A. news bulletin [199].